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Effective Learning Management System Using Platform as a Service Infrastructure

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Abstract

A learning management system (LMS) is a technology that is almost used by all learning institutions. Many types of systems are present in the learning process such as Moodle, and EdX. These management systems are open source but have monolithic architecture and require complex system specifications to run. This research aims to develop a LMS with a Platform as a Service (PaaS) architecture. The method used is Concurrent Design which is adapted from the Web-Based Instructional Design development model. The result of the research is an LMS with a combination of authentication infrastructure, data storage, and data centers that are separate and run independently by each service provider. The results of the black box test state that all features that have been produced have met the specifications set. The latency test shows the LMS can handle requests of around one hundred milliseconds per one thousand requests. The technology acceptance test has positive results, the LMS is perceived as useful and easy to use in the learning process

Keywords:
Learning Management System, Platform as a Service, Learning, Application Architecture

1. Introduction

A Learning Management System (LMS) is a networked learning software that assists in delivering online learning content, communicating with learners, and controlling learner performance[1]. One of the main changes is the utilization of technology to facilitate learning. LMS has become a very efficient alternative solution in supporting the learning process, including aspects such as material, placement, management, and assessment [2]. The application allows for an interactive learning process, as questions from learners can be asked through social features. This change confirms the change of technology and digital platforms in shaping a more dynamic and inclusive learning process [3].

In recent years, LMS implementation has become a common practice in higher education [4]. One of the most common implementations is the use of Moodle modified to suit the needs of distance learning[5], [6], [7]. One of its advantages is the high retention rate of learners on learning materials and to regulate the learning process independently[8][9]. A study mentioned that Moodle is ranked first and followed by Edmodo, and Schoology [10]. It is a popular LMS based on a variety of features, can be personalized, and is open source. [11][12][13]. However, Moodle still has many shortcomings, starting in terms of complex architecture, single instance hosting, and soft lock [14]. The specifications for installing Moodle still seem to be in a monolithic form. Monolithic architecture requires centralized resources and has high specifications [15]. However, there was a degradation of

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performance in Moodle which resulted in users having difficulty in utilizing the elements in Moodle[16].

To address the issues, the PaaS approach can be used as a solution for LMS designed with monolithic architecture like PaaS services including Google Cloud, Microsoft Azure, Vercel Inc, Supabase, and Github. LMS development with PaaS technology and architecture helps the development process to be more flexible and provides room for scalability. Utilization of PaaS provides control to administrators and LMS development teams in performing data management, and privacy of LMS users. Separation of components of the LMS service can be done easily using PaaS thus increasing the reliability of the LMS in the learning process. PaaS provides a development platform and environment that provides services and storage, hosted on cloud computing[17].

A study explores LMS development using Amazon Web Service [16]. Another research revealed that the use of PaaS is a possible and widespread practice in the development of learning applications [18]. The research conducted shows that the use of PaaS is used to separate the numerous services used in Moodle. The separation of services includes Web Server, Data Storage & Learning Content, Authentication System, and System Database [19]. The research provides a general description of multi-tenancy that can be used as a form of components that are mutually separated but can be integrated into a larger container. Another study conducted LMS development using SaaS with different infrastructures [20].

LMS applications with PaaS architecture have a small distribution (10%), the rest is the use of monolithic cloud computing infrastructure (Single Server) [21]. Integrating an LMS with PaaS provides significant advantages in scalability, customization, and efficiency for educational and training environments. PaaS enables LMS platforms to be developed, deployed, and maintained with greater flexibility by offering ready-to-use infrastructure, development tools, and runtime environments. This allows educational institutions and organizations to tailor LMS functionalities to their specific needs while reducing the burden of managing underlying hardware and software resources. Moreover, PaaS supports faster deployment cycles and seamless integration with other applications and data sources, enhancing the overall learning experience and system responsiveness [29].

Moreover, PaaS with LMS enhances system reliability and performance by leveraging cloud-based infrastructure that automatically scales according to user demand. This is especially beneficial in remote or hybrid learning scenarios, where user traffic may fluctuate significantly. Security features provided by leading PaaS providers also ensure the protection of sensitive user data and compliance with privacy standards. A study revealed that cloud-based LMS implementations demonstrate improved accessibility, cost-effectiveness, and user engagement. It highlights that PaaS adoption in educational technology contributes to better resource management and continuous system innovation [30]. Therefore, this paper develops LMS with PaaS architecture and evaluates the feasibility, reliability, and acceptance of LMS in mass and continuous learning processes.

2. Method

This study presented Concurrent Design which contains a process where system development is conducted iteratively based on predetermined specifications. The iterative principle allows development to make revisions and feature development simultaneously. The speed and level of risk due to design process errors are well minimized due to the fast iterative principle. The design stage of development focuses on designing system designs based on needs analysis and specification identification. The design stage produces a user flow diagram, a use-class diagram, and a list of features that will be realized at the development stage. The development stage is the concrete stage of the LMS development process. The development stage is conducted by using a programming language and configuring the agreed architecture. The initial implementation and formative evaluation stages are combined into a feature assessment process with Blackbox Testing, Unit & Integration Testing, and Technology Acceptance Model [22].

2.1. Material Identification

The study focuses on the project-based learning process that contains various materials in the form of learning videos and short text materials. The materials are used by learners as learning resources in the process of project work. Each learner has different performances to different abilities. Different conditions of learners require the LMS to be able to store progress in a personalized manner for each learner. This requires profile and authentication features as a means of storing learners' learning progress. For an overview of the product to be developed, see the table 1 below:

Table 1. Overview of proposed LMS

Aspect	Description
Name	LMS IMGV-3D
Domain	https://imgv.my.id
Authentication	Account SSO UM (siakad @um.ac.id)
Feature	Profile User, Leaderboard, Content Unlocking, Quiz, YouTube Video Embed, Auth SSO, Progress Stats

2.2. User Identification

From the results of the needs analysis that has been conducted, there are specifications of users who will utilize the LMS. Each user has unique needs and goals. Table 2 is an overview of users who will utilize the System.

Table 2. User & Roles Identification

Users	Description
Learners	Learners aim to complete learning activities, view grades, and view materials and performance.
Educator	Educators aim to supervise the learning achievements, grades, and performance of each learner.
Administrator	The administrator aims to solve technical problems that occur on the LMS such as quiz data and materials.

2.3. Functional Identification

After understanding the type and purpose of each LMS user, the next step is functional identification. Functional identification is the stage of determining the features and services available on the LMS. Table 3 describes the functional requirements of the LMS.

Table 3. Proposed LMS Features

Fitur	Access Right	Description
Authentication	Pe, Va, Pb, Ad	UM SSO Email Authentication
Dashboard	Pe, Va, Pb, Ad	Learning progress information.

Fitur	Access Right	Description
Contents & Material	Pe, Pb, Ad	View Video material
Grades	Pe, Va, Pb, Ad	See Grades
Quizzes	Pe	Take quizzes
Surveys	Pe	Provide suggestions
Add Grades	Va, Pe, Ad	Performing assessment
Modify Grades	Va, Pe, Ad	Changing performance progress

2.4. Infrastructure Identification

PaaS provides a development platform and environment that provides services and storage, hosted in the cloud [17]. PaaS was chosen as the approach to technology architecture in LMS. The choice of PaaS architecture type allows for development with a variety of different technologies. This strategy allows a more flexible development process because the technology architecture used is not locked into a rigid ecosystem. The non-rigid architectural design allows the development process to iterate faster, under the needs and principles of the WBID methodology. Table 4 describes the Infrastructure Identification of the LMS.

Table 4: Infrastructure Identification

Infrastructure	Services
Vercel Enterprise	Web Server, Gateway API, Load balancer
GitHub Enterprise	Repository Kode & Task Management
Google Cloud	Auth System SSO UM
Supabase Inc	Database and Gatekeeping Authentication
PTIK UM	Photo Storage Data

2.5. Identification of Development Tools

LMS development tools are frameworks and applications used in the real LMS development stage. Some forms of LMS development tools include frontend, backend, repository system, and package manager. The utilization of various development tools is based on the uniqueness and characteristics of each different tool and has divergent functions. The choice of GitHub as a repository is due to the convenience and variety of features that are very comprehensive for collaborative application development[23]. Meanwhile, the use of NextJS 13 is due to its ability to deliver fast website performance and a simple development experience[24].

2.6. Product Evaluation with TAM

Product evaluation is conducted through black box testing, latency testing, and technology acceptance tests by beta testers. Testing is intended to measure the reliability of the system that has been developed. If there are bugs or discrepancies with the specifications, revisions will be made. Blackbox testing is conducted iteratively under the progress of the development stages. Each feature package will be assessed gradually by beta testers and ensure that the output produced by the system is under the input and specifications set at the design stage. Blackbox Testing is a testing technique without having any knowledge of the internal workings of the application [25]. The integration of LMS components is evaluated using the latency test. The latency test is a test that is useful for knowing the performance of a component in running a process with time parameters as a benchmark [26].

The TAM is conducted at the final stage if all features on the LMS have passed the black box test stage. The TAM test is intended as a measure of the ease and usefulness of the LMS through the eyes of potential LMS users. The results of the TAM test are used as material for fundamental revisions of the product that has been developed as well as a benchmark for the feasibility of the system to be released to a wider range of potential users. TAM is widely used to study the adoption of various technologies, and TAM is the most influential theory [27][28].

TAM Mathematical Formulas:

1. **Perceived Usefulness (PU)**

$$PU = \frac{1}{n}\sum_{i=1}^{n} U_i$$

Where:

- PU = Perceived Usefulness
- U_i= Score of the i^{th} usefulness item (U01 to U15)
- n= Total number of usefulness items (in case, $n = 15$)

2. Perceived Ease of Use (PEOU)

$$PEOU = \frac{1}{m}\sum_{j=1}^{m} EOU_j'$$

Where:

- $PEOU$ = Perceived Ease of Use
- EOU_j' = Adjusted score of the j^{th}ease of use item (reversed if negatively worded)
- m= Total number of ease of use items (here, $m = 15$)

For negatively worded items:

$$EOU_j' = 8 - EOU_j$$

3. Behavioral Intention to Use (BI)

$$BI = \alpha \cdot PU + \beta \cdot PEOU + \varepsilon$$

Where:

- BI = Behavioral Intention to Use
- α, β = Regression coefficients
- ε = Error term

Using formulas in TAM measurement helps quantify user perceptions like Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), making the analysis more objective and consistent. It allows researchers to calculate averages, adjust for negative statements, and apply models to predict user acceptance more accurately. This strengthens the reliability and validity of the results in technology adoption studies.

3. Result and Discussion

After the development stage, the product was produced in the form of a project-based learning LMS. The product that has been developed can function functionally and can be used by learners and learners in the learning process, the following are the results of the development and product evaluation results that have been carried out.

4.1 Functional Implementation

The results of the agreed user flow development are continued at the concrete development stage. Development is carried out through a website programming process using the NextJS 13 framework and shadCN UI. On the authentication page, users are asked to log in via a UM SSO account, namely using an email with the suffix @um.ac.id or @students.um.ac.id. Users will be directed directly to the SSO page without the need to input the UM username or SIAKAD password. Learning activities are integrated with the material page. The learning activity section is located at the very end of the material. Two activities can be accessed by learners, namely surveys and quizzes. The quiz is only available if the learner has not submitted the score into the system. As for the survey, learners are required to fill in a minimum of 100 characters describing their learning experience. On the learner dashboard page, there is information that describes the general state of learning, such as learner performance, and the total number of learners who have validated the product development performance, to read the survey results given by the learners.

4.2 Infrastructure Implementation

From the developed architecture design, there are five services used in the LMS architecture. The five services run independently in terms of infrastructure but play a role in the LMS functionality. PaaS providers will provide a suitable environment for general developers to build web applications without deep domain expertise in back-end server development and front-end client development or website administration[17].

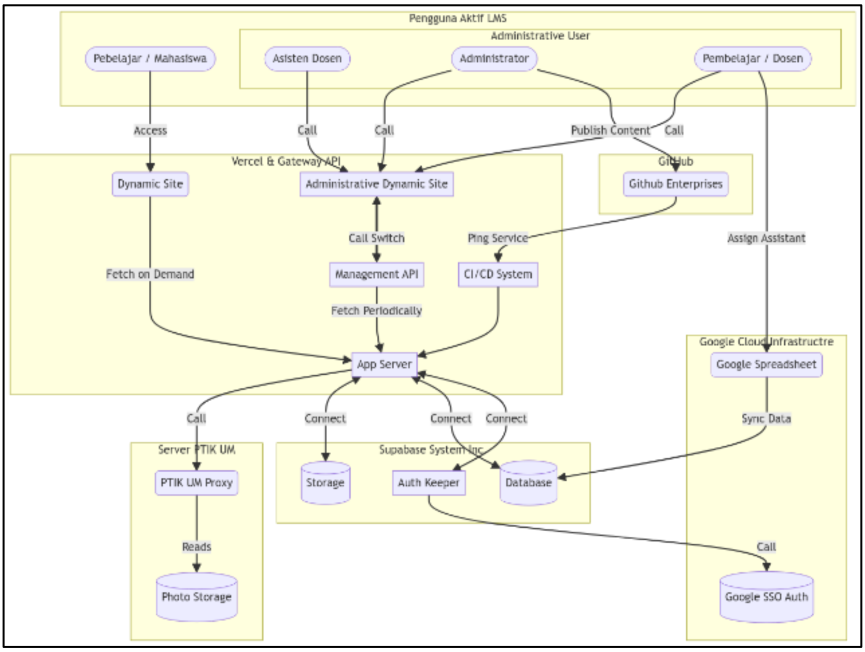

Fig.1 Architecture Diagram of LMS

Table 5: Connection matrix of consumers and service providers

Task	Consumer	Provider	Protocol
GET userprofile	App Server (vercel)	Database (supabase)	GraphQL
GET authdata	Authenticator (supabase)	Users API (GCloud)	OAuth 2.1
UPDATE data	App Server (vercel)	Database (supabase)	GraphQL
GET userphoto	App Server (vercel)	Storage (PTIK UM)	Rest API
UPDATE lcontent	App Server (vercel)	Database (supabase)	GraphQL
UPDATE users	Authenticator (supabase)	Database (supabase)	GRPC
UPDATE grades	App Server (vercel)	Database (supabase)	GraphQL
DEL session	Authenticator (supabase)	Database (supabase)	GRPC
POST updatever	Heartbeat Service	Github Builders	Webhooks
Web Builder	Github Builders	App Server (vercel)	GRPC
Sync UM	Heartbeat Service	Services API (UM)	REST API
Gatekeep	Users API (GCloud)	Services API (UM)	REST API
Access	LMS Users	Cloudflare	HTTPS
Load balancing	App Server	Cloudflare	PNI

According to Table 5, the process of repairing LMS features in production conditions can also be possible because of the Heartbeat feature. Heartbeat is a feature that checks the health of the entire infrastructure. Heartbeat will send a signal to GitHub Builders if there is performance degradation in one of the services. GitHub Builders will automatically re-deploy services that experience performance degradation. The heartbeat feature can also automatically migrate servers when the latest LMS version is released by development. This is extremely helpful for developers to quickly make revisions and maintenance without disturbing LMS users.

LMS authentication uses a combination of Supabase & Google Cloud infrastructure. Supabase is used as a gatekeeper and session database for users. NextJS integration with supabase as an authentication system can run at both server and client authentication levels. To be able to connect with the State University of Malang SSO system, LMS uses Google Cloud as an identity connector based on an email address with the domain @um.ac.id. Through the OAuth API, Supabase interconnects the UM profile contained in the Google Account.

The Web Server implementation uses infrastructure managed by Vercel Inc. Vercel Inc. allows development to be done iteratively and quickly. The principle of iterative and fast is present because of the Continuous Integration and Continuous Delivery features which are inherently the main features of Vercel Inc. CI/CD is a major strength in the development process because it allows for revision and development without the need to do a staging process so that errors and features can be released quickly. The speed of development is supported by Github as the LMS source code repository service. The repository on GitHub that has been integrated with Vercel can automatically identify changes that are present.

4.3 Testing Results

Testing is conducted in two stages, namely Blackbox Testing, and Technology Acceptance Model. Blackbox testing is conducted by the development team independently based on predetermined scenarios and methods. The TAM test was conducted with prospective LMS users after the Blackbox test was declared complete.

Blackbox testing focuses on the results of LMS feature development. Each feature that has been realized is evaluated for reliability and the resulting output. From the results of the tests that have been conducted, all features that have been developed are declared following the specifications. From this test, it is stated that the LMS can continue to be evaluated through the Technology Acceptance Model (TAM). Table 6 shows details of the black box test results.

Table 6: LMS Blackbox Test Results

Feature	Expected Output	Result
Authentication	Email @um.ac.id	Expected
Dashboard	Correct Information	OK
Learning Contents	Video Playable	OK
Grades	Realtime Data	OK
Quizzes	Correct Answer	OK
Add Grades	Realtime Update	OK
Modify Grades	Realtime Update	OK

After black box testing is complete, the next step is latency testing using Apache JMeter. Testing is conducted on several endpoints using several colocation points. Testing with multiple colocation points is used to simulate the position of students in remote learning. The endpoints evaluated are database access points, app server access points, and load balancer access points. Table 7 shows latency test output using a millisecond time unit.

Table 7: Latency Test Output

Endpoints / from Location	Avg. Response Time	Avg. Network Speed
Dashboard / Malang (UM)	103 ms / 1K req.	2700 kbps
Dashboard / Jakarta (Biznet)	075 ms / 1K req.	5000 kbps
Dashboard / Padang (Telkomsel)	128 ms / 1K req.	1400 kbps
Quizzes / Malang (UM)	193 ms / 1K req.	2630 kbps
Quizzes / Jakarta (Biznet)	134 ms / 1K req.	4790 kbps
Quizzes / Padang (Telkomsel)	274 ms / 1K req.	1273 kbps
Learn. Material / Malang (UM)	128 ms / 1K req.	2320 kbps
Learn. Material / Jakarta (Biznet)	114 ms / 1K req.	4780 kbps
Learn. Material / Padang (Telkom)	136 ms / 1K req.	1489 kbps
Authentication / Malang (UM)	057 ms / 1K req.	3000 kbps
Authentication / Jakarta (Biznet)	032 ms / 1K req.	5000 kbps
Authentication / Padang (Telkom)	078 ms / 1K req.	3000 kbps
AVERAGE	**121 ms / 1K req.**	**3115 kbps**

Table 7 shows the average latency obtained from four endpoints at the three test points is 121 milliseconds per thousand requests. This result is incredibly good, and it can be concluded that the app server can process requests with an average processing time that is quite short. Looking at the average network speed column, with a three Mbps connection, all LMS features can be used smoothly. This shows that the PaaS architecture can be used with users spread from various regions, starting from Malang, Jakarta, and Padang. This is possible because the database used is spread across various regions and interconnected so that each user will be connected to the data center closest to their geographical area.

A full implementation test was conducted to measure learner responses to the LMS. The full implementation test process was conducted on one hundred learners who took project-based learning. During the pilot test, learners were asked to fill in the "LMS Acceptance" questionnaire. This questionnaire was used as an instrument to collect data regarding learners' responses to the usefulness and ease of use of the LMS in Table 8.

Table 8: Descriptive TAM test results

Questionnaire	Mean	Median	Mode
Usefulness			
U01	4,97	5	6
U02	5,67	6	7
U03	5,52	6	6
U04	5,86	6	7
U05	5,52	6	6
U06	5,66	6	6
U07	5,55	6	6
U08	5,49	6	7
U09	4,2	4	4
U10	5,59	6	7
U11	5,69	6	7
U12	5,41	5	5
U13	5,7	6	6
U14	5,77	6	6
U15	5,57	6	6
Ease of Use			
EOU01 (Negative Statement)	3,2	3	2
EOU02 (Negative Statement)	3,28	3	2
EOU03 (Negative Statement)	2,96	3	2
EOU04 (Negative Statement)	3,48	3,5	2
EOU05 (Negative Statement)	3,71	4	4
EOU06	5,05	5	4
EOU07 (Negative Statement)	3,21	3	4
EOU08	5,46	6	6
EOU09 (Negative Statement)	3,98	4	4
EOU10 (Negative Statement)	3,03	3	2
EOU11	5,7	6	7

Questionnaire	Mean	Median	Mode
EOU12	5,68	6	6
EOU13	5,68	6	6
EOU14	5,77	6	7
EOU15	5,55	6	6

From Table 8, only a few learners gave negative responses to both aspects evaluated. However, in the usefulness aspect, the statements coded U01 and U09 showed lower scores than the other statements. Both statements are about the difficulty in product validation and the reduction of time spent on unproductive things. The difference in response to these two statements can be explained because the LMS is not designed to assist in the standard validation of learning products and manage learners' study time to work on the product. On the ease-of-use aspect, several learners gave negative responses, especially on statements EOU09 and EOU05. The statement relates to the effort that users must spend and the unexpected behavior of the LMS. This negative response is normal at the development stage, given the possibility of technical errors that are beyond the control of development.

The results of the full implementation test on the aspects of usefulness and ease of use showed that the LMS received positive responses from the learners who became the test subjects. This indicates that the LMS development provides convenience and benefits for learners undergoing project-based learning.

4. Conclusion

This study revealed that the usefulness dimension shows consistently high scores, with mean values ranging from 4.20 to 5.86, and most median and mode values clustered around 6 and 7. These results indicate that the majority of respondents perceived the LMS as a valuable tool that supports and enhances the learning process, especially in project-based learning environments. For the ease-of-use category, the responses were more varied, particularly for negatively worded statements (e.g., EOU01–EOU05, EOU07, EOU09, EOU10), which received lower mean scores (mostly between 2.96 and 3.71), indicating disagreement with the negative wording—thus implying a positive perception of usability. In contrast, positively framed items (e.g., EOU06, EOU08, EOU11–EOU15) received higher mean scores, ranging from 5.05 to 5.77, with median and mode values consistently high (mostly 6 or 7). This suggests that while some minor usability issues were identified, the system overall was perceived as user-friendly and intuitive by the majority of users.

The results obtained from the black box testing, latency measurements, and acceptance testing indicate that the developed LMS is both feasible and appropriate for implementation in project-based learning environments. The integration of multiple technology services into the system was effectively achieved, although several users expressed concerns regarding performance during the pilot phase. Despite these limitations, learners reported perceivable benefits and ease of use, highlighting the LMS's positive contribution to the learning experience. Furthermore, the adoption of a PaaS architecture demonstrated advantages in supporting distance learning, particularly in terms of scalability and ease of maintenance within production environments. Based on these findings, the PaaS model presents a viable architectural reference for future LMS development, especially in contexts where users are geographically dispersed.

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