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Design of Training Cost Tracking Application at the Learning and Development Management Department of PT Bio Farma (Persero) Website Based

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Abstract

The advancement of digital technology is now a crucial factor in financial management, especially in the process of tracking employee training costs. This research aims to design and develop a website-based application that supports the Learning and Development Management Department of PT Bio Farma in monitoring training costs in real-time. The system development follows the Waterfall model which includes the stages of requirements analysis, system design, implementation, and testing. The application is equipped with key features, such as real-time cost monitoring, data integration for various Payment methods, including reimburse, transfer request, down Payment, down Payment liability, and Guarantee Letter. Testing was conducted using black-box testing to ensure the functionality of the application, as well as user evaluation to assess the effectiveness of the system in improving the efficiency of recording training costs. The test results show that this application can reduce the potential for recording errors, speed up the administrative process, and support data-based decision making more accurately and efficiently.

Keywords: Tracking cost, training, web-based application

1 INTRODUCTION

Advances in digital technology now play an increasingly important role in facilitating financial management in companies (Setyasih, et al., 2024), including in training activities at PT Bio Farma (Persero). PT Bio Farma, located in Bandung, is a state-owned pharmaceutical company engaged in vaccine production and distribution, with a mission to support public health through quality health products. As a large company that focuses on research and development, Bio Farma has several important departments, one of which is the Learning and Development Management Department. This department is responsible for the implementation of employee training and development activities, including the management of costs for various training activities.

However, in the implementation of training cost management, the Learning and Development Management Department often faces obstacles. One of the main issues is the difficulty in monitoring expenditure in real-time during activities, which often results in discrepancies between recorded and actual expenditure. In addition, the manual process of making reimbursements, transfer requests, advances, advance accountability, Guarantees is time consuming and prone to recording errors. These constraints indicate the need for a more integrated system so that the cost management process in training activities can run more efficiently, transparently, and accurately. Without a structured system, delays in recording and reporting costs can occur, hampering smooth administration and causing budget discrepancies. In addition, the lack of real-time visibility into expenditure can reduce the effectiveness of training evaluation and strategic decision-making. This could potentially result

in sub-optimal resource allocation, difficulty in measuring the effectiveness of training investments, and delays in adjusting policies based on organizational needs.

As a solution, a web-based application was designed that has several key features to address these issues. The application includes a real-time cost monitoring feature to facilitate budget monitoring during training activities, ensuring that all expenses are recorded in a timely and accurate manner. In addition, this application is equipped with automatic reimbursement, transfer request, advance payment, Guarantee creation features that can simplify the cost submission process and reduce the risk of recording errors, approval and disbursement processes without the need for separate documents in Word or Excel. Thus, this application is expected to make the flow of cost management more efficient and structured.

In research conducted by Fendi Puji Atmiko et al who made a desktop application for controlling production costs which aims to keep costs incurred in accordance with the target and budget realization reports (Atmiko, et al., 2017). Leni Oktavia et al created a web-based application that aims to control production and operational costs and supervision of production costs, journals, ledgers, and income statements (Oktavia, et al., 2015). Arni Retno Mariana et al created a web-based application that aims to estimate products by changing the semi-manual system to an application that has a database-integrated system so that cost estimates can be better (Mariana, et al., 2021). Nurani & Syuryadi created a web and android-based application that aims to manage data and estimate the cost of food commodities on the market (Nurani & Syuryadi , 2022).

This research designs a tracking cost application to manage special costs in training activities at PT Bio Farma (Persero) to run more effectively and transparently. The system development uses the Waterfall model, which includes the stages of analysis, design, coding, and testing. This application is equipped with real-time monitoring features, reimbursement creation, transfer requests, advances, advance accountability, automatic guarantees, and training financing recapitulation reports to improve financial data accuracy. With this system, the expenditure monitoring process is more efficient, workflow is faster, and budget-related decisions can be made based on more accurate and relevant data. This application not only provides a practical solution in expense monitoring, but also speeds up workflow, allowing budget-related decisions to be made based on more accurate and relevant data.

2 LITERATURE REVIEW

2.1 Website

Website is a collection of HTML documents owned by a person or agency which contains data and information stored on a web server, and can be briefly defined as a collection of web pages stored in a domain / subdomain on the world wide web (Miftahuljannah & Suharso, 2023).

2.2 Application

The application is an applicable tool that functions specifically. The definition of an application in general is an applied tool that functions in an integrated and special way according to needs, it can also be interpreted as a device from a computer that can be functioned by users (Alfiansyah & Junianto, 2023).

2.3 Cost Management

Cost management practices are critical to achieving successful projects/jobs, minimizing cost overruns, and ensuring positive outcomes. Key practices such as efficient resource allocation, quality control, change management, and progress monitoring and control contribute to cost control and reduce cost overruns (Shah, et al., 2023).

2.4 Training

Training is an activity aimed at developing skills, experience, knowledge and changes in attitude. Job-related training is usually given to employees whose tenure has been long enough. Training is usually a set of individual activities that are useful for improving practical skills and knowledge so that the employee will have a more professional performance (Susilo, et al., 2022).

2.5 PHP

PHP (Personal Home Page) is a programming language used to manage databases and website content, making it possible to create a dynamic web. In addition, PHP can be combined with HTML to develop various features on a website (Arafat, et al., 2022).

2.6 MySQL

MySQL is a system for database management that has a function to connect PHP scripts through query commands, allowing to manage and manipulate data efficiently to develop the web (Wulandari & Nurmiati, 2022).

2.7 JavaScript

JavaScript is a script-based programming language that functions to increase interactivity in a web document. From this definition, it can be concluded that JavaScript is used to add dynamic features to HTML and enrich the appearance and functionality of a web page (S, et al., 2021).

3 RESEARCH METHODS

This research uses the Waterfall method, which consists of several sequential stages. The stages are described as follows, and an illustration of the Waterfall model can be seen in Figure 1.

3.1 Analysis

At this stage, identification of system requirements is carried out through several methods:

1. Observation: Directly observing the workflow of training cost management in the Learning and Development Management Department of PT Bio Farma (Persero) to understand the system requirements in detail.
2. Interview: Conducted to gather system requirements and information on the challenges faced in recording and monitoring training costs from the Manager and two staff from the Learning and Development Management Department of PT Bio Farma (Persero).
3. Literature Study: Reviewing various references related to information systems and training cost management methods to ensure that the system developed has a strong foundation and is in accordance with best practices.

3.2 Design

This stage aims to use UML diagrams (activity diagrams, use case diagrams and class diagrams) to describe the workflow and the corresponding system (Setiaji & Sastra, 2021):

1. Activity Diagram: Depicts the flow of user activity in the system, from SPRL creation to financial report monitoring.
2. Use Case Diagram: Shows the relationship of functions available in the application.

3. Class Diagram: Describes the relationships between entities, methods and attributes used to support business processes in the application.

3.3 Coding

At this stage, the system is developed using various technologies, including:

1. Programming Languages: PHP and JavaScript, which are used to build the application logic and improve the interactivity of the interface.
2. Framework: Bootstrap is applied to design a responsive and user-friendly interface.
3. Database: MySQL is used as the database management system, which is designed to handle training fee transactions efficiently.

3.4 Testing

The system is tested using the Black-box Testing method, which focuses on testing the functionality of each feature without looking at the source code. This test aims to ensure that the application can run according to user needs, and all features have functioned properly according to the specifications set (Fikri & Voutama, 2023).

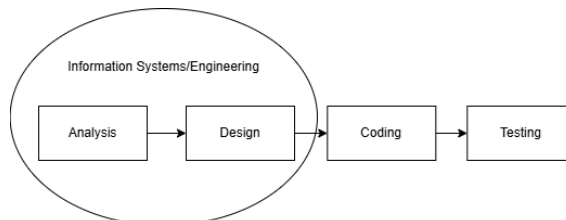


Figure 1. Waterfall Method (A.S & Shalahuddin, 2019)

4 RESULTS AND DISCUSSION

The results of the analysis based on interviews and observations of the Learning and Development Department show the main needs for the training cost tracking application, namely: real-time cost monitoring, management of payment methods (reimbursement, advance & advance liability, transfer request, Guarantee), automatic financial report generation.

4.1 System Design

The system design consists of designing activity diagrams, use case diagrams, activity diagrams and class diagrams. Figure 2 This diagram shows the Admin workflow in the system. Admins can login to access the Dashboard, SPRL, and Reports. Payment features include Advance, Advance Accountability, Reimburse, Transfer Request, and Guarantee Letter. The include relationship indicates the dependency between features, such as Advance Accountability which can only be done after an Advance is created. After completion, the Admin can log out of the system. While Figure 3 explains the activities carried out in the training monitoring process starting from inputting SPRL, making Payment, creating reports to find out the expenditure of training costs in a certain period. Then Figure 4 displays a class diagram that represents the structure of the SPRL system in managing training and financial administration. This diagram consists of several main classes, including SPRL, Users, Participant, Training Type, Payment, Report, and various payment methods such as Advance, Reimburse, Guarantee, and Transfer Request. Each class has a specific role and is interconnected to support the process of recording training data and payment transactions. SPRL as the main entity has a relationship with Users who can create SPRL, as well as with Participants to record training participants. TypeTraining is associated with SPRL to determine the

type of training, such as Overseas, In-house, Internal, and Domestic Training, each with its own attributes and cost calculation methods. The system also includes financial management with the Payment class, which is associated with various payment methods, including Advance, Reimburse, Guarantee, and Transfer Request, ensuring that every transaction is properly recorded. In addition, the Report class allows the generation of reports based on specific timeframes.

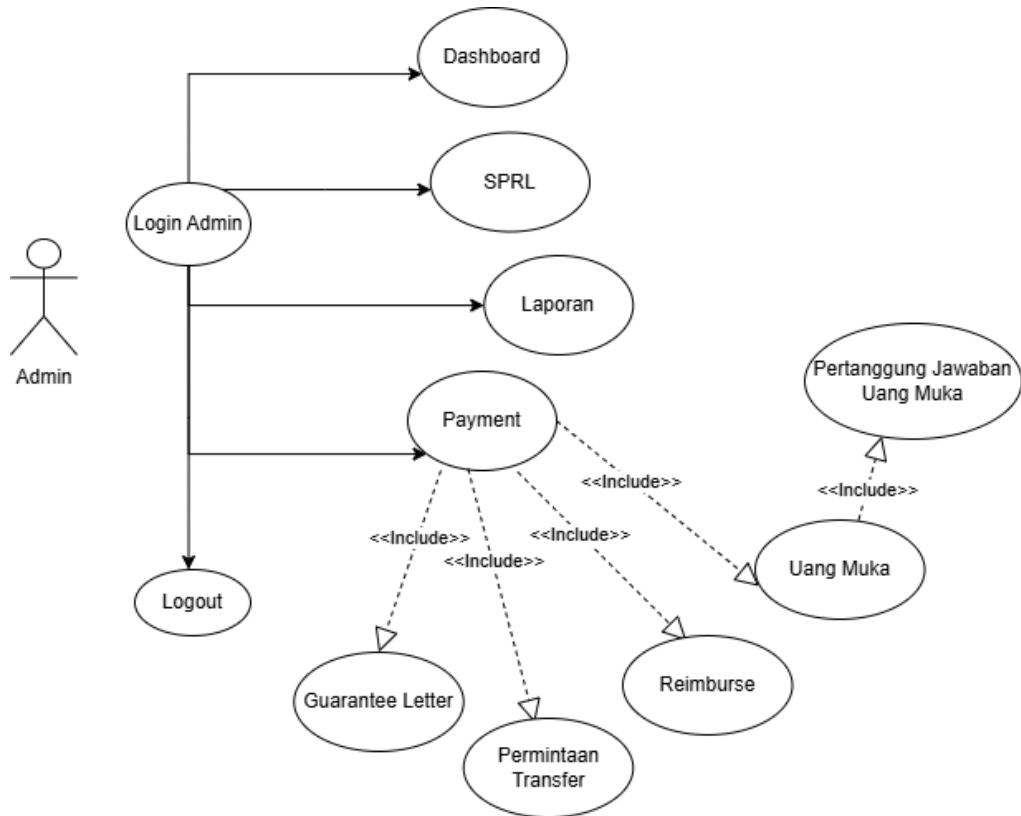


Figure 2. Use Case Diagram Tracking Cost

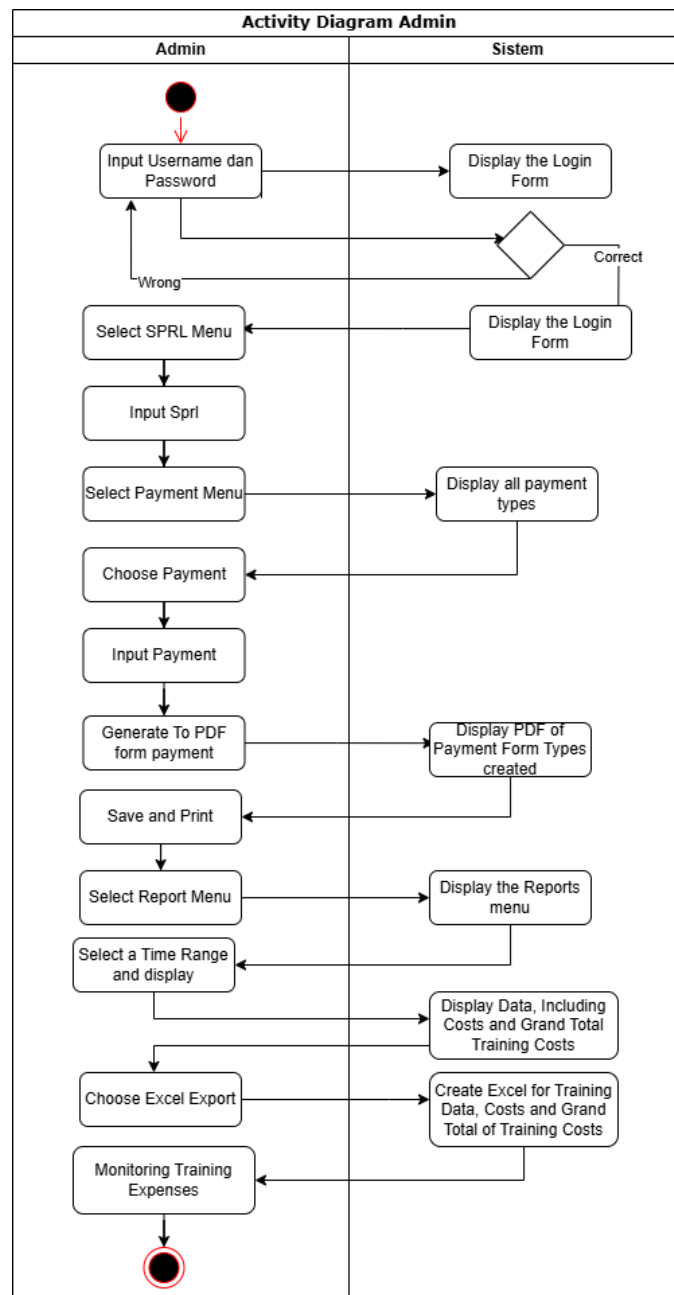


Figure 3. Activity Diagram

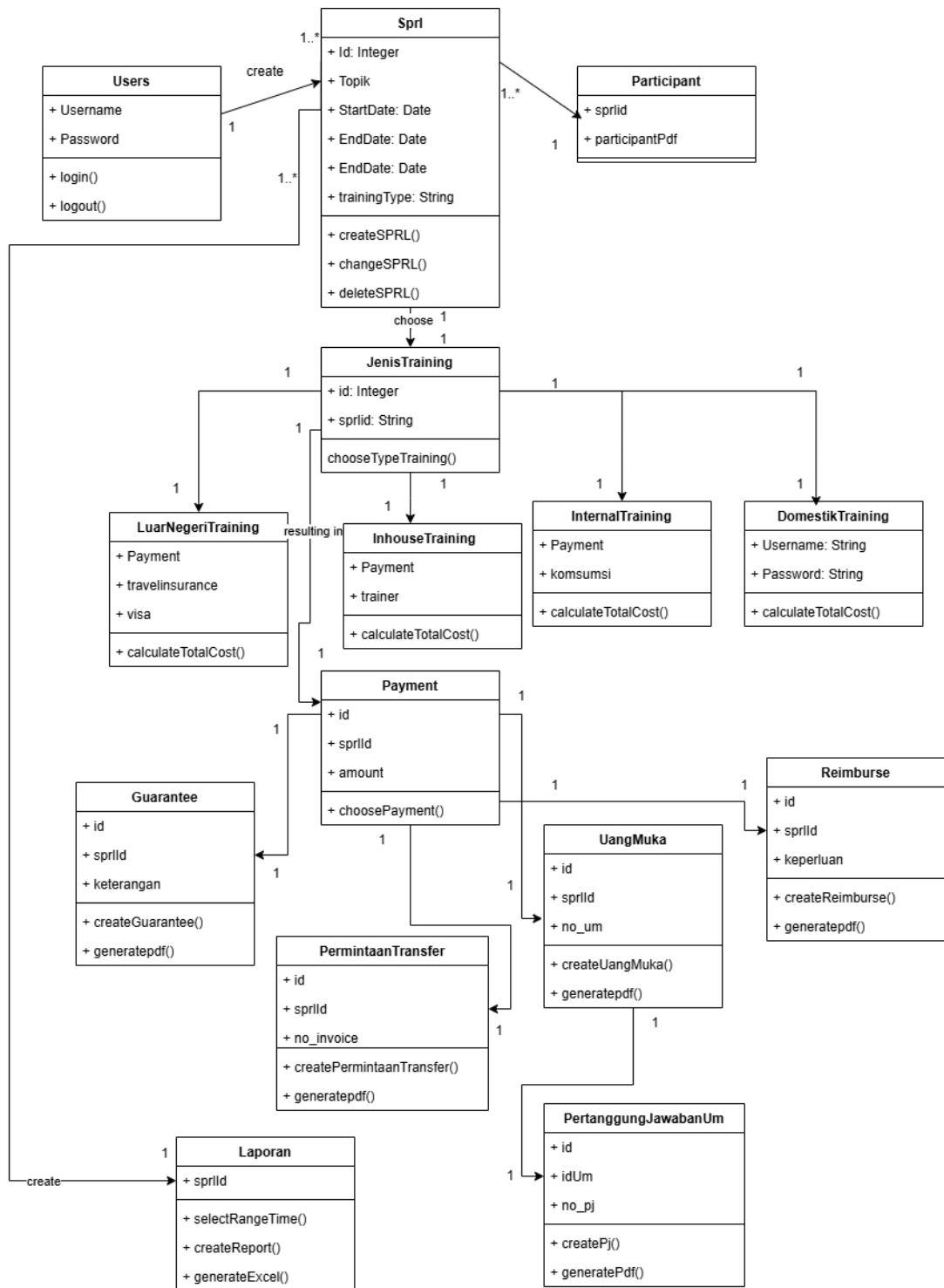


Figure 4. Class Diagram

4.2 Implementation

At this stage of system implementation, it contains the results of the implementation of designs and needs in the Development and Learning Management Department of PT Bio Farma (Persero).

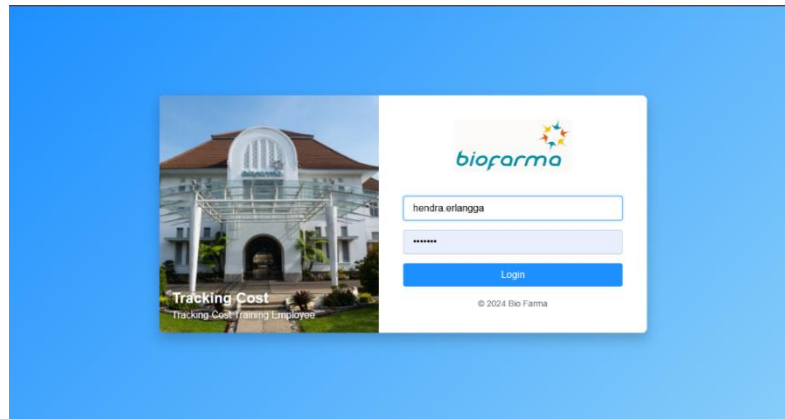


Figure 5. Login

Figure 5 accesses the cost tracking application. On this page, the admin is required to enter a username and password that has been registered previously. This login process aims to ensure that only users who have valid credentials can enter the system, so that data and information security is maintained.

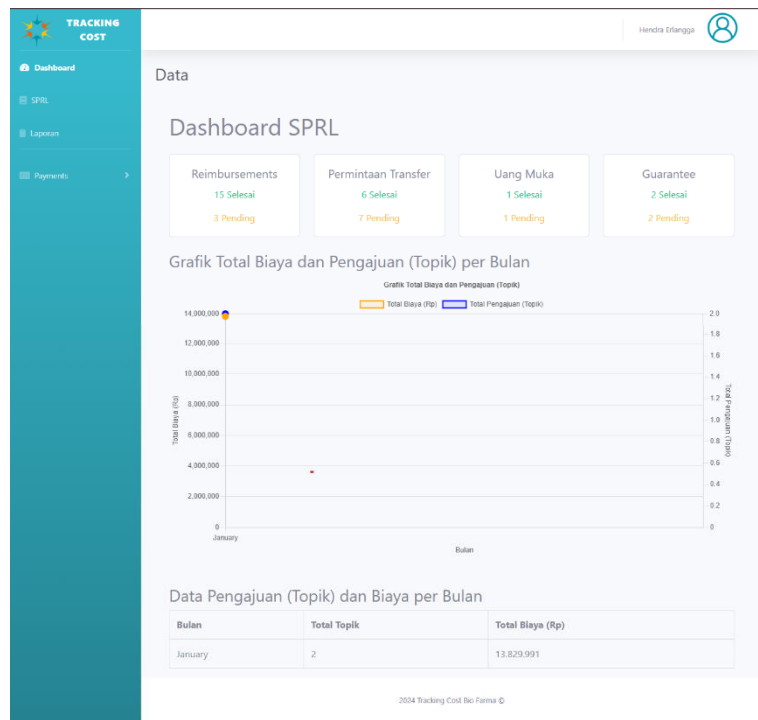


Figure 6. Dashboard

Figure 6 is a view of the dashboard that displays cost data from SPRL input in real-time. The dashboard can also be used for monitoring, the admin can immediately see when he first logs in, in the Dashboard view, information is provided regarding the graph of total costs and submissions (topics) per month, submission data tables (topics) and costs per month, but here the admin can only monitor all cost data per month. Admins can monitor the status of payments related to training activities. This includes payments that are still pending or have not been made, as well as payments that have been successfully completed. With this feature, admins can easily find out the number of

payments that still need to be processed and use it as a reminder to follow up on transactions that have not yet been made.

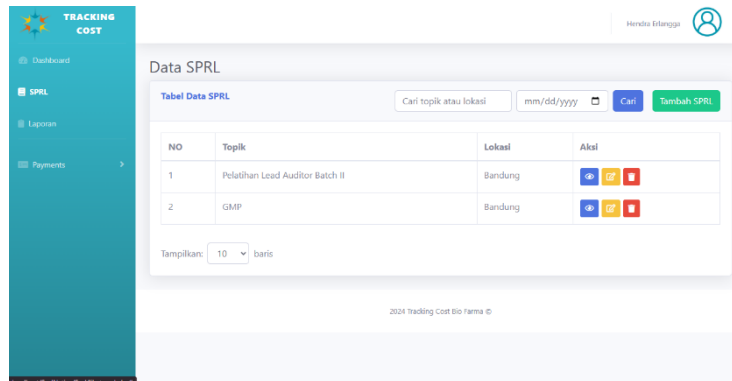


Figure 7. SPRL Menu

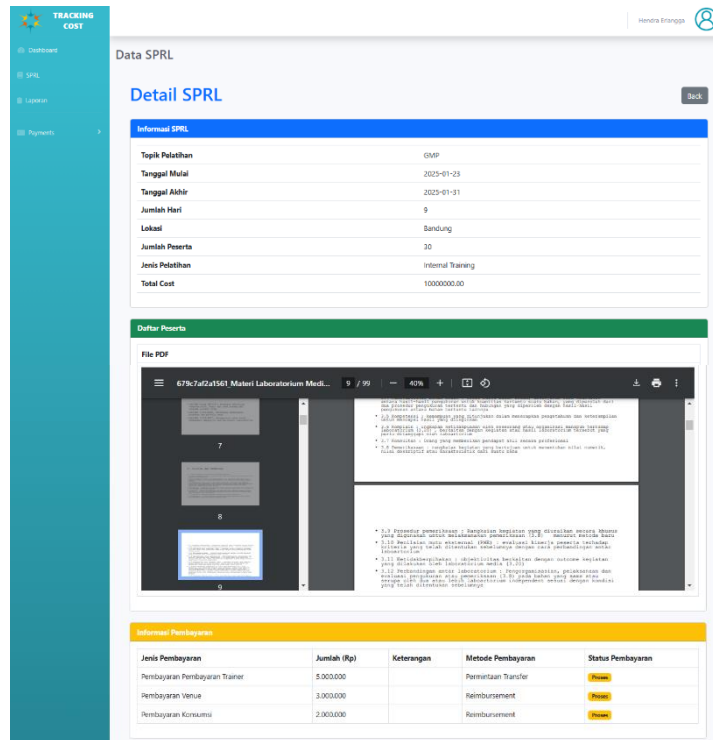


Figure 8. SPRL Detail

Figure 7 displays the SPRL (Surat Pengajuan Realisasi Learning) feature which is used to manage the submission of each training, starting with the process of inputting data such as training topics, start and end dates, number of days (auto-filled), location, number of participants and participant list in pdf form. The admin also selects the type of training, which determines the available payment methods and types: Public Training - Domestic (Training, Venue, Transportation, SPPD), Public Training - Overseas (Training, Venue, Transportation, Visa, Travel Insurance, SPPD), Inhouse Training (Trainer, Venue, Consumption, Others), Internal Training (Trainer, Venue, Consumption). After that, the admin fills in the payment amount, description (optional), and chooses one of the four payment methods then save.

Figure 8 displays the SPRL data that has been saved, the admin can search and view the SPRL details again which contains the training topic, date, number of participants, total cost, list of participants, as well as payment details such as training type, amount, payment method and payment status, the payment status is divided into “Process” and “Done”, if a payment has been made, the status automatically changes to “Done”, while if it has not been made then the status will remain in “Process”, this aims to allow the admin to monitor the progress of training payments.

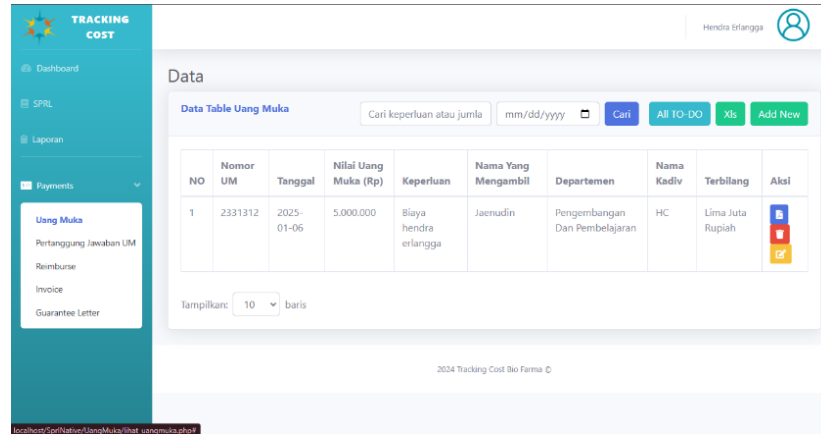


Image 9. Advance Payment

Figure 9 shows an example of the payment system used to manage transactions, including reimburse requests, advances, advance liability, transfer requests, and guarantees. Data is automatically retrieved from SPRL. Each menu in the Payment feature-such as Advance, Advance Liability, Reimburse, Invoice, and Guarantee Letter-allows admins to create payments according to the inputted SPRL. There is a “To Do” feature, which helps admins view unprocessed transactions and instantly create payments with the selected method. However, Advance Accountability can only be created based on completed Advance data. The table in this menu displays all available Advance data, so admin can select and input the accountability according to the available form, after the transaction is created, admin needs to click “Done” in “To Do” for the payment status in SPRL Details to change.

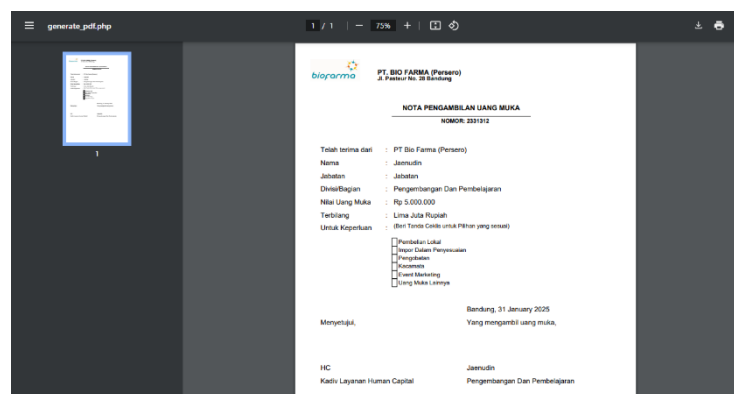


Figure 10. Result Generate PDF Payment Advance

Figure 10 displays the Down Payment PDF Generate, here the admin can Generate PDF, where each payment method has a different PDF format. Although the input flow is similar, each method has different inputs and outputs. Admins can also edit or delete incorrect payment data without affecting the original SPRL data. If required, all payment data can be exported to Excel.

4.3 System Testing

Testing was carried out using the Blackbox method, this test can be seen in Table 1.

Table 1. System Testing

Feature Tested	Scenario	Result	Remarks
Login	Enter username and password	Valid	Successfully displays the dashboard page
Add SPRL Data	Click "Add SPRL" button and fill in all SPRL data	Valid	Successfully added SPRL data
Search SPRL Data	Enter SPRL name in the search field and click "Search"	Valid	Successfully displayed the searched SPRL
Edit SPRL Data	Click the pencil icon and edit the data	Valid	Successfully updated SPRL data
Delete SPRL Data	Click the trash bin icon to delete the data	Valid	Successfully deleted SPRL data
View SPRL Details	Click the eye icon to view details	Valid	Successfully displayed SPRL detail
Add Advance Payment Data	Click "Add New" and create an advance payment	Valid	Successfully added advance payment data
Edit and View Advance Payment Data	Click the pencil icon and modify advance payment	Valid	Successfully viewed and updated advance payment data
Delete Advance Payment Data	Click the trash bin icon to delete advance payment	Valid	Successfully deleted advance payment data
Generate Advance Payment PDF Form	Click the document icon to auto-generate the form	Valid	Successfully auto-generated the advance payment form
Export to Excel	Click the "XLS" button	Valid	Successfully exported advance payment data to Excel
View Advance Payment To-Do List	Click "All To Do" to view the full To-Do list	Valid	Successfully displayed all To-Do items
Create Advance Payment from To-Do	Click "Create" button to make an advance payment	Valid	Successfully created and added advance payment data
Mark To-Do as Done	Click "Done" to remove item from To-Do list	Valid	Successfully removed item from To-Do list
Add Reimbursement Payment Data	Click "Add New" and create a reimbursement	Valid	Successfully added reimbursement data
Edit and View Reimbursement Payment Data	Click the pencil icon and modify reimbursement	Valid	Successfully viewed and updated reimbursement data
Delete Reimbursement Payment Data	Click the trash bin icon to delete reimbursement	Valid	Successfully deleted reimbursement data
Generate Reimbursement PDF Form	Click the document icon to auto-generate the reimbursement form	Valid	Successfully auto-generated the reimbursement form

Feature Tested	Scenario	Result	Remarks
Export to Excel (Reimbursement)	Click the "XLS" button	Valid	Successfully exported reimbursement data to Excel
View Reimbursement To-Do List	Click "All To Do" to view all To-Do items	Valid	Successfully displayed all reimbursement To-Do items
Create Reimbursement from To-Do	Click the "Create" button to make a reimbursement	Valid	Successfully created and added reimbursement data
Mark To-Do as Done (Reimbursement)	Click "Done" to remove the item from the To-Do list	Valid	Successfully removed item from reimbursement To-Do list
Add Transfer Request Payment Data	Click "Add New" and create a transfer request	Valid	Successfully added transfer request data
Edit and View Transfer Request Payment Data	Click the pencil icon and modify transfer request	Valid	Successfully viewed and updated transfer request data
Delete Transfer Request Payment Data	Click the trash bin icon to delete transfer request	Valid	Successfully deleted transfer request data
Generate Transfer Request PDF Form	Click the document icon to auto-generate the form	Valid	Successfully auto-generated the transfer request form
Export to Excel (Transfer Request)	Click the "XLS" button	Valid	Successfully exported transfer request data to Excel
View Transfer Request To-Do List	Click "All To Do" to view all To-Do items	Valid	Successfully displayed all transfer request To-Do items
Create Transfer Request from To-Do	Click the "Create" button to make a transfer request	Valid	Successfully created and added transfer request data
Mark To-Do as Done (Transfer Request)	Click "Done" to remove the item from the To-Do list	Valid	Successfully removed item from transfer request To-Do list
Add Guarantee Payment Data	Click "Add New" and create a guarantee	Valid	Successfully added guarantee data
Edit and View Guarantee Payment Data	Click the pencil icon and modify guarantee	Valid	Successfully viewed and updated guarantee data
Delete Guarantee Payment Data	Click the trash bin icon to delete guarantee	Valid	Successfully deleted guarantee data
Generate Guarantee PDF Form	Click the document icon to auto-generate the form	Valid	Successfully auto-generated the guarantee form
Export to Excel (Guarantee)	Click the "XLS" button	Valid	Successfully exported guarantee data to Excel
View Guarantee To-Do List	Click "All To Do" to view all To-Do items	Valid	Successfully displayed all guarantee To-Do items
Create Guarantee from To-Do	Click the "Create" button to make a guarantee	Valid	Successfully created and added guarantee data
Mark To-Do as Done (Guarantee)	Click "Done" to remove the item from the To-Do list	Valid	Successfully removed item from guarantee To-Do list

Feature Tested	Scenario	Result	Remarks
Add Advance Payment PJ Data	Click the “Add” button and create a PJ Advance Payment	Valid	Successfully added PJ Advance Payment data
Edit and View PJ Advance Payment Data	Click the pencil icon and modify PJ Advance Payment	Valid	Successfully viewed and updated PJ Advance Payment data
Delete PJ Advance Payment Data	Click the trash bin icon to delete PJ Advance Payment	Valid	Successfully deleted PJ Advance Payment data
Generate PJ Advance Payment PDF Form	Click the document icon to auto-generate the form	Valid	Successfully auto-generated the PJ Advance Payment form
Export PJ Advance Payment to Excel	Click the “XLS” button	Valid	Successfully exported PJ Advance Payment data to Excel
Select Report Date Range	Click the “Start Date” and “End Date” buttons to select SPRL period	Valid	Successfully selected the report date range
Display Report Data	Click the “Display” button	Valid	Successfully displayed report data
Export Report Data to Excel	Click the “Export Excel” button	Valid	Successfully exported report data to Excel

5 CONCLUSION

The implementation of the website-based Cost Tracking Application has successfully integrated the overall management of training costs, including real-time cost monitoring, reimbursements, transfer requests, guarantees, advances, and accountability for advances. With this system, training financial data is recorded centrally, making it easier to manage administration and speeding up the process of recording and financial reporting. The efficiency of the system is reflected in the reduction of time required for recording transactions and the ease of tracking expenditure history. In addition, the real-time monitoring feature allows users to control the budget more effectively, avoid wasting costs, and ensure every transaction is well documented. Transparency in cost management is also increased as every expenditure can be monitored directly by relevant parties, reducing the risk of recording errors and increasing accountability in the financial management process. For further development, this system can be improved by adding an analytics module that serves to evaluate the effectiveness of training costs on improving employee competence. This module can present data-based analysis reports, such as budget comparison with training results, identification of spending patterns, and cost efficiency recommendations based on historical data. Thus, companies can make more data-driven strategic decisions in planning future training budgets.

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Development of a Web-Based Internship Monitoring Application for Teachers at PT Chlorine Digital Media

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Abstract

The advancement of information technology has driven digital transformation across various sectors, including the management of *Praktik Kerja Lapangan* (PKL) programs. PT Chlorine Digital Media faces several administrative challenges, such as manual certificate distribution, delayed feedback, and unintegrated reports. This study aims to develop a web-based application using the Laravel framework due to its advantages in security, scalability, and efficient data management. Meanwhile, the Waterfall method was chosen for its systematic development stages, ensuring that each process aligns with system requirements. The results show that the developed application enhances efficiency and transparency in PKL data management, allowing teachers to access grades and certificates in real-time while expediting report generation. Beyond PKL, this system can be implemented for certification management, training evaluation, and internship monitoring in various institutions to support data-driven digital administration.

Keywords: PKL, Laravel, Digital Certificate, Internship Assessment, Web-Based Information System.

1 INTRODUCTION

The development of information technology today has had an increasingly significant impact across various sectors, including the effective and efficient management of information. Web-based technologies, particularly the Laravel framework, are widely used due to their ability to build secure, scalable, and easily maintainable web applications. PT Chlorine Digital Media leverages this teacher Internship Program (*Praktik Kerja Lapangan*/PKL) under their supervision (Sinlae et al., 2024).

However, PT Chlorine Digital Media faces several key challenges in managing the teacher internship program. Based on observations and firsthand experience during the Industrial Work Practice (Kuliah Kerja Industri/KKI) at the company, it was found that the current PKL data management system is still manual, leading to various operational issues. One of the main problems is the manual distribution of PKL certificates, where each document must be reviewed and sent individually to participants. This causes delays and increases the risk of errors in certificate distribution.

In addition, teachers participating in the internship program have to wait a considerable amount of time to receive their evaluations and feedback, as the assessment process is conducted separately from the main system. These delays hinder teachers from reflecting on and improving their PKL outcomes. The lack of an integrated system connecting activity reports with evaluation data also presents a challenge, as compiling reports takes considerable time due to the need to collect data manually from various sources.

Using the Laravel framework in web application development offers several advantages, including robust security, flexibility in data management, and ease of adding modules as needed. By utilizing this technology, an application can be designed to address the issue of certificate distribution

by providing a fast and accurate manual upload feature. Additionally, an interactive dashboard can assist teachers in monitoring their evaluations and accessing grades and feedback directly. The report generation process can also be integrated with other data, thus streamlining and simplifying report management. Research by (Walukow et al., 2023) indicates that the implementation of information technology in administration can increase data management efficiency, minimize human error, and accelerate information distribution.

Furthermore, (Toni & Hadi, 2023) emphasize that Laravel provides significant advantages in academic system development, particularly in terms of security and ease of database management. In the context of teacher internship management, the use of Laravel has also been proven to improve the effectiveness of PKL participant management systems, as discussed by (Rosadi et al., 2020), who developed a Laravel-based system to facilitate the registration, monitoring, and evaluation of internship participants in a more structured and automated manner. Additionally, research by (Shalihin et al., 2022) shows that implementing Laravel in internship systems can optimize certificate document storage and management, thereby reducing errors in manual document distribution.

This study aims to develop a more structured and efficient teacher internship management system by utilizing the Laravel framework. With this system, it is expected that the management of reports, certificates, and assessments can be carried out more automatically and with minimal errors. Moreover, this research contributes by providing a technology-based solution that enhances the administrative effectiveness of internship programs, while also offering easy access for teachers and administrators in managing internship data digitally.

The novelty of this research lies in the implementation of automated certificate and assessment management features using Laravel, which have not been widely adopted in similar systems. Unlike previous studies that focused more on internship registration and monitoring, this research integrates digital certification and data-driven evaluation features that can be accessed in real-time by teachers and administrators. Through this approach, the system not only enhances administrative efficiency but also enriches the monitoring and reporting functions in a more comprehensive manner.

The application is expected to improve the efficiency and effectiveness of teacher internship data management while providing an integrated solution for various administrative needs. With a more modern and structured system, the internship program management can be carried out more effectively, meet user needs, and support data-driven decision-making.

2 LITERATURE REVIEW

This section reviews the theories and concepts underlying the research on the development of a web-based information system to manage internship certificates, assessments, and report generation. The literature review includes discussions on web-based information systems, the application of the Laravel framework, the digitalization of internship certificates, transparency in internship assessments, and the integration of internship reports with participant data.

2.1 Web-Based Information Systems

A web-based information system is designed to manage and present data over the internet, allowing users to access information anytime and anywhere with an internet connection. According to (Fitriani et al., 2024), the implementation of a web-based academic information system using the Rapid Application Development (RAD) method can improve the efficiency and effectiveness of academic data management.

In addition, web-based systems offer more flexibility compared to desktop-based systems because they do not require additional software installation and can be accessed from various devices.

2.2 Laravel Framework in Web System Development

Laravel is one of the most widely used PHP frameworks in web application development. It offers various features that facilitate developers in building applications, such as a routing system, Eloquent ORM, and enhanced security. According to (Mustamiin et al., 2020), Laravel enables faster application development due to its Model-View-Controller (MVC) architecture, which separates business logic from the presentation layer, making system maintenance and development more manageable. Their study showed that Laravel is highly effective in building web-based exam management systems due to its features that support efficient data management.

2.3 Digitalization of Internship Certificates

The digitalization of internship certificates aims to replace the manual printing process with digital certificates that can be accessed and verified online. In their study, (Palingga Ninditama et al., 2022) stated that digitalization in academic administration, including internship certificates, provides advantages in terms of faster data management and reduces the risk of document loss. With a web-based system, internship participants can download their certificates upon program completion without needing to visit the institution in person.

2.4 Transparency in Internship Assessment

Transparency in internship assessment is an important factor in increasing participants' trust in the evaluation system. A transparent system allows participants to view their assessment results in real time and understand the evaluation criteria used. (Isrohatul Ghoniyah & Handayanto, 2024), in their research, developed a web-based information system that enhances transparency in internship assessment, allowing participants to monitor their grades in real time and providing access to the evaluation criteria used by supervisors. This system also reduces uncertainty in the assessment process, ensuring that participants understand each step taken in evaluating their performance.

2.5 Integration of Internship Report with Participant Data

The integration of internship reports with participant data aims to streamline documentation processes and ensure that all participant information is centralized in one system. (Palingga Ninditama et al., 2022), explained in their study that web-based academic systems can be used to automate internship reports by linking them directly to participant data, thereby simplifying tracking and evaluating participant performance. As a result, manual data entry can be avoided, reducing the risk of administrative errors.

3 RESEARCH METHODS

3.1 Data Collection Method

This research uses interviews as the primary method of data collection. Interviews were conducted with relevant parties at PT Chlorine Digital Media, such as the Director and IT staff who also acted as mentors during the internship. The purpose of the interviews was to understand the problems and needs within the existing system, including certificate management, grading, and report generation. The interview method was chosen because it provides direct information from individuals with in-depth knowledge of the system. As explained in the research methods module of Esa Unggul University, qualitative research interviews involve two-way communication aimed at obtaining the most accurate data possible (Adhandayani, 2020).

3.2 System Development Method

The system development method used in this project is the Waterfall model. This method was selected due to its structured and systematic workflow, which is suitable for developing the internship management application. The development process begins with requirement analysis, followed by system design, implementation, testing, and concludes with maintenance. This approach ensures that each stage is completed thoroughly before moving on to the next.

The stages of the Waterfall method applied in the development of the internship application are as follows:

1. **Requirement Analysis**

Developers collect user requirements through discussions, observations, surveys, or interviews, and then analyze them to determine the software specifications. In this stage, interviews were conducted with relevant parties such as academic supervisors and PKL participants to identify challenges in the PKL management process. The collected data were analyzed to formulate system specifications aimed at streamlining PKL document management, including features for certificate uploads, grade access, and automated PKL report generation.

2. **System and Software Design**

The requirement specifications are analyzed to design the system, including hardware preparation and the overall software architecture. Based on the defined specifications, system design includes user interface layout and software architecture. This stage also involves selecting the technologies to be used, such as frameworks and databases, and structuring the system to ensure usability and performance efficiency.

3. **Implementation and Unit Testing**

The software is developed in small modules, each tested for functionality and verified against the desired criteria. The system is developed incrementally by building functional modules such as certificate upload features, grade validation, and automated report generation. Each module is individually tested to ensure it performs according to the predefined specifications.

4. **Integration and System Testing**

The individually tested modules are integrated into a complete system, followed by comprehensive testing to identify any system errors or failures. After separate module testing, the next step is to combine all components into a single cohesive system. System testing is carried out to ensure there are no errors or conflicts between modules and to verify that the application functions as intended by the users.

5. **Operation and Maintenance**

The software is deployed and maintained, including bug fixes, system improvements, and adjustments based on user needs. After the application is used by users, regular maintenance is performed to fix any bugs found, enhance system performance, and adjust features according to the latest requirements (adminlp2m, 2022).

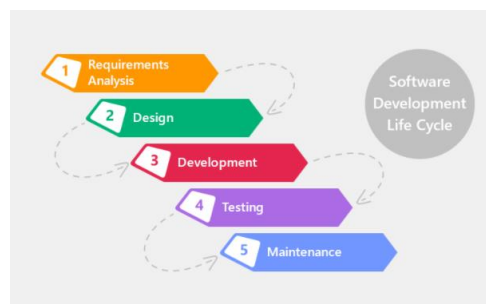


Figure 1. Waterfall Method

4 RESULTS AND DISCUSSION

4.1 System Design

The system design of this application adopts a visual modeling approach using Use Case Diagrams and Activity Diagrams. Use Case Diagrams are used to illustrate the interaction between users and the system, as well as the main functions that users can perform in the application.

In the development of this application, Figure 2 below presents the Use Case Diagram, which shows the interaction between users and the system and the main features available in the application. This diagram illustrates how teachers and admins play a role in managing various features provided.

Teacher have access to register, manage their profiles, upload PKL reports, participate in competency tests, download certificates, and view evaluation results. Meanwhile, admins are responsible for managing user data, reviewing and grading PKL reports, providing competency test evaluations, and uploading certificates to the system.

With the Use Case Diagram, the development of the application can be more structured as the system requirements are clearly defined. This diagram ensures that each developed feature aligns with the user roles and supports building an effective workflow in the application.

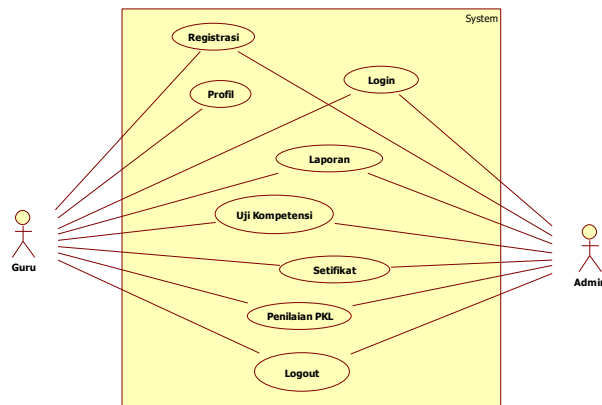


Figure 2. Use Case Diagram

Meanwhile, the Activity Diagram is used to illustrate the flow of activities and processes within the system, providing a deeper understanding of user-system interaction during each operational phase of the application.

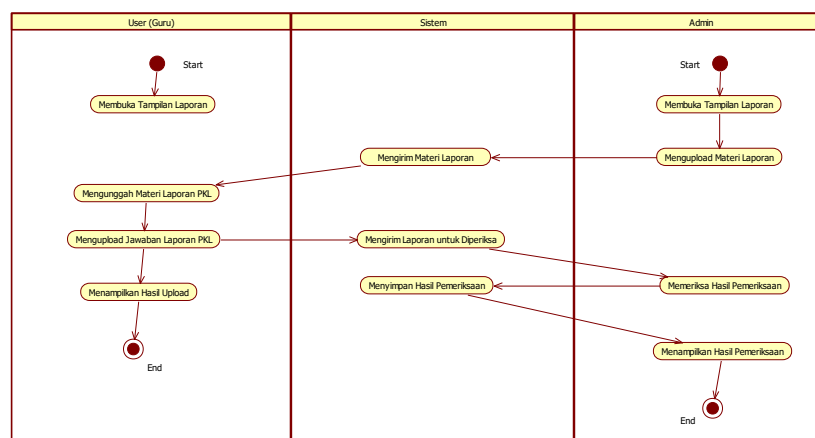


Figure 3. Activity Diagram – Report

Figure 3 shows the Activity Diagram for the Report feature, where teachers can upload PKL reports, which are then reviewed by the admin before being saved and displayed back to the teacher.

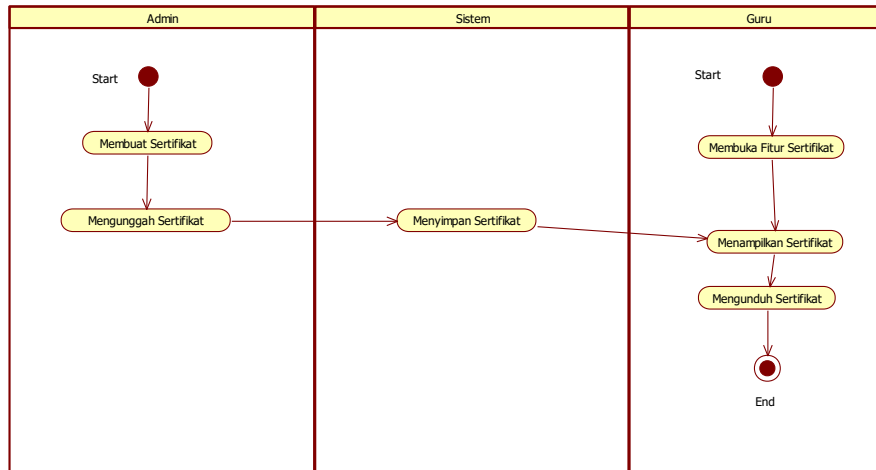


Figure 4. Activity Diagram – Certificate

Figure 4 illustrates the Activity Diagram for the Certificate feature, where the admin creates and uploads certificates, which can then be viewed and downloaded by the teacher.

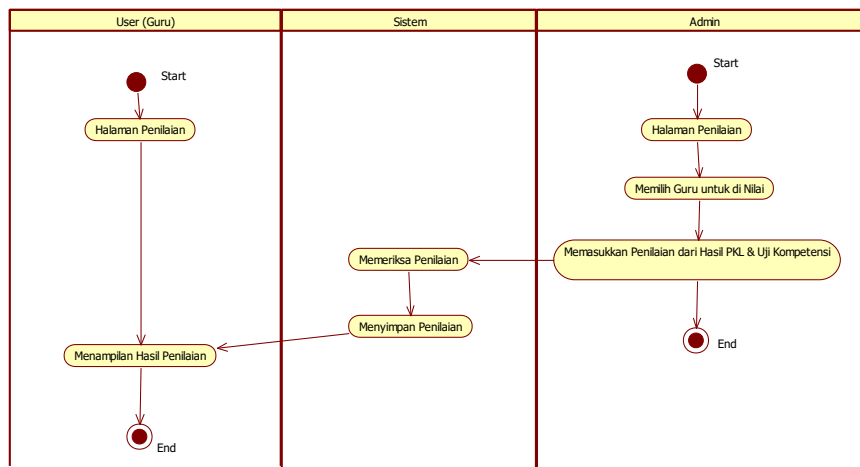


Figure 5. Activity Diagram – Assessment

Figure 5 explains the Activity Diagram for the Assessment feature, where the admin provides scores based on PKL and competency test results, and the system stores and displays the results to the teacher.

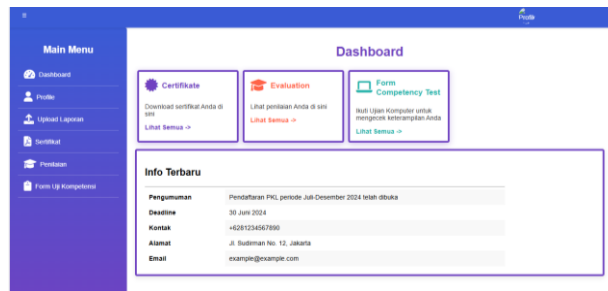


Figure 7. Dashboard Page

This is the main page after the user logs in. On the dashboard, PKL teachers and admins can view summary information related to the PKL program, such as report lists, certificate status, and assessment.



Figure 8. Report Page (Admin)

This page is used by admins to manage PKL reports. Admins can view the list of reports to be completed by PKL teachers, edit reports, and delete unnecessary ones.

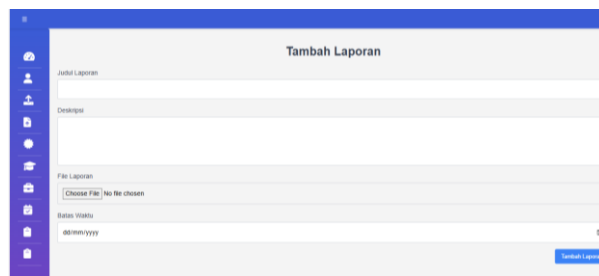


Figure 9. Add Report Form Page (Admin)

This page is used by admins to add new reports for PKL teachers to complete. Admins can input the title, description, and upload report files to be sent to the teacher.



Figure 10. Report Page

This page displays a list of reports that PKL teachers need to complete. Teachers can view the report status and select a report to work on.

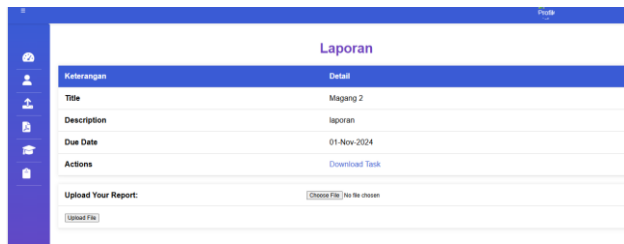


Figure 11. Report Details Page

After selecting a report, the teacher is directed to this page to view report details and upload the answers according to the instructions provided.

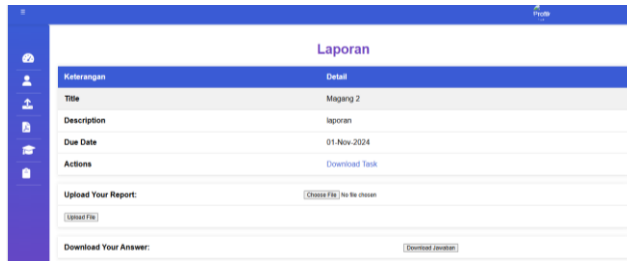


Figure 12. Report Upload Confirmation Page

This page confirms that the report has been successfully uploaded by the PKL teacher. The admin can now review the submitted report.

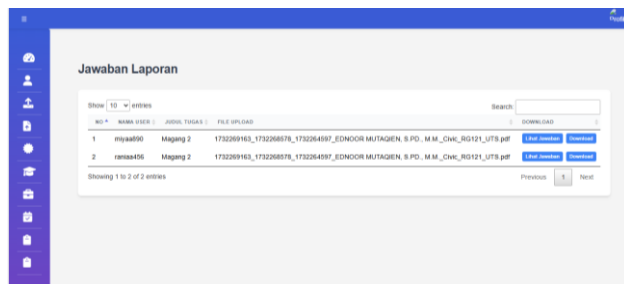


Figure 13. Report Answer Page (Admin)

This page is used by the admin to view report answers submitted by PKL teachers. The admin can give feedback or revise the submitted answers.



Figure 14. Certificate Page (Admin)

This page contains a list of certificates available for PKL teachers. Admins can view, manage, and add new certificates.



Figure 15. Add Certificate Form Page (Admin)

This page is used to add new certificates based on type or category. Admins manually upload certificates so they can be accessed by PKL teacher.



Figure 16. Certificate Page

This page shows the certificates available for download by PKL teachers. Certificates are categorized according to the type specified by the admin.

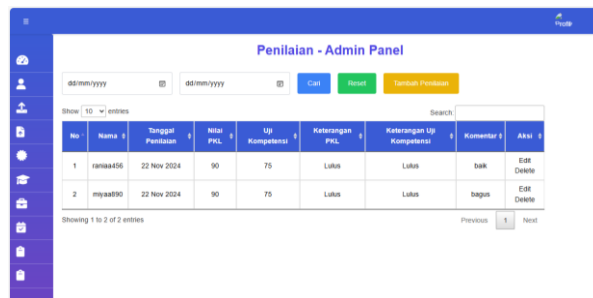


Figure 17. Assessment Page (Admin)

This page is used by the admin to view and manage evaluations for PKL teachers. Admins can assign scores, edit, or delete assessments if necessary.



Figure 18. Add Assessment Form Page (Admin)

This page allows admins to add assessments for PKL teachers. Admins can input scores, notes, and save the results.



The screenshot shows a web interface titled "Penilaian" (Assessment). It displays a summary box with the following information: Nama: canisa456, Catatan/Komentar: baik, and Tanggal Penilaian Dilakukan: 22 Nov 2024. Below this is a table with the following data:

No	Mata Pelajaran	Nilai	Keterangan
1	Praktik PKL	90	Lulus
2	Ujian	75	Lulus

Figure 19. Assessment Page

This page displays the assessment results for PKL teachers during the PKL and Competency Test activities. It contains information about passing status as well as feedback or suggestions provided to the teacher.

4.3 System Testing

Table 1. System Testing – Teacher

No.	Feature	Purpose	Test Steps	Expected Result
1	Login	Ensure successful login	Enter correct email & password, login	User logs in and is redirected to dashboard
2	Login	Ensure failed login	Enter incorrect email or password	Error message appears
3	Register	Ensure account registration	Enter valid data and register	Registration successful, redirected to dashboard
4	Register	Ensure failed registration	Enter invalid data	Error message appears
5	Report	Ensure teachers can download/upload reports	Teacher downloads report, uploads answer, saves	Report downloaded and answer saved
6	Certificate	Ensure certificate is saved and accessible	Upload certificate, save, view result	Certificate saved and accessible
7	Assessment	Ensure teacher can view assessment	Teacher opens graded PKL assessment	Teacher can view assigned grade

Table 1 presents the teacher system testing results, showing that most key features function as expected. However, some shortcomings were identified, such as the lack of a password reset option on the login page and unclear error messages during registration.

Table 2. Teacher System Test Results

No.	Feature	Test Result	User Feedback	Suggested Improvements
1	Login	Works, but no "Forgot Password" option	Users want easier account recovery	Add password reset via email
2	Register	Works with valid data, but error messages are vague	Users want clearer errors, e.g. for duplicate email or weak passwords	Improve clarity of error messages

No.	Feature	Test Result	User Feedback	Suggested Improvements
3	Report	Teachers can upload, but unsupported file formats not specified	Upload issues due to unsupported formats	Add allowed file format info and auto-conversion
4	Certificate	Upload/view works, but lacks upload confirmation	Users want confirmation of successful upload	Add success notification after upload
5	Assessment	Teachers can view scores but not notified of updates	Users unaware of updated scores	Add notifications or highlights for score changes

Table 2 summarizes teacher feedback on the system. Login works, but users request a “Forgot Password” option. Registration is successful, but error feedback needs improvement. Reports and certificates function correctly, though users face file format issues and lack upload confirmations. Assessments are accessible, but users aren’t informed of updates. Proposed solutions include notifications and clearer file format guidance.

Table 3. System Testing – Admin

No.	Feature	Purpose	Test Steps	Expected Result
1	Login	Ensure successful login	Enter correct email & password	Admin logs in and accesses dashboard
2	Upload Report	Ensure report is saved	Select report, upload file, save	Report saved successfully
3	Certificate Form	Ensure certificate is saved	Open form, select file, save	Certificate saved successfully
4	Assessment	Ensure admin can manage grading	Select report, enter score, save	Score saved and editable

Table 3 shows the admin system testing results. Login and uploads are generally successful, although large files sometimes fail without error notifications. Certificates are managed well, but searching for specific files is difficult. The assessment feature functions but lacks data export options.

Table 4. Admin System Test Results

No.	Feature	Test Result	User Feedback	Suggested Improvements
1	Login	Works well.	No significant issues	No changes needed
2	Upload Report	Works, but large files fail silently	Need file size indicators	Add file size limits and auto-compression
3	Certificate Form	Saved, but hard to locate specific entries	Hard to search certificates	Add search and filter options by teacher name/date
4	Assessment	Successfully provided and updated grades, but there is no option to export grade data in Excel or PDF format.	Admin wants printable/downloadable data	Add a feature to export grades to Excel/PDF format for documentation purposes.

Table 4 summarizes the admin's feedback on the system. The main issues include file size limitations when uploading reports, difficulty in searching for certificates, and the absence of a grade export feature. The proposed solutions include adding a file size indicator, implementing a search feature, and providing an option to export grades to Excel/PDF format.

Table 5. Development Challenges and Solutions

No.	Category	Challenge	Solution
1	Data Validation	Need stricter input validation	Implement frontend/backend validation
2	Notifications and Feedback	Users unaware of changes	Add notifications/confirmation after actions
3	File Management	Upload file size limits	Use compression or integrate cloud storage
4	Accessibility and Navigation	Admins struggle finding files	Add search and filter functions

Table 5 lists key development challenges including data validation, feedback, file management, and navigation. Suggested solutions involve strengthening input validation, adding alerts, optimizing file handling, and improving searchability.

5 CONCLUSION

The development of the web-based *Praktek Kerja Lapangan* (PKL) monitoring application at PT Chlorine Digital Media has successfully provided a solution to administrative issues that were previously handled manually. By utilizing the Laravel framework, this application enables efficient management of digital certificates, transparent grading, and integration of PKL reports with participant data. The system implementation simplifies access to PKL information for teachers, allows them to receive real-time feedback, and download certificates without the need for time-consuming manual administrative processes.

Test results show that the system functions well and offers significant benefits in improving the effectiveness and efficiency of PKL management. Moving forward, further development can be carried out by adding automation features in the grading process and integrating the system with other educational platforms.

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Design of a Web-Based Student Internship Application at PT Chlorine Digital Media Using the Waterfall Method

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Abstract

In the digital era, information systems play an important role in improving the efficiency of managing the internship program (PKL). PT Chlorine Digital Media faces various challenges in managing internship data, such as attendance recording, task assignment, and job vacancy recommendations. To address these issues, a web-based system has been developed using the Laravel framework. This system includes main features such as online attendance, task management, and job recommendations that can assist students in finding career opportunities that match their skills. The development method utilized is the SDLC (System Development Life Cycle) model, with a systematic approach in the design, implementation, and testing of the system. It is expected that this application design will improve efficiency, reduce human errors in data recording, and provide easier access for students and administrators.

Keywords: Information Systems, Internship, Attendance, Job Recommendations, Laravel.

1 INTRODUCTION

In today's digital era, information technology has brought significant changes across various sectors, including industry and education. The integration of technology in the education sector continues to evolve in response to the growing demand for efficiency and effectiveness in the learning process. One of the areas affected by this development is the Field Work Practice program (Praktik Kerja Lapangan, or PKL), which plays an important role in bridging the gap between educational institutions and industry.

According to research by (Nufriansyah1 et al., 2023), the implementation of web-based systems for managing PKL programs can enhance administrative efficiency and simplify the monitoring of students during their internships. Moreover, web-based information systems are considered more effective in maintaining data consistency compared to manual data entry (Samsudin & Januar, 2024). In line with these findings, various prior studies have also discussed the application of web-based information systems in the education sector. For example, an article published on eCampuz emphasizes that web-based academic information systems can improve administrative efficiency in higher education by providing more efficient, accessible, and secure academic data management (Trisandy Mahany, 2024). In addition, research by (Burhan et al., 2023) shows that the use of digital technology in student data management reduces administrative errors and increases transparency in the educational process.

Field Work Practice is commonly referred to as PKL (Praktik Kerja Lapangan) or PRAKERIN (Praktik Kerja Industri), is a component of vocational education. The PRAKERIN program is implemented based on the Regulation of the Minister of Industry No. 3 of 2017 concerning Guidelines for the Development and Promotion of Competency-Based Vocational High Schools, which align with industry needs. The main objective of this program is to strengthen the relationship between the educational and industrial sectors. Moreover, the program is also supported by the

Decree of the Minister of Education and Culture No. 323/U/1997 and Law No. 20 of 2003 on the National Education System, both of which emphasize the importance of skill development in students to meet the needs of society, the nation, and the state (Admin, 2024).

PT Chlorine Digital Media is a technology development company that offers various services, including social media management, website development, promotional video production, product photography, and TikTok account management. As a partner to various sectors, the company provides opportunities for students to undertake PKL or internship programs. However, the implementation of PKL at this company faces several challenges, such as manual attendance recording, limited monitoring of task completion by students, and the absence of a system for providing job recommendations to students who have completed their internships. Therefore, a web-based system is needed to facilitate PKL management for both students and administrators. This application is designed to monitor attendance, manage tasks, and provide job recommendations for students who have completed their PKL programs.

In developing this system, the author chose the Waterfall method due to its structured and sequential approach. The process begins with requirements analysis, followed by design, implementation, testing, and maintenance. This model is particularly suitable for the project, as the system requirements were clearly defined from the outset, minimizing the risk of mid-development changes. Additionally, the Waterfall method supports comprehensive documentation practices, ensuring that each phase is completed thoroughly before proceeding to the next—an essential factor in building a complex system such as a PKL management application.

2 LITERATURE REVIEW

In this research, the author developed a web-based software application using the Waterfall method within the Software Development Life Cycle (SDLC). The theoretical foundation used in this study includes the following:

2.1 Website

A website is a collection of interrelated web pages accessible via the internet, serving as a medium for information dissemination and user interaction. In web-based software development, a user-friendly and responsive interface is crucial for ensuring a positive user experience. Common technologies used in website development include HTML, CSS, JavaScript, and PHP for server-side scripting (Mianti et al., 2023).

2.2 Waterfall Method

The Waterfall method is a linear and sequential software development model in which each phase must be completed before moving on to the next. The phases typically include requirement analysis, system design, implementation, testing, and maintenance. This approach is best suited for projects with well-defined requirements, as it offers a structured workflow and supports comprehensive documentation. (Fachri & Rizal, 2024)

2.3 UML (Unified Modeling Language)

UML (Unified Modeling Language) is a standardized modeling language used to describe, visualize, and document object-oriented software systems. In web-based application development, UML aids in designing system architecture through various diagram types, including use case, activity, and class diagrams (Raynaldi & Somya, 2023).

2.4 Laragon

Laragon is a development environment for PHP-based applications that provides an integrated stack, including Apache, MySQL, PHP, and Node.js. It also features automatic virtual host configuration and SSL support, making the development process more streamlined for developers (Rajabovich, 2023).

2.5 MySQL

MySQL is an open-source relational database management system commonly used in web application development. It is valued for its reliability, scalability, and flexibility in managing structured data, making it a preferred choice for many web-based systems (Jurnal Informatika dan Komputer et al., 2023).

2.6 Laravel Framework

Laravel is an open-source PHP framework that simplifies web application development by offering a structured, efficient, and maintainable codebase. It supports the Model-View-Controller (MVC) architectural pattern and includes features such as routing, authentication, and database management, which accelerate and streamline the development process (Sinlae et al., 2024).

2.7 PHP

PHP (Hypertext Preprocessor) is a widely used server-side scripting language for web development. It enables developers to build dynamic and interactive web pages and supports interaction with databases such as MySQL. One of PHP's key features is cURL, which allows communication with external servers and integration with third-party APIs and services (Kalmukov, 2024).

3 RESEARCH METHOD

3.1 Data Collection Method

This study employed interviews as the primary data collection method to gather system requirements directly from stakeholders, including the Director and IT staff. These interviews aimed to gain insights into the existing workflow, identify challenges, and understand expectations for the new system. In addition to interviews, direct observations were conducted during the student internship at the company. These observations offered additional perspectives on daily work patterns and operational issues that might not have been revealed during the interviews. All findings were documented and analyzed to ensure that the system design aligned with the company's needs.

3.2 System Development Method

Software development in this study follows the Waterfall method, a model within the Software Development Life Cycle (SDLC). The term "Waterfall" is derived from the analogy of a cascading flow, where each phase is completed sequentially from top to bottom (Albi Panatagama, 2023). The stages include requirement analysis, system design, implementation, testing, and maintenance. Figure 1 illustrates the stages involved in the Waterfall method (Agusdar, 2013).

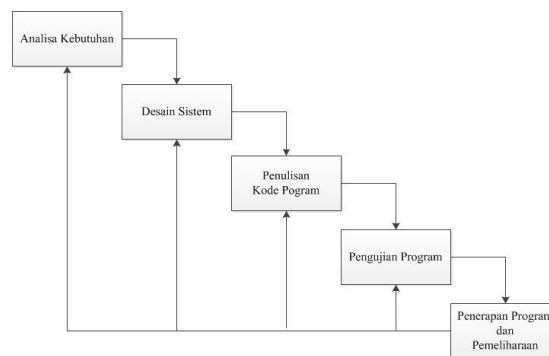


Figure 1. Waterfall Method

The stages are as follows:

1. **Requirement Analysis**, in this stage, system requirements were identified based on the key features to be developed—namely task management, job recommendation, and attendance tracking. The analysis involved collecting information on how students would manage their tasks, how job suggestions would be delivered, and how attendance data would be recorded.
2. **Design**, this stage involved designing the overall system architecture, including the database schema, use case diagrams, activity diagrams, and user interface (UI) layouts.
3. **Implementation (Coding)**, at this stage, the system was developed according to the previously designed specifications, using the Laravel framework for the backend and MySQL as the database system.
4. **Testing**, testing was conducted to ensure the system functioned correctly and fulfilled user requirements. The prototype was presented to the Director and IT staff to evaluate whether the implemented features effectively supported the PKL program.
5. **Maintenance**, the maintenance phase aims to ensure the system continues to operate smoothly by fixing bugs, optimizing performance, and adapting features in response to evolving user needs or operational requirements.

4 RESULTS AND DISCUSSION

4.1 System Design

The system design for this application incorporates a Use Case Diagram and several Activity Diagrams. Figure 2 illustrates the Use Case Diagram that outlines the interactions between users and the system during the development process.

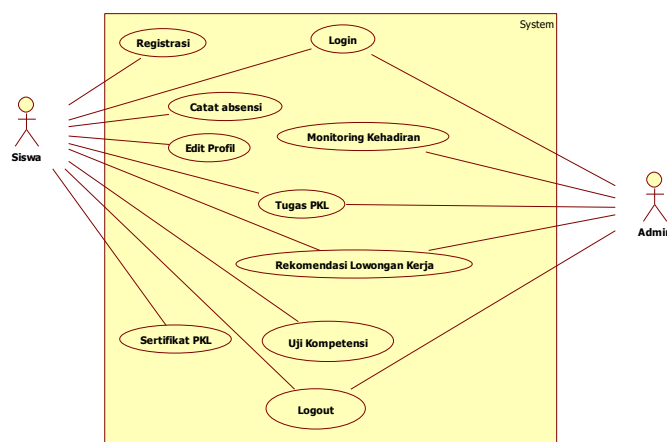


Figure 2. Use case diagram

Figures 3, 4, and 5 depict the Activity Diagrams for the Attendance, Task Management, and Job Recommendation features, respectively. Figure 6 presents the database schema utilized in developing the application.

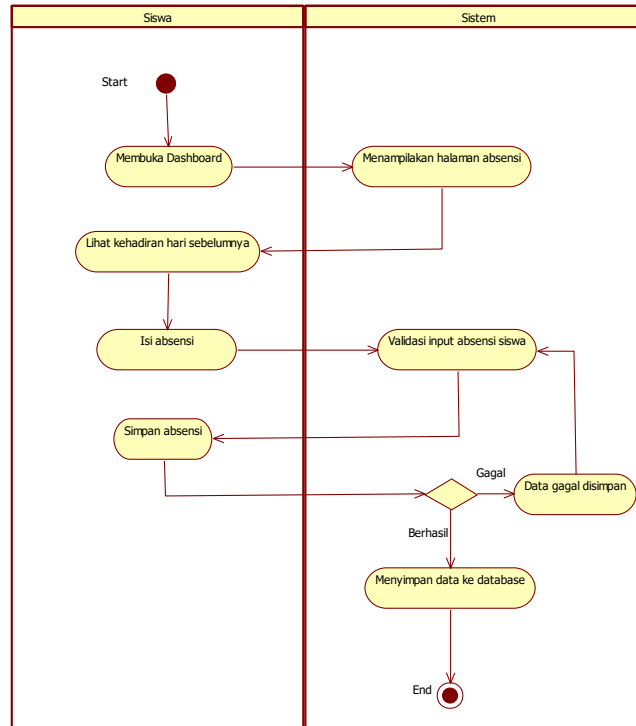


Figure 3. Attendance Activity diagram

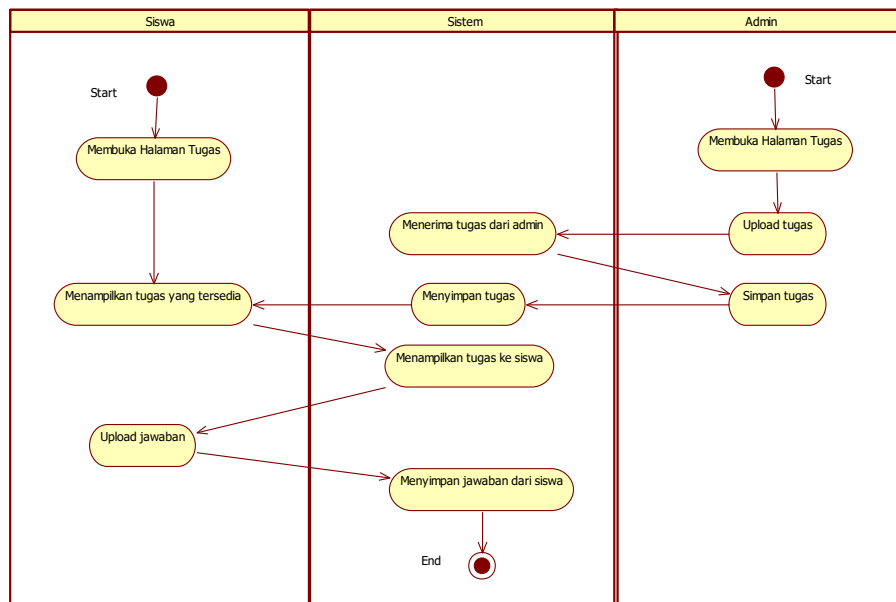


Figure 4. Task Activity diagram

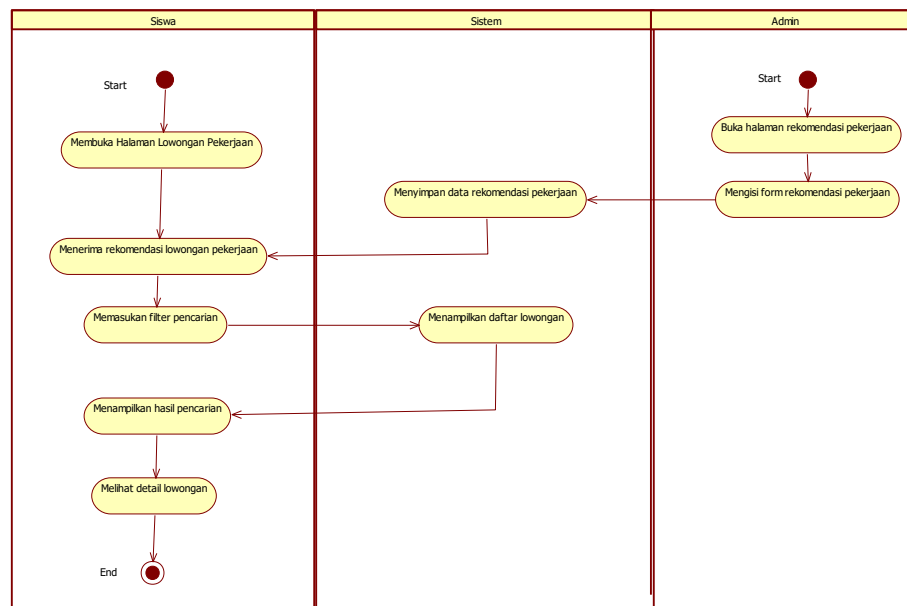


Figure 5. Job Recommendation Activity diagram

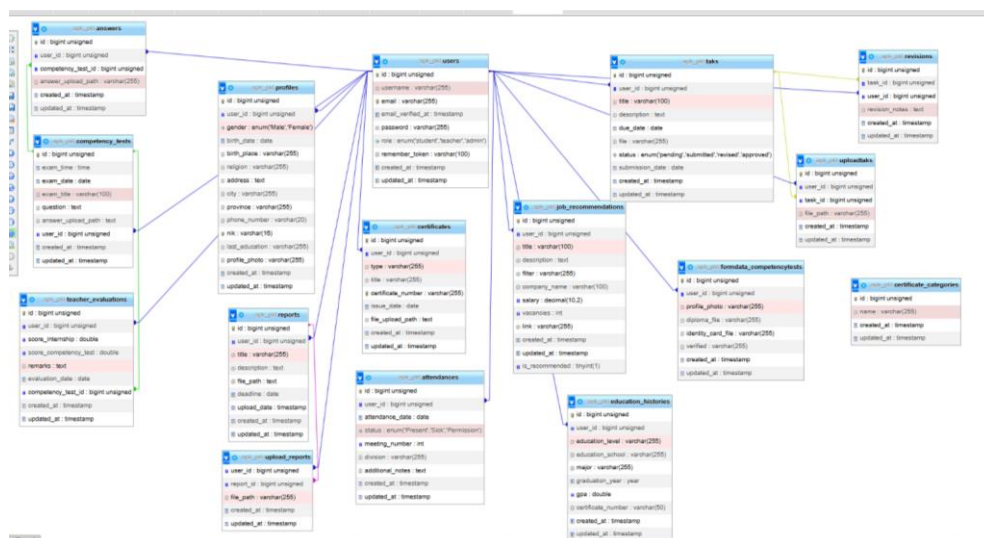


Figure 6. Database Schema

The database in this application does not separate data between student and teacher internships, resulting in a larger number of managed tables. This integration was implemented to ensure that all information can be accessed within a single system without requiring cross-database integration. However, this approach leads to a more complex database structure, as it must accommodate the differing data types, features, and access privileges associated with both students and teachers.

4.2 System Implementation

System implementation relies heavily on a well-designed user interface, as it significantly affects user experience and satisfaction. At this stage, the Laravel framework was used to develop the system's codebase. The following are screenshots of the Design of a Web-Based Student Internship Application at PT Chlorine Digital Media Using the Waterfall Method

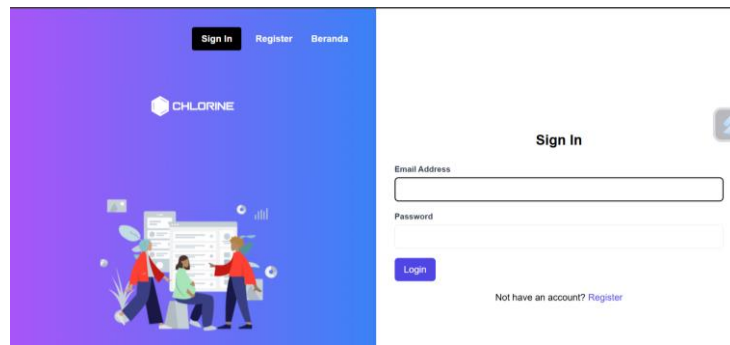


Figure 7. Login Page

Figure 7 login page. Users must enter a valid email and password to gain access to the dashboard.

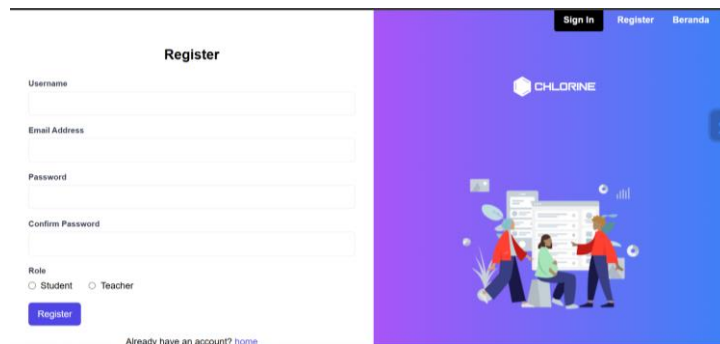


Figure 8. Register Page

Figure 8. New users can create accounts by providing their name, email, password, password confirmation, and user role.

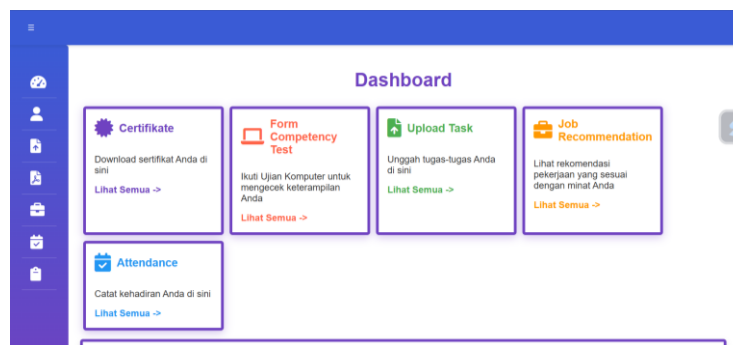


Figure 9. Dashboard Page

Figure 9. The main interface that displays system features based on user permissions.



Figure 10. Task Page

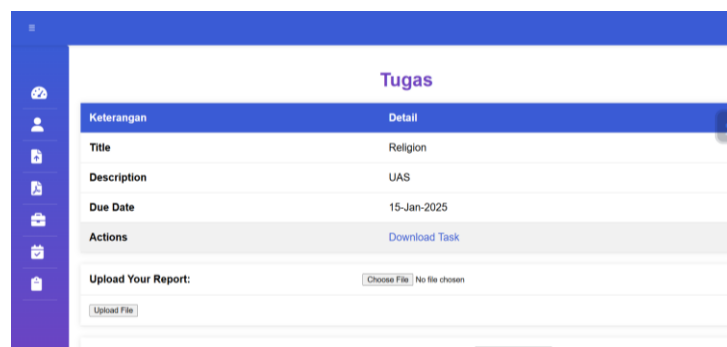


Figure 11. Task Page

Figure 10 and Figure 11. Show assigned internship tasks along with related details and deadlines.

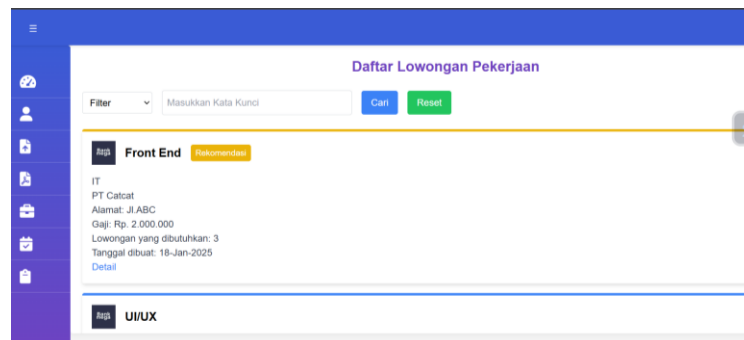


Figure 12. Job Recommendation Page

Figure 12. Displays job opportunities submitted by the admin. Students can filter and search for relevant positions.

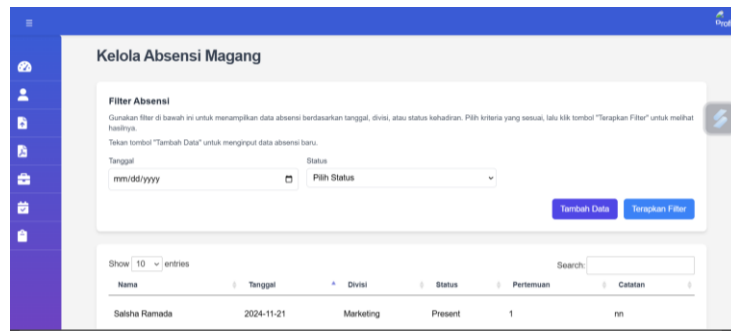


Figure 13. Attendance Page

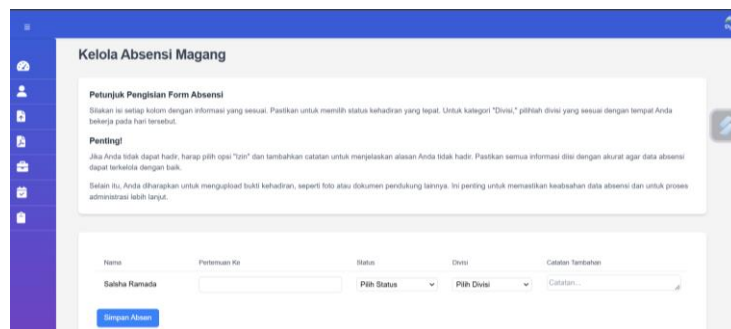


Figure 14. Attendance Page

Figure 13 and figure 14. Allow students to submit daily attendance, including status (present, sick, permission) and division.

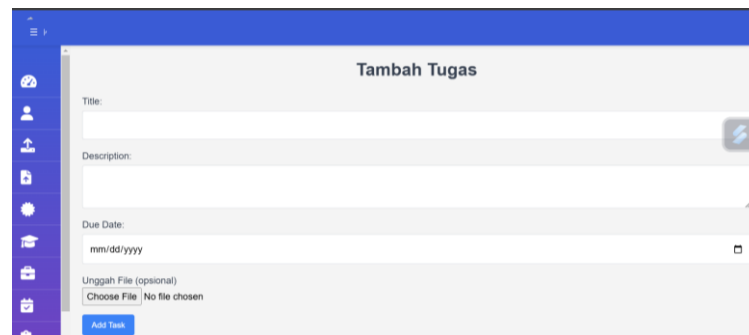


Figure 15. Add Task Form (Admin)

Figure 15. This form allows administrators to assign new tasks, which will then be displayed to internship students in their task dashboard.

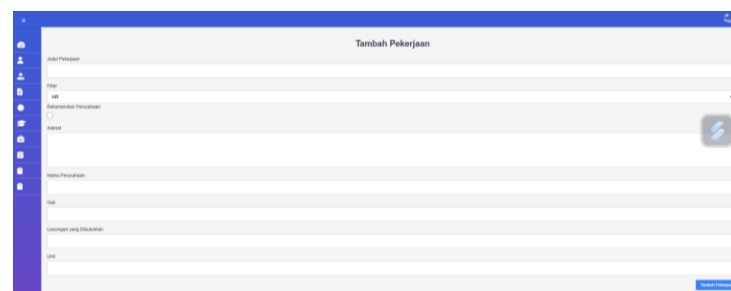


Figure 16. Add Job Recommendation Form (admin)

Figure 16. Administrators can add job recommendations for internship students. Job postings marked as highly recommended by the company are prioritized and displayed at the top of the list.

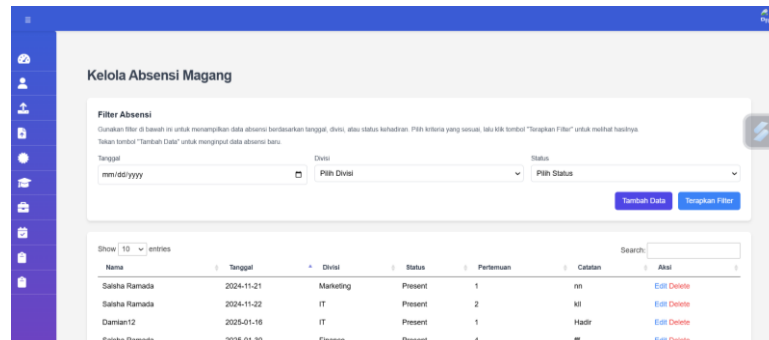


Figure 17. Attendance Page (admin)

Figure 17. This page enables administrators to edit or delete student attendance records to correct input errors or update information.

4.3 System Testing

Table 1. Student System Testing

No	Feature	Objective	Testing Steps	Expected Result
1	Login	Validate successful login	Enter valid email and password	User is redirected to the dashboard
2	Login	Validate failed login	Enter invalid credentials	Error message is displayed
3	Register	Validate account registration	Fill in all fields with valid data	User is registered and redirected to dashboard
4	Register	Handle invalid data input	Enter incomplete/invalid data	Error message is displayed
5	Task Submission	Ensure task upload functionality	Select a task and upload file	Task is submitted successfully
6	Job Recommendation	Validate job filter functionality	Select filter criteria and search	Filtered job list is displayed
7	Attendance	Record attendance entry	Select date, division, and attendance status, then save	Attendance data is saved

Table 2. Admin System Testing

No	Feature	Objective	Testing Steps	Expected Result
1	Login	Validate admin login	Enter valid credentials	Admin is redirected to admin dashboard
2	Task Upload	Ensure admin can upload tasks	Fill out task form and submit	Task is successfully added
3	Job Vacancy Upload	Validate job submission functionality	Input job details and submit	Job recommendation is added

No	Feature	Objective	Testing Steps	Expected Result
4	Edit Attendance	Confirm attendance can be edited	Select record to edit, make changes, and save	Record is updated
5	Delete Attendance	Confirm record deletion works	Select record to delete and confirm	Record is deleted

5 CONCLUSION

The implementation of a web-based system for managing Field Work Practice at PT Chlorine Digital Media has facilitated student monitoring and ensured well-organized data management. The system also provides job vacancy recommendations for students who have completed their internships. By applying the Waterfall method in system development, each phase was executed in accordance with the company's requirements, making it an effective solution within the educational sector.

For future enhancements, the system could be further developed by optimizing mobile responsiveness to improve accessibility on smartphones and tablets. Integration with professional networking platforms such as LinkedIn or job portals may also serve as a strategic addition to increase students' employment opportunities after completing their internships.

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Impact of Security Testing on Software Quality : A Systematic Literature Review

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Abstract

This Systematic Literature Review (SLR) maps the current research landscape on application security testing and assessment. Following the PRISMA framework, this review synthesizes findings from 40 primary studies, which were selected from five scientific databases for the period of 2010–2025 based on rigorous inclusion and exclusion criteria. The study was conducted to address the challenge of selecting the most effective security methods from numerous available options. The main findings highlight three key points. First, application security evaluation uses two categories of metrics: internal code quality as an indirect risk indicator and specific security metrics (like CVSS scores) for direct impact assessment. Second, no single method (SAST, DAST, IAST) is considered sufficient; the trend indicates the adoption of a hybrid approach to maximize detection coverage. Third, research is overwhelmingly dominant in web applications, creating a significant research gap in mobile and embedded systems. Overall, this review provides a comprehensive roadmap for practitioners and researchers, emphasizing the urgent need for standardized benchmarks and the expansion of research focus to non-web platforms.

Keywords: Security Testing Method, Application Security Testing, Software Quality Metrics, Software Security Metrics, Software Vulnerability Assessment

1 INTRODUCTION

In the digital age, web applications have become critical to businesses and services, but this reliance is accompanied by an increase in cyber threats (Altulaihan et al., 2023; Aydos et al., 2022; Humayun et al., 2022). Common vulnerabilities such as SQL Injection (SQLi) and Cross-Site Scripting (XSS) continue to be major risks, demonstrating the importance of effective security testing (Al Fansha et al., 2021; Kuncoro et al., 2022; Ravindran & Potukuchi, 2022; Tudela et al., 2020).

To address this, security testing methods such as static (SAST), dynamic (DAST), and interactive (IAST) analysis are widely used (Altulaihan et al., 2023; Tudela et al., 2020). Each method has drawbacks: SAST is prone to false positives (Esposito et al., 2024; Ravindran & Potukuchi, 2022), DAST has limited code coverage (Tauqeer et al., 2021), and manual penetration testing is costly (Seth et al., 2025; Tauqeer et al., 2021). Hence, the current trend is towards a combination of various techniques for more comprehensive results (Abdulghaffar et al., 2023; Tudela et al., 2020).

This research also focuses on quantifying security through software quality metrics (e.g., code complexity) as indicators of potential vulnerabilities (Colakoglu et al., 2021; Siavvas et al., 2021) and specific security metrics such as the Security Index (Siavvas et al., 2021). This is part of the evolution towards data-driven vulnerability assessments that leverage machine learning for automation of threat classification and prioritization (Hussein et al., 2025; Le et al., 2022), as well as

multi-criteria decision-making (MCDM) techniques for improved objectivity (Anjum, Agarwal, et al., 2020; Anjum, Kapur, et al., 2020).

Despite the availability of these diverse methods and metrics, practitioners and researchers often face challenges in selecting and integrating the most effective approaches for their specific contexts. While many individual studies have discussed specific aspects, a comprehensive and structured review is lacking to synthesize this broad research landscape. Therefore, to address this gap, this research aims to answer the following key Research Questions (RQs):

- a) RQ1: What software quality metrics are commonly used to evaluate the effect of security testing?
- b) RQ2: How do different security testing methods (SAST, DAST, IAST) affect software quality metrics?
- c) RQ3: Is there a difference in the impact of security testing based on the application type (web, mobile, embedded)?

With the variety of methods, tools and metrics available, practitioners and researchers are often faced with the challenge of selecting and integrating the most effective approaches for their specific context. While many individual studies have addressed certain aspects, there is still a lack of comprehensive and structured reviews to synthesize this vast research landscape. A systematic review is needed to map the state-of-the-art, identify key trends, highlight research gaps, and provide actionable guidance for practitioners and researchers.

- a) Research Objectives

The purpose of this Systematic Literature Review (SLR) is to map, analyze, and synthesize existing research regarding methods, metrics, and tools for application security testing and assessment.

- b) Structure of the paper

This research is organized into several chapters. Chapter II will describe the methodology used to conduct this Systematic Literature Review, including the search strategy, study selection criteria and data extraction process. Chapter III will present the results and discussion in an integrated manner, starting with the study demographics and then continuing with the analysis to answer each research question. Finally, Chapter V will present the conclusions of the entire research and provide recommendations for future research directions.

2 LITERATURE REVIEW

Application security testing has evolved significantly to meet the challenges of increasingly complex cyber threats. In general, these methods can be classified into three main categories, each of which has its own unique characteristics, advantages, and disadvantages.

- a) Static Application Security Testing (SAST)

SAST, or static testing, is a “white-box” approach in which the source code or bytecode of an application is analyzed without the need to run the application (Li, 2020). The goal is to find code patterns that correspond to known security flaws, such as those listed in the Common Weakness Enumeration (CWE). The main advantage of SAST is its ability to detect vulnerabilities early in the software development life cycle (SDLC), even before the code is compiled. However, a fundamental weakness of SAST is its tendency to generate a high false positive rate, which can burden development teams with time-consuming manual verification (Esposito et al., 2024). Popular tools in this category include SonarQube, Checkmarx, and Fortify.

- b) Dynamic Application Security Testing (DAST)

In contrast to SAST, DAST is a “black-box” approach that tests applications at runtime (Aydos et al., 2022). DAST simulates an outside attack by sending a malicious payload to the application's entry points (e.g., login form, URL parameters) to find real exploitable

vulnerabilities. The advantage of DAST lies in its ability to find vulnerabilities at the runtime and server configuration level that would not be detected by SAST. However, the disadvantages are that the test coverage may be incomplete and the difficulty in identifying the specific lines of code that are the root of the problem. Industry-standard tools for DAST include OWASP ZAP, Burp Suite, and Acunetix.

c) Interactive Application Security Testing (IAST)

IAST emerged as a hybrid approach that combines the strengths of SAST and DAST. It works by embedding an agent within the running application environment. When dynamic testing (both manual and automated) is performed, the IAST agent monitors the execution flow and data flow from within the application. This allows IAST to identify vulnerabilities with very high accuracy and provide full context down to the vulnerable lines of code, thus significantly reducing false positives (Seth et al., 2025). Examples of IAST tools include Contrast Assess and Checkmarx IAST.

d) Comparative Analysis of Testing Methods

To provide a clearer overview, the characteristics of each testing method are summarized in table 1. This comparison highlights the trade-offs between coverage, accuracy, and integration capabilities that organizations must consider when designing their security testing strategy.

Table 1. Comparison of SAST, DAST, and IAST Methods

Aspect	SAST (Static)	DAST (Dynamic)	IAST (Interactive)
Approach	White-box (Analyzes source code)	Black-box (Tests running application)	Grey-box (Analyzes from within the running application)
Strengths	<ul style="list-style-type: none"> - Early detection in SDLC - 100% code coverage - Enforces coding standards 	<ul style="list-style-type: none"> - Low false positive rate - Detects runtime & configuration issues - Language agnostic 	<ul style="list-style-type: none"> - Very high accuracy - Real-time feedback - Provides exact line of code - Ideal for CI/CD
Weaknesses	<ul style="list-style-type: none"> - High false positive rate - Lacks runtime context - Can be noisy 	<ul style="list-style-type: none"> - Slow scan times - Incomplete coverage - No visibility into source code 	<ul style="list-style-type: none"> - Can introduce performance overhead - Requires application instrumentation - Coverage depends on functional testing
Popular Tools	SonarQube, Checkmarx, Fortify	OWASP ZAP, Burp Suite, Acunetix	Contrast Assess, Checkmarx IAST

To evaluate the impact of security testing, metrics are needed that can quantitatively measure the quality and security posture of applications.

a) The Role of Software Quality Metrics

Traditional software quality metrics, such as those focusing on complexity, cohesion, and coupling, are increasingly recognized as indirect indicators (proxies) of security. Research shows a strong correlation between low-quality code (e.g., high complexity, low cohesion) and the likelihood of security vulnerabilities (Colakoglu et al., 2021; Kalouptsoglou et al., 2023). Therefore, these metrics are often used in the early phase to identify “risky areas” in the code that require more intensive security testing attention.

b) Specific Security Metrics

In addition to general quality metrics, metrics explicitly designed for security are also widely used. The Common Vulnerability Scoring System (CVSS) is an industry standard for assigning a technical severity score to a vulnerability, which is critical to the prioritization process (Allodi et al., 2020). Other metrics such as vulnerability density, measured as the number of vulnerabilities per thousand lines of code (KLOC), are also used to provide a quantitative picture of source code health (Siavvas et al., 2021). Finding vulnerabilities is only half the job; prioritizing which ones to fix first is the next challenge. The literature suggests two main approaches to address this. First is the use of Multi-Criteria Decision-Making (MCDM) methods such as AHP or BWM, which allow organizations to prioritize vulnerabilities based not only on technical severity, but also other factors such as business impact and ease of exploitation (Anjum, Agarwal, et al., 2020). Second, and more modern, is the data-driven approach or Software Vulnerability Prediction (SVP). This field leverages machine learning techniques to train models that can automatically predict, classify, and prioritize vulnerabilities based on historical data from previous projects (Le et al., 2022).

Reviews of literature consistently shows that no single method or metric is superior in all situations. The inherent weaknesses of each approach have driven a strong trend towards hybrid and integrated approaches. Many studies have concluded that a strategic combination of SAST, DAST, and IAST results in better detection coverage and higher accuracy rates than the isolated use of a single method (Tudela et al., 2020). It is this trend that forms the basis of this research to further analyze how the impact of various combinations of these testing methods on overall application quality.

3 RESEARCH METHODS

This research uses the Systematic Literature Review (SLR) method with reference to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework. This methodology was chosen to ensure a transparent, complete, and replicable review process, as per standards in the software engineering and cybersecurity fields (Alaoui & Nfaoui, 2022; Kohl et al., 2018). The study selection process follows the four phases of PRISMA:

a) Identification

A search was conducted on five scientific databases (IEEE Xplore, ACM Digital Library, Scopus, SpringerLink, ScienceDirect) using keywords such as “Security Testing Method” and “Software Quality Metrics”. The specified publication time span is from January 2010 to June 2025.

b) Screening

This stage involved removing duplicate records, followed by relevance screening based on the title and abstract of each article.

c) Eligibility

The full text of articles that passed the screening was examined in depth based on the detailed inclusion and exclusion criteria outlined in table 2.

Table 2. Inclusion and Exclusion Criteria

Criteria	Justification
Inclusion Criteria	
1. The study must be a peer-reviewed journal article or conference proceeding.	To ensure the scientific validity and quality of the included studies.
2. The study must be written in the English language.	To ensure the researcher's comprehension and avoid misinterpretation.
3. The study's primary focus must be on security testing methods or software quality metrics in the context of security.	To maintain high relevance to the research questions.
4. The study must provide empirical results, case studies, or a structured review that can be synthesized.	To ensure that the data extracted is based on evidence and analysis.
Exclusion Criteria	
1. Studies that are not primary or secondary scientific literature (e.g., editorials, prefaces, summaries, white papers, patents).	To exclude non-scientific sources that have not undergone a peer-review process.
2. Studies where the full text is inaccessible.	The full text is required for in-depth analysis and data extraction.
3. Studies that, after a full-text review, are found not to directly answer any of the research questions.	To ensure the final set of studies is highly focused and relevant.

From this rigorous process, a final set of 40 primary studies was selected for further analysis. The entire selection process, from identification to final inclusion, is visually summarized in the PRISMA flow diagram presented in figure 1.

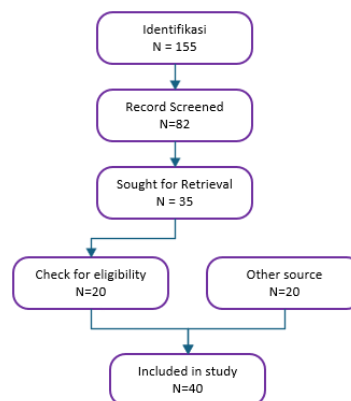


Figure 1. PRISMA Flowchart

After conducting the study selection, the following steps were conducted:

- Quality Assessment Each selected study was assessed for quality using a checklist to ensure the reliability of its objectives, methodology, and conclusions (Alaoui & Nfaoui, 2022).
- Data Extraction and Synthesis Data were extracted from each study using standardized forms to record relevant information such as methodology, object of analysis, and key findings. The data were then analyzed using thematic synthesis to group the findings into themes that answer the research questions and identify patterns in the literature (Esposito et al., 2024).

4 RESULT AND DISCUSSION

4.1 Overview and Demographics of the Selected Study

This section aims to provide context to the existing research landscape by presenting the basic characteristics of the 40 primary studies that form the basis of our analysis.

a) Flow of Study Selection Using PRISMA

Our study selection process strictly follows the PRISMA workflow to ensure transparency and replicability. This process is visualized in the PRISMA Flowchart.

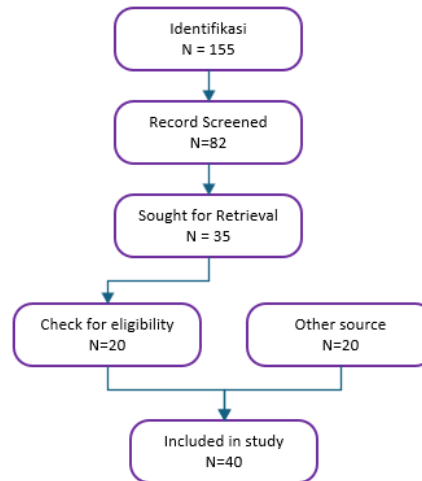


Figure 2. Prisma Flowchart

The initial search yielded 155 articles. After 73 duplicates were removed, 82 articles remained. Based on titles and abstracts, 62 irrelevant articles were excluded, leaving 35 articles for full-text review. Of these 35 articles, 15 were again excluded as they did not meet the criteria. However, we added 20 relevant articles from other sources, so the final total of studies analyzed was 40.

b) Publication Characteristics

Analysis of the 40 selected primary studies revealed some interesting publication characteristics and trends.

i. Publication Distribution per Year

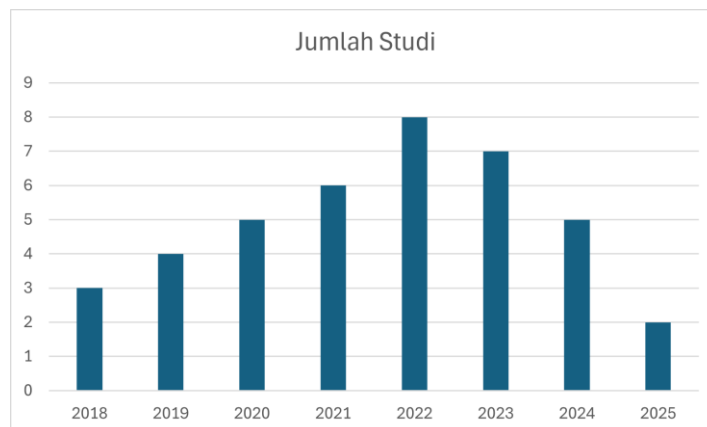


Figure 3. Publication Distribution per Year Graphic

The distribution chart of 40 studies from 2018 to mid-2025 shows a growing research interest, which peaked in the 2022-2023 period with 15 studies (37.5%). After that, the number decreases slightly, although the data for 2025 is not yet complete. Overall, this distribution confirms that the majority of the literature is very recent, making the topic very dynamic and the findings in this review relevant to the state-of-the-art.

ii. Type of Publication Venue (Journal vs. Conference)

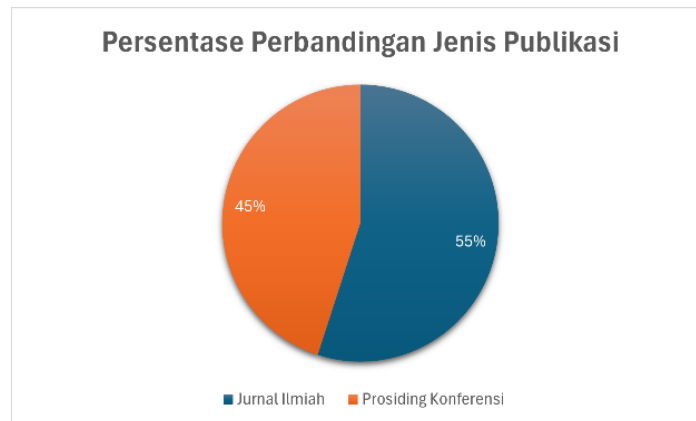


Figure 4. Graph of The Percentage of Publications Used by Type

The distribution of the 40 studies showed a healthy balance between publications in Journals (55%) and Conference Proceedings (45%). The majority of studies (22 out of 40) published in journals signifies maturity and strong validation in this field. Meanwhile, a significant portion of the conference proceedings (18 out of 40) show that this research remains active and innovative. This balance reflects a healthy research field, where rapid innovation (from conferences) is balanced with deep validation (from journals).

iii. Dominant Research Types and Methodologies

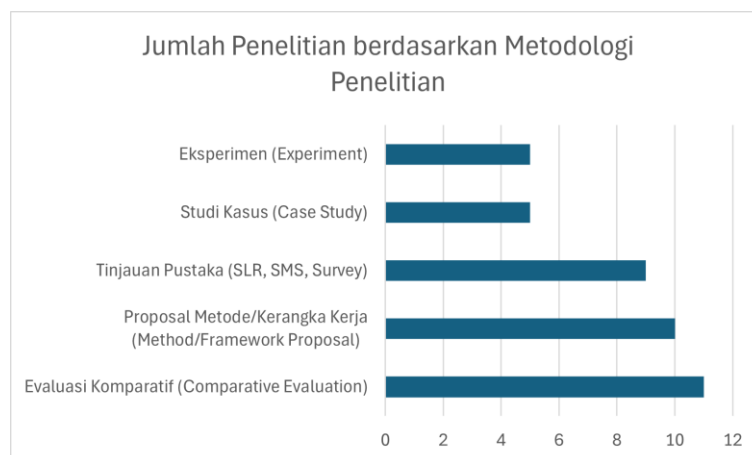


Figure 5. Number of Studies Based on Research Methodology

The classification of the 40 studies by methodology shows a very pragmatic and solution-oriented research focus. The main distribution is:

- Comparative Evaluation: 11 studies (27.5%) that compared tools or methods.
- New Method Proposals: 10 studies (25%) that introduced innovative approaches.
- Literature Reviews: 9 studies (22.5%) that synthesize knowledge.

d. Case Studies and Experiments: 5 studies each (25% in total).

Overall, the majority of studies focused on evaluating and developing practical approaches. The significant share of literature reviews also indicates that the field is in a phase of knowledge consolidation to determine future research directions.

4.2 Analysis of Findings and Discussion Based on Research Questions

As a basis for our analysis and discussion, Table 1 below provides a comprehensive summary of the 40 primary studies we have reviewed. The table includes the title, main focus, methodology, object of analysis, and key findings of each study, which will serve as a key reference in answering our research questions.

Tabel 3. State of The Art

Title	Discussion
Business-layer client-side racer: dynamic security testing of the web application against client-side race condition in the business layer	Client-side race condition detection in web applications. Black-box Dynamic Testing (DAST) (BLCSR Method). Web Application. The BLCSR method proved to be 96.7% faster and 98.29% more network traffic efficient.
Planning-based security testing of web applications with attack grammars	Test automation for SQLi and XSS vulnerabilities. Automated Planning (AI) using PDDL and Attack Grammars. Web Application. Planning models can generate diverse test suites for vulnerability detection.
Measuring the accuracy of software vulnerability assessments: experiments with students and professionals	Measuring vulnerability assessment accuracy using CVSS v3. Comparative experiment between students and professionals. Vulnerability Assessment Process. Security background improved accuracy, but there was no significant difference between trained students and professionals.
On Combining Static, Dynamic and Interactive Analysis Security Testing Tools To Improve OWASP Top Ten Security Vulnerability Detection in Web Applications	Improves detection of OWASP Top Ten vulnerabilities. Combination of SAST, DAST, and IAST tools on OWASP Benchmark. Web Application (Benchmark). A combination of tools (especially involving IAST) is much more effective than using a single tool.
Two-phase methodology for prioritization and utility assessment of software vulnerabilities	Prioritizing software vulnerabilities. Multi-Criteria Decision-Making (MCDM): AHP and BWM. Vulnerability Prioritization Process. BWM method shows better and consistent performance than AHP for prioritization.
Dynamic vulnerability assessments of software-defined networks	Dynamic vulnerability assessment of Software-Defined Networks (SDN). CVSS and Bayesian Network for relationship analysis between vulnerabilities. SDN Network. Shows how vulnerability status can be dynamically updated based on dependency relationships.

Title	Discussion
Software Product Quality Metrics: A Systematic Mapping Study	Mapping the trends and research landscape of Software Product Quality Metrics (SPQM). Systematic Mapping Study (SMS). SPQM literature. Maintainability & Reliability related metrics are most dominant; there is a need for metrics for AI & IoT.
A hierarchical model for quantifying software security based on static analysis alerts and software metrics	Quantitatively measure the internal security level of software. Hierarchical model (SAM) based static analysis (SAST) and code metrics. Source Code (Java). Proposes a single Security Index that aggregates various low-level indicators.
Deep Learning for Vulnerability and Attack Detection on Web Applications: A Systematic Literature Review	Analyzing the use of Deep Learning (DL) for web attack detection. Systematic Literature Review (SLR). DL Literature for Web Security. Lack of standardized datasets is a major challenge; CNN & LSTM are the most commonly used models.
A Survey on Data-driven Software Vulnerability Assessment and Prioritization	Provides a taxonomy and comprehensive overview of data-driven vulnerability assessment. Literature Survey. Vulnerability Assessment Literature. Presents a taxonomy of tasks: exploitation prediction, impact, severity, and vulnerability type.
A Systematic Literature Review on the Characteristics and Effectiveness of Web Application Vulnerability Scanners	Analyzing the characteristics and effectiveness of web application vulnerability scanners (WVSs). Systematic Literature Review (SLR). WVS literature. Existing WVS evaluations are very inconsistent and mostly focus only on SQLi and XSS.
Security testing of web applications: A systematic mapping of the literature	Mapping research in the field of web application security testing. Systematic Literature Mapping (SLM). Web Security Testing Literature. DAST is more commonly used than SAST; Burp Suite & OWASP ZAP are the most popular tools in research.
Code Analysis with Static Application Security Testing for Python Program	Developed a custom SAST code auditing tool for the Python language. Abstract Syntax Tree (AST) analysis with plug-in architecture. Source Code (Python). The proposed tool is faster and has higher detection rate than Fortify & SonarQube on Python.
Enhancing Web Application Security through Automated Penetration Testing with Multiple Vulnerability Scanners	Test automation by combining multiple scanners (WAVS). Automation framework that integrates Arachni & OWASP ZAP. Web Application (Benchmark). Union List of multiple scanners was shown to improve recall and F-measure significantly.
An Efficient Security Testing for Android Application Based on Behavior and Activities Using Improved PCA and DNN-KNN Classifier	Malware detection on Android apps based on behavior and activity. Feature extraction from log files with PCA and classification with DNN-KNN. The proposed model achieved 98% accuracy in detecting malware.

Title	Discussion
An efficient security testing for android application based on behavior and activities using RFE-MLP and ensemble classifier	Android malware detection using feature selection and ensemble learning. RFE-MLP for feature selection and stacking Bi-LSTM, DBN, RBFN. The ensemble model achieved very high accuracy (99.78%) in classifying malware.
Comparing effectiveness and efficiency of Interactive Application Security Testing (IAST) and Runtime Application Self-Protection (RASP) tools in a large java-based system	Comparing the effectiveness and efficiency of IAST and RASP. Comparative case study on a large-scale Java system (OpenMRS). IAST & RASP tools. IAST is highly efficient (second only to manual testing) & effective. RASP is only effective for Injection attacks.
Analisis Metode Open Web Application Security Project (OWASP) pada Pengujian Keamanan Website: Literature Review	Analyzing the use of the OWASP method in website security testing. Scoping Review of Indonesian-language literature. OWASP Method Literature. OWASP Top Ten is the most commonly used method, and OWASP ZAP is the most popular tool.
Evaluating software security maturity using OWASP SAMM: Different approaches and stakeholders perceptions	Evaluating software security maturity using OWASP SAMM. Case study in a financial company using surveys and focus groups. Software Development Process. Demonstrated that survey-based lightweight assessment is an efficient alternative to measure security maturity.
Secure software development and testing: A model-based methodology	Proposed a model-based secure development methodology for DevSecOps. Model-based methodology that links threats to test plans. Development & Testing Process. This methodology can automatically generate security test plans from threat modeling.
A Survey on Web Application Penetration Testing: Models and Tools	Survey on models and tools for penetration testing of web applications. Literature Review (Survey Paper). Web Penetration Models & Tools. Reviews various methodologies (PTES, OSSTMM) and tools (DAST, SAST), concluding the need for a hybrid approach.
Software vulnerability prediction: A systematic mapping study	Mapping research in the field of Software Vulnerability Prediction (SVP). Systematic Mapping Study (SMS). SVP literature. Most SVP studies use code metrics on C/C++ projects; the lack of standardized datasets is a major challenge.
A Review on Web Application Vulnerability Assessment and Penetration Testing	Review methods of vulnerability assessment and penetration testing of web applications. Literature Review (Review Paper). Web Vulnerability Assessment Process. Emphasizes the importance of a hybrid approach (automated + manual) for effective security coverage.

Title	Discussion
A Review on Web Application Security: Attacks and Defenses	Reviews web application attacks and their defense mechanisms. Literature Review (Review Paper). Web Application Security. Advocates a defense-in-depth strategy with integrated security throughout the SDLC.
Reviewing Software Testing Models and Optimization Techniques: An Analysis of Current Research and Future Trends	Analyze software testing models and their optimization techniques. Systematic Literature Review (SLR). Software Testing Models & Techniques. Discovered an increasing trend of adoption of Agile models and use of meta-heuristic algorithms for test optimization.
An Extensive Comparison of Static Application Security Testing Tools for Java and C/C++ Applications	Extensive comparison of Static Application Security Testing (SAST) tools. Comparative Evaluation on Benchmarks. SAST tools for Java & C/C++. Found significant performance variability among SAST tools; no single tool is superior for all cases.
Advancements in Security Testing: A Comprehensive Review of Methodologies and Technologies	A comprehensive review of advances in security testing. Literature Review (Review Paper). Security Testing Methodology. Highlights the shift-left trend and the new role of AI/ML in improving security testing efficiency.
Analysis of Security Testing Techniques for Web Applications	Analysis and comparison of various security testing techniques. Qualitative & Quantitative Analysis. Web Security Testing Techniques. Each technique (SAST, DAST, IAST, Manual) has advantages and disadvantages; a combination of techniques is recommended.
Assessment of Software Vulnerabilities using Best-Worst Method and Fuzzy Cognitive Maps	Prioritasasi kerentanan perangkat lunak menggunakan MCDM. Best-Worst Method (BWM). Proses Prioritasasi Kerentanan. BWM terbukti menjadi metode yang efektif dan lebih konsisten untuk memprioritaskan kerentanan daripada metode tradisional.
Security Threat and Vulnerability Assessment and Measurement in Secure Software Development	Overview of threat and vulnerability assessment in SSDLC. Literature Review. SSDLC process. Emphasizes the importance of integrating security practices (threat modeling, risk analysis) from the beginning of the SDLC.
Software Vulnerability Assessment and Classification Using Machine Learning	Vulnerability classification using Machine Learning. Text Mining & Machine Learning. Vulnerability Description (NVD). Machine Learning can automate the classification of vulnerability type (CWE) and severity with accuracy.

Title	Discussion
Vulnerabilities Mapping based on ATT&CK, CWE, and CAPEC for Web Application Penetration Testing	Vulnerability mapping to standard frameworks such as ATT&CK. Conceptual mapping methodology. Risk Assessment Process. Mapping to ATT&CK provides the context of real-world attacks, helping to prioritize fixes.
Large language models in information security and penetration testing	Exploring the application of Large Language Models (LLMs) in cybersecurity. Literature Review (Review Paper). LLM technology. LLMs have great potential for security automation but also carry the risk of misuse by attackers.
Mitigating Security Risks in Firewalls and Web Applications	Risk mitigation strategies in firewalls and web applications. Best Practice Review. Firewall & WAF. Emphasizes the importance of layered security and proper WAF configuration for web application protection.
A security testing mechanism for detecting vulnerabilities in Android applications	Propose a new security testing mechanism for Android apps. A specialized (possibly hybrid) testing mechanism. Platform-specific mechanisms are more effective in detecting unique vulnerabilities such as permissions issues.
Vulnerability Analysis and Security Assessment of Secure Software-Defined Networking	Propose a new security testing mechanism for Android apps. A specialized (possibly hybrid) testing mechanism. Platform-specific mechanisms are more effective in detecting unique vulnerabilities such as permissions issues.
Online tools supporting the conduct and reporting of systematic reviews and systematic maps: A case study on CADIMA and review of existing tools	Review of online tools that support SLR implementation. CADIMA tool use case studies and other tool reviews. Literature Review Process. Online tools such as CADIMA can improve efficiency and collaboration in conducting SLR.
SWOT analysis of software quality metrics for global software development: A systematic literature review protocol	Proposed a protocol for a future SLR on software quality metrics. SLR protocol for SWOT analysis. SLR methodology. Provided a solid methodological basis for future research on quality metrics in GSD.
Tool-based approach to assessing web application security	Evaluate tool-based approaches to web application security testing. Tool-based approaches (SAST & DAST) compared to manual testing. Web Application (Case Study). Automated approaches are effective for quick detection, but miss logic vulnerabilities found manually.

a) Metrics Used for Security Testing Evaluation

To answer the first research question regarding evaluation metrics, the literature analysis shows that researchers and practitioners consistently use two main categories of metrics to measure the impact of security testing activities. The first category is Internal Code Quality Metrics, which serve as indirect indicators of the security posture of an application. These metrics include

measures such as Complexity (e.g., Cyclomatic Complexity), which assesses the logical complexity of the code; Coupling, which measures dependencies between modules; and Cohesion, which assesses the interconnectedness of functionality within a module. Logically, code that is less complex, less coupled, and more cohesive tends to be easier to maintain and secure. The second category is Specific Security Metrics, which directly measure security attributes. Among these metrics, the most predominantly used are the Common Vulnerability Scoring System (CVSS) to assess the technical severity of vulnerabilities, Vulnerability Density which is usually calculated as the number of findings per thousand lines of code, and aggregate metrics such as the Security Index which brings together various indicators into a single score. From the discussion, it can be seen that code quality metrics are proactive for early risk identification, while security-specific metrics are more reactive as they measure the outcome of the testing cycle. Current trends show a shift towards aggregated metrics that can present a holistic view of security that is more easily understood by non-technical stakeholders.

b) Impact of Different Testing Methods on Metrics

The second research question explored how different testing methods-SAST, DAST, and IAST-affect quality and security metrics. The analysis showed that each method has a specific and unique impact. Static Application Security Testing (SAST), which analyzes source code without running it, directly affects internal code quality metrics and effectively reduces vulnerability density by finding insecure code patterns. In contrast, Dynamic Application Security Testing (DAST) tests applications at runtime, thus impacting metrics related to application behavior and is highly effective in identifying vulnerabilities such as Cross-Site Scripting (XSS) and SQL Injection (SQLi). Meanwhile, Interactive Application Security Testing (IAST) is emerging as an approach that offers the best balance. By combining static and dynamic analysis, IAST is able to improve precision (by reducing false positives) and recall (the ability to find vulnerabilities) simultaneously. Given that each method has its own limitations-such as high false positives in SAST or limited test coverage in DAST-the literature strongly recommends adopting a hybrid approach. Combining these three methods is considered the best strategy to maximize test coverage and positive impact on the entire spectrum of security metrics.

c) Differences in Testing Impact Based on Application Type

Investigation into the third research question revealed that the impact and focus of security testing varied greatly depending on the application platform, and there was significant unevenness in the focus of research. Web applications were the most dominant platform studied, where security testing almost always focused on identifying and mitigating vulnerabilities listed in the OWASP Top 10 list. For these platforms, success is often measured by a decrease in the number of such critical findings. For mobile applications, the focus shifts to more specific areas, such as analyzing excessive application permissions, user privacy issues, and testing impact on device performance, such as battery and memory consumption. On the other hand, for embedded systems and networks, where research areas are still very limited, security is often measured through operational metrics such as reliability, availability, and system integrity. This confirms that the concept of “security” itself is contextual and has different meanings across platforms. More importantly, the lack of studies on IoT and embedded platforms highlights a significant and urgent research gap to fill.

d) Implications of Findings and Future Research Directions

The findings of this systematic review offer a number of important implications. For industry practitioners, the key guidance is to adopt a hybrid approach to testing, as no single tool is perfect. It is highly recommended to consider IAST to improve efficiency, as well as integrating security practices early on in the software development lifecycle through DevSecOps or Shift-Left. Additionally, practitioners are encouraged to actively use metrics for continuous security monitoring, rather than simply as a tool to find vulnerabilities. For academic researchers, this review highlights some promising future research directions. There is an urgent need to develop

benchmarks and standardized datasets that can be used to fairly compare different tools. Further research is also urgently needed to explore security on non-web platforms, such as IoT and embedded systems. In addition, the utilization of advanced technologies such as AI and Large Language Models (LLM) for intelligent automation in security analysis as well as the development of more contextualized vulnerability prioritization models (considering business impact) are areas of great potential to be explored.

e) Research Limitation

It is important to recognize that this study has some limitations that are natural in a systematic literature review. Firstly, there is a potential publication bias, where the review is limited to studies that have been formally published and are available in English, thus possibly overlooking negative results or relevant studies from other regions. Secondly, there is the possibility of selection bias, where the keywords used may not have captured all relevant studies due to differences in terminology. Lastly, although PRISMA's rigorous methodology has been applied, the process of data interpretation and synthesis is not completely free from researcher subjectivity, which may affect the final results.

5 CONCLUSION

This Systematic Literature Review (SLR) of 40 studies maps the application security assessment landscape with three key findings:

a) Evaluation Metrics

Security is measured using two types of metrics, namely internal code quality metrics (such as complexity) as an indicator of risk, and specific security metrics (such as CVSS) to measure direct impact.

b) Testing Methods

Each method (SAST, DAST, IAST) has a unique impact. Trends show that hybrid approaches, especially those involving IAST, are the most effective for accuracy.

c) Application Focus

Research is predominantly on web applications, while there is a significant research gap on mobile and embedded platforms, where security is also about reliability and availability.

Therefore, developer organizations are advised to integrate a combination of SAST, DAST, and IAST in their SDLC stages.

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Design and Implementation of a Java-Based Inpatient Information System for Hospitals as a Digitalization Solution for Medical Services

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Abstract

Hospitals are facilities that offer medical care to the public. One of the services provided is inpatient care. The process of finding beds and patient rooms can be time-consuming, leading to the development of the BedFinder application, a hospital inpatient information system application. In addition to searching for beds and patient rooms, the BedFinder application also allows for the addition of the number of beds and rooms. The BedFinder application is a desktop-based application developed using the agile methodology to adapt to user needs. Users can utilize this application on hospital computers and laptops to search for specific beds and patient rooms, as well as add to the number of beds and rooms. The BedFinder application was created based on the previously developed mockup designs. With the implementation of the BedFinder application, the process of searching for beds and patient rooms, as well as adding to the number of beds and rooms, becomes more efficient, thus increasing productivity.

Keywords: Hospital, inpatient care, java, prototype, interface.

1 INTRODUCTION

Hospital is one of the health institutions that has an important role in providing health services for the community. One of the services provided by the hospital is inpatient services, where patients can live in hospitals to get intensive care and better treatment.

In the implementation of inpatient services, there are various aspects that need to be considered by the hospital, one of which is coordination of the room. Coordination of the room in the hospital is one of the most important things, because it will affect the effectiveness and efficiency of the inpatient services provided. One of the challenges that is often faced by the hospital is difficulty in coordinating the availability of rooms, the number of patients being treated, and the schedule of family visits or people who come to visit the patient.

To overcome this problem, an effective and efficient solution is needed in managing inpatient services in hospitals. One solution that can be applied is to use a Java -based hospital inpatient information system application that is run on the admin computer. This application can help the admin coordinate the room and provide accurate and timely information systems for families or people who come to visit patients.

The use of information systems in the management of hospital medical records has become increasingly important and needed in maintaining the efficiency and accuracy of the health service process. In several previous studies, efforts have been made to develop a Java -based medical record management information system. For example, Ayuningrum et al. conduct a system approach in managing medical records at Mitra Sehat Hospital Situbondo. The study aims to improve efficiency

and accuracy in managing medical records by utilizing a Java-based system (Ayuningrum, et. al., 2020). In addition, Cahyanto also applies web service technology to the medical record data information system at XYZ Hospital. This research provides an overview of the importance of using web service technology in facilitating the exchange of medical record information between systems, although in this study in the form of desktop applications (Cahyanto, 2018). Next, Haitami et al. developing a hospital medical record management information system using Java, which provides effective solutions in medical record management in hospitals (Haitami & Septiani, 2020). Laura Florentina Fresha et al. also reviewing a review of the medical record management system at Bina Kasih Hospital Pekanbaru in 2021, which provides insight into the implementation and success of the system (Silitonga & Supriatin, 2022). Another study, conducted by Widia et al., describing the use of Microsoft Visual Studio in the Correspondence Information System for Medical Records in Hospitals (Widia, et. al., 2021).

Sikiru and Oyekunle (2021) developed a web-based hospital management system focusing on enhancing operational efficiency. The system includes modules for patient management, staff administration, financial operations, and pharmaceutical inventory within an integrated platform. In a related study, Rahman (2022) designed a similar web-based hospital management system with an emphasis on a user-friendly interface and the integration of various hospital service modules. His research highlighted the need for systems capable of managing patient data, coordinating doctors' schedules, and maintaining centralized medical records to deliver faster and more accurate healthcare services.

Earlier, Haux (2004) conducted a strategic review of hospital information systems, stressing the importance of structured and integrated management within healthcare institutions. His work underscored key concepts, system architectures, and applicable strategies to support data management, enhance service quality, and improve operational performance.

More recently, Marbella, Akbar, and Setiawan (2024) designed and implemented a web-based patient management system with a particular focus on patient data integration. Their system aimed to address challenges in patient registration, medical record documentation, and service scheduling, while maintaining medical data security as a top priority. Although several studies have explored Java-based electronic medical record management systems, significant limitations and challenges remain in their application to the regulatory frameworks of psychiatric hospitals. These gaps highlight the need for further research to develop more comprehensive and reliable solutions.

Although many studies have examined the creation of a Java-based medical record management system, there are still standards and challenges that stand out in the case of applying this solution in the regulation of the real hospital. As large as previous research has focused on the specific components of note management, such as the storage of this shortage shows the need for further work that members of a more complete and capable solution.

However, although many previous studies have been conducted in the development of information systems in Java -based medical record management, there are still gaps and challenges in its application. Some studies only focus on certain aspects in managing medical records, while some others have not reached the optimal success rate. Therefore, further research is needed that can overcome deficiencies and optimize the application of Java -based medical record management information systems in hospitals.

This research aims to develop and implement the java-based applications of inpatient information systems based on a comprehensive and effective. This study will discuss various important aspects in managing medical records, including data storage, data collection, integration with other systems, and information security. Through the implementation of a good information system, it is expected that hospitals can improve operational efficiency, increase data accuracy, and improve health services to patients.

This research is based on a collection of literature that has been done previously. Some relevant related studies include research by Arif (2018), which examined the management of medical record

archives at Aminah Hospital Tangerang, and Suraja (2019), which discussed the management of medical records at health service facilities. In addition, Irawan and Utama (2022) implemented the RAD (Rapid Application Development) development method and the Black Box test in the e-Archives administration. Taking into account the contribution of previous research and fixing existing deficiencies, this research is expected to make a significant contribution in the development of Java-based hospital inpatient information systems.

2 LITERATURE REVIEW

A. Inpatient Information System in Hospitals

Inpatient information system is one of the subsystems of the hospital information system that aims to manage administrative and medical data on patients undergoing inpatient treatment. This system includes recording patient identity, bed management (bed management), monitoring of maintenance status, to setting family visit schedules. Manual systems tend to cause various obstacles such as late data access, information inconsistencies, and low work efficiency (Haitami & Septiani, 2020).

B. Java as a Programming Language for Application Development

Java is an object-oriented programming language that is very popular in developing medium to large scale applications. Stable, safe, and flexible JAVA characteristics make it ideal for the development of hospital information system applications that demand reliability and scalability (Haitami & Septiani, 2020).

3 RESEARCH METHODOLOGY

The agile method is an approach or framework in the software development based on the principles of team collaboration, open communication, rapid adaptation to changes, and delivery of software iteratively and incrementally. Agile methods are used as an alternative to traditional software development methods that tend to be more rigid and formal, such as the waterfall method. The following are the stages in the agile model used in making Java-based hospital inpatient information system applications:

- Requirements Analysis

At the needs analysis stage, the beginning of software development, where developers meet with clients to gather the requirements and understand the problems that this application wants to solve. At this stage, the main goal is to ensure that all application needs needed by the client are clearly understood by the developer. In the Java-based hospital inpatient information system application, developers must understand the needs needed by the admin and also the family or people who come to visit the patient.

- Design

At the design stage, after collecting requirements, the next stage is to design architecture and system design. At this stage, the developer will design the user interface, selecting programming languages, database design, and system infrastructure. Developers must ensure that system design has been understood by all related parties.

- Implementation

At the implementation phase, after designing system design, developers will start implementing the program code using the Java programming language. At this stage, the developers must pay attention that the program code must be in accordance with the design that was created in the previous stage.

- Testing

In the testing stage, after the program code is completed, the developers must test the applications that have been made. The purpose of this test is to ensure that the application runs as desired by the client and there are no errors in the system.

4 RESULTS AND DISCUSSION

The purpose of making an interface in the Inpatient Hospital - Java based Hospital Inpatient Information System Application Research is to describe the expected user interface of the hospital inpatient information system application. The interface also aims to get the initial feedback from the user and related parties, so that improvements and adjustments can be made before entering further development stages. The following is the display of the interface that will be created a hospital inpatient information system application that will be called a BedFinder.

4.1 Activity Diagram

Activity Diagram aims to describe the workflow or sequence of activities in the process of managing Java -based hospital medical records. Activity diagrams use elements such as activities, decisions, lines, and liaison to visualize the steps that must be taken in managing medical records, there are eight swimlane in the application of inpatient information system. The main goal is to ensure an efficient and accurate workflow in managing medical records, thereby improving health services to patients. The following is an activity diagram in detail the components and relevant examples to help understand the use of this diagram in practice, which can be seen in Figure 1.

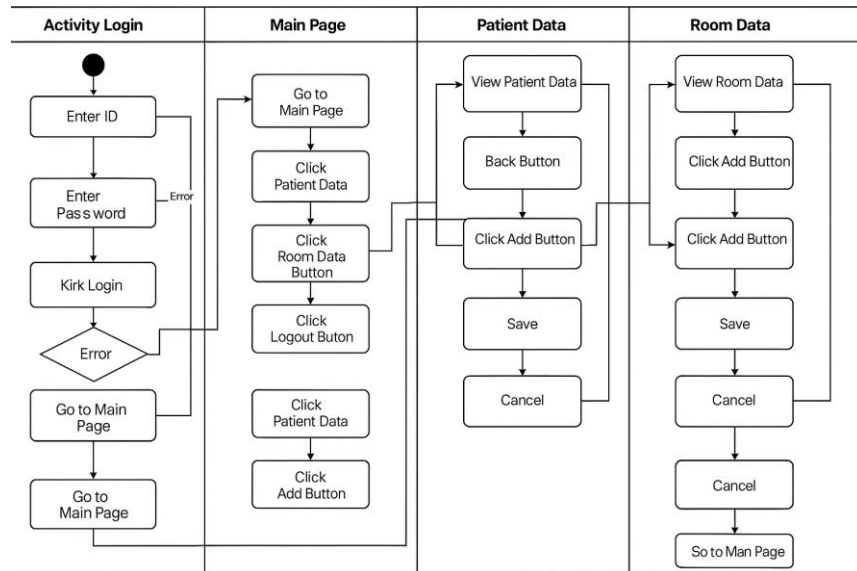


Figure 1. BedFinder Activity Diagram.

4.2 Design

4.2.1 Database Design

The database aims to explain the concepts and roles in the Java -based hospital inpatient information system. The database acts as a place to store integrated medical record data, as well as the need for efficient structures and designs to support accurate and easily accessible data management. By understanding the appropriate database and design concepts, hospitals are expected to be able to build a reliable, safe and efficient inpatient information system in managing medical records, thereby improving the quality of health services and patient satisfaction. Design of BedFinder’s database can be seen in Figure 2.

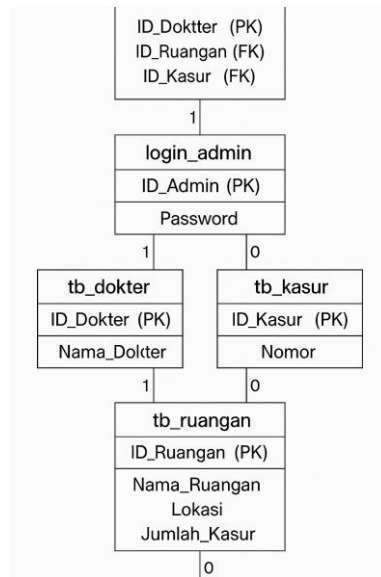


Figure 2. BedFinder's Database.

4.2.2 User Interface Design

The purpose of making an interface in the Java Inpatient Hospital -based Hospital Inpatient Information System Application Research is to describe the expected user interface of the hospital inpatient information system application. The interface also aims to get the initial feedback from the user and related parties, so that improvements and adjustments can be made before entering further development stages. The following is the display of the interface that will be created a hospital inpatient information system application that will be called a BedFinder. Figure 3 shows the login page interface of the hospital inpatient information system application, where users are required to enter their username and password to access the system securely.



Figure 3. Login Page User Interface.

Figure 4 displays the main page interface of the hospital inpatient information system application, which provides users with access to the primary features and navigation menus for managing inpatient data.

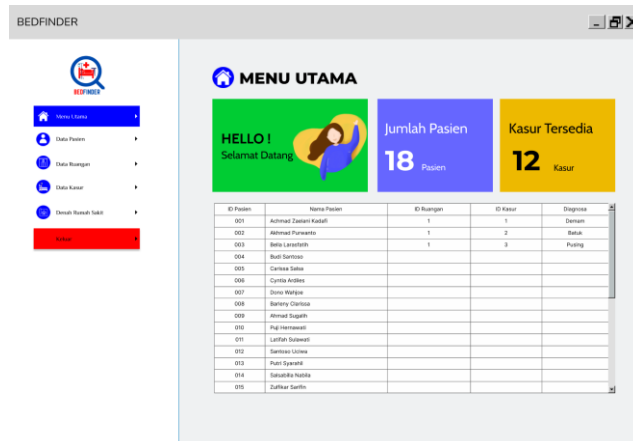


Figure 4. Main Page User Interface.

Figure 5 presents the patient data page interface of the hospital inpatient information system application, which facilitates the structured recording, retrieval, and management of patient information to support accurate and efficient healthcare services.

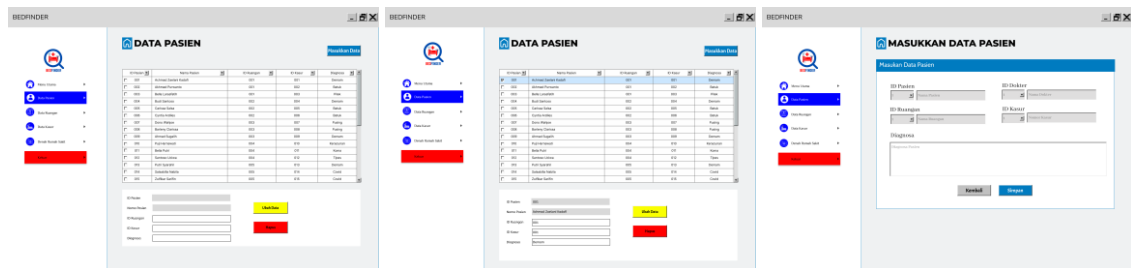


Figure 5. Patient Data Page User Interface.

Figure 6 illustrates the room data page interface of the hospital inpatient information system application, which provides menu options for viewing room data and inputting new room information, thereby enabling systematic management of room availability, assignments, and classifications to optimize inpatient accommodation planning.

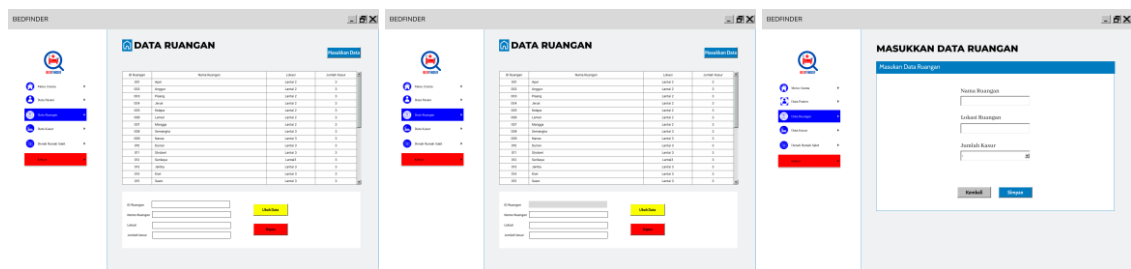


Figure 6. Room Data Page User Interface.

Figure 7 depicts the bed data page interface of the hospital inpatient information system application, which allows users to view existing bed records and input new bed information, thereby supporting efficient allocation and management of inpatient facilities.

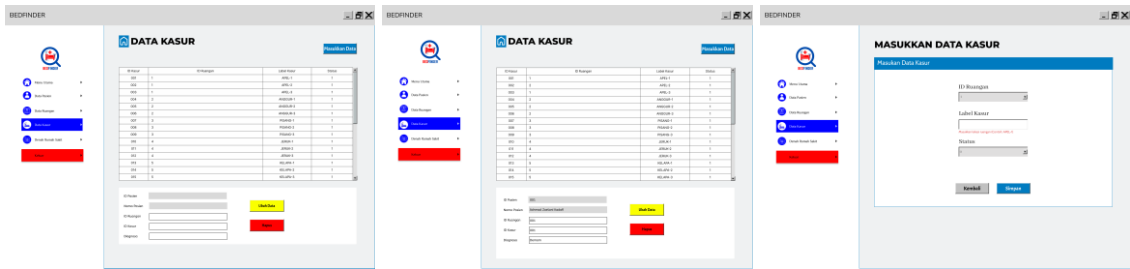


Figure 7. Bed Data Page User Interface.

Figure 8 presents the hospital layout page interface of the hospital inpatient information system application, which displays the hospital’s floor plan to provide a visual representation of room locations and facilitate efficient navigation and facility management.

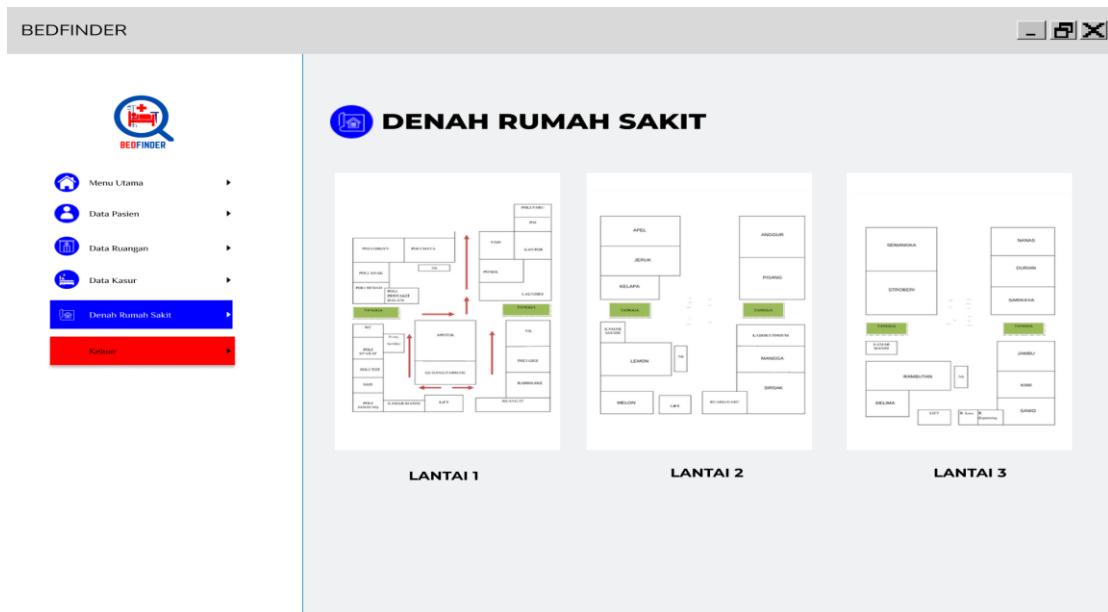


Figure 8. Hospital Layout Page User Interface.

4.3 BedFinder Implementation

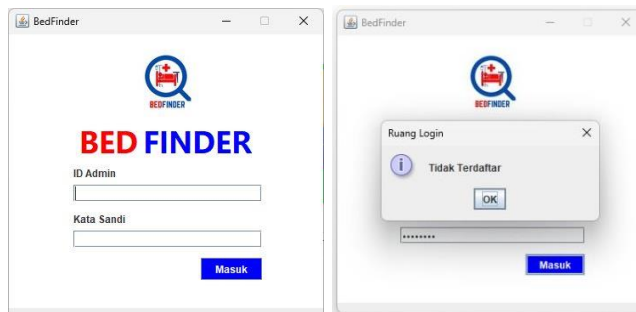


Figure 9. Login Page.

The figure 9 shows the login page of the application, where users can input their Admin ID and password. After clicking the "Login" button, the user will be directed to the main menu if the

credentials are correct. However, if the Admin ID or password is entered incorrectly, a notification will appear indicating that the ID and password do not match.

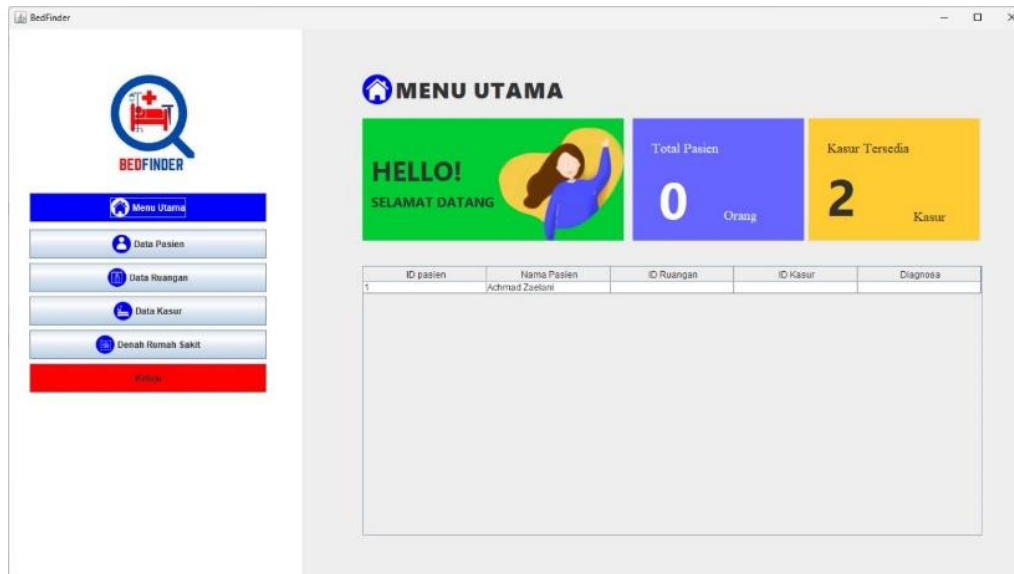


Figure 10. Main Page.

After logging in, several menu options are available, one of which is the main page. On this page, users can view information such as the total number of patients, available beds, and a table containing patient ID, patient name, room ID, bed ID, and diagnosis.

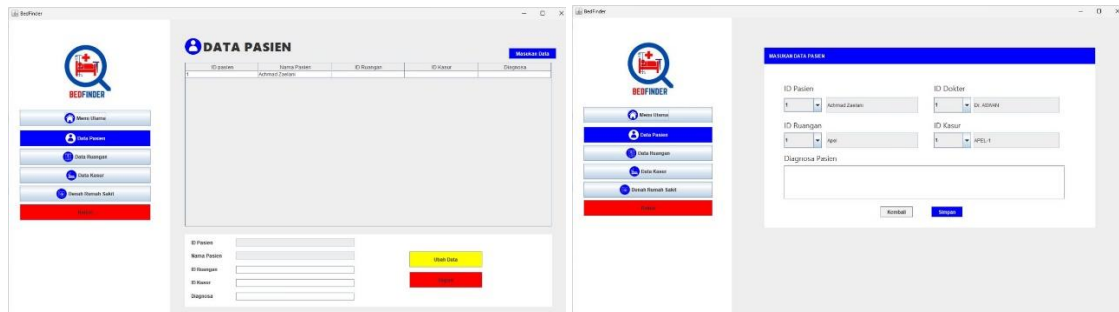


Figure 11. Patient Data Page.

Figure 11 shows mocking or patient data interface. Pada this page, ketika users choose patients from the table, they can modify the room ID, the written place, and diagnosis. In addition to editing, users can delete patient data after the patient is no longer accepted. However, this action does not permanently delete records of inpatients is suggested by the hospital but will no longer appear in the BedFinder application. In addition, the user eliminates the option to drain the information of new patients entering details such as patient IDs, room IDs, doctor IDs, bed IDs, and diagnoses.

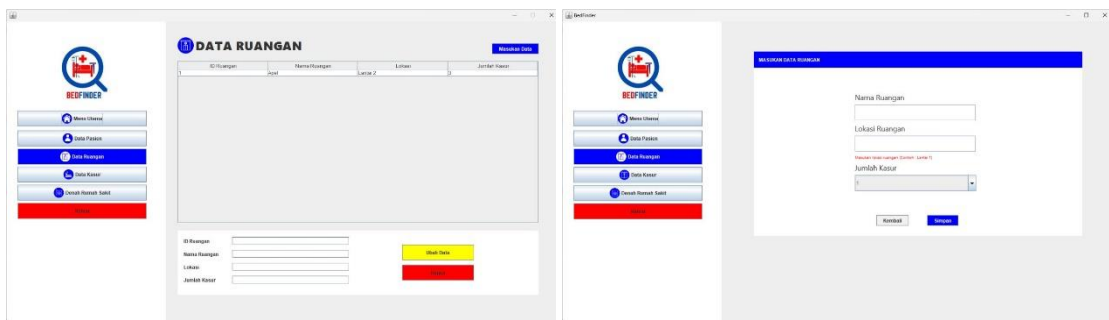


Figure 12. Room Data Page.

Figure 12 presents mocking room page data. This interface features a table that includes a room ID, room name, floor location, and the number of beds. From this page, users can add new entries, and update or delete existing room data. In the room data input section, users can enter details such as room IDs, room names, room labels, and number of beds.

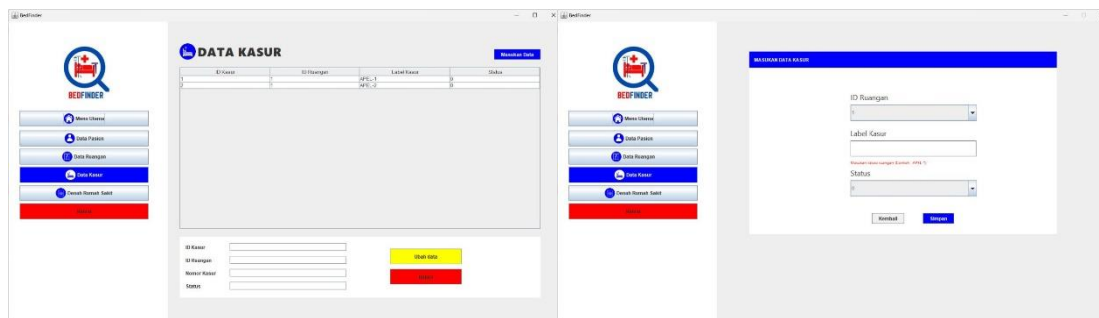


Figure 13. Bed Data Page.

Figure 13 displays the Mock-Up Data Bed page. This page presents a table that contains information such as bed IDs, room IDs, bed labels, and status. From here, users can add new bed notes, as well as update or delete existing ones. Data Bed Input Form allow users to enter details including room IDs, bed labels, and status.



Figure 14. Hospital Layout Page.

Figure 14 presents a mock-up of the Hospital Layout page, which illustrates the hospital's three floors. The primary purpose of this page is to provide precise spatial information, assisting users in locating the specific rooms where patients are admitted.

4.4 Test Identification

Black box testing is a Luna device testing method that focuses on evaluating the usefulness and function of an application. The method of all related subsistence, including the user interface and user experience (UI/UX), database, dependencies, and integrated systems, without requiring enlargement of knowledge about internal codes. Examiners conducted on the applications of Ruci Sangan -based inpatient information systems are based on the UI/UX function and application features that were previously determined in the specifications of the Lamkatana device. A total of 23 cases of tests were executed using the black box testing method.

Table 1. Black Box Testing of the Hospital Inpatient Information System Application.

No	Page	Actor Action	Correct System Response	Incorrect System Response	Compliant	Non-Compliant
1	Login	Enter ID and Password	Redirected to the main menu	Remain on the login page	✓	
2	Main Menu	Sort Patient ID	Patient IDs sorted in order	Patient IDs not sorted	✓	
3	Main Menu	Sort Patient Name	Patient Names sorted in order	Patient Names not sorted	✓	
4	Main Menu	Sort Room ID	Room IDs sorted in order	Room IDs not sorted	✓	
5	Main Menu	Sort Bed ID	Bed IDs sorted in order	Bed IDs not sorted	✓	
6	Main Menu	Sort Diagnosis	Diagnoses sorted in order	Diagnoses not sorted	✓	
7	Patient Data Menu	Enter new patient data	Redirected to patient data entry page	Remain on Patient Data page	✓	
8	Patient Data Menu	Edit patient data	Successfully updated data	Failed to update data	✓	
9	Patient Data Menu	Delete patient data	Successfully deleted data	Failed to delete data	✓	
10	Patient Data Entry Menu	Save patient data	Successfully saved patient data	Failed to save patient data	✓	
11	Patient Data Entry Menu	Return to Patient Data page	Successfully returned to Patient Data page	Failed to return to Patient Data page	✓	
12	Room Data Menu	Enter new room data	Redirected to room data entry page	Remain on Room Data page	✓	
13	Room Data Menu	Edit room data	Successfully updated data	Failed to update data	✓	
14	Room Data Menu	Delete room data	Successfully deleted data	Failed to delete data	✓	

No	Page	Actor Action	Correct System Response	Incorrect System Response	Compliant	Non-Compliant
15	Room Data Entry Menu	Save room data	Successfully saved room data	Failed to save room data	✓	
16	Room Data Entry Menu	Return to Room Data page	Successfully returned to Room Data page	Failed to return to Room Data page	✓	
17	Bed Data Menu	Enter new bed data	Redirected to bed data entry page	Remain on Bed Data page	✓	
18	Bed Data Menu	Edit bed data	Successfully updated data	Failed to update data	✓	
19	Bed Data Menu	Delete bed data	Successfully deleted data	Failed to delete data	✓	
20	Bed Data Entry Menu	Save bed data	Successfully saved bed data	Failed to save bed data	✓	
21	Bed Data Entry Menu	Return to Bed Data page	Successfully returned to Bed Data page	Failed to return to Bed Data page	✓	
22	Hospital Layout Menu	Redirected to Hospital Layout page	Display hospital layout	Hospital layout not displayed	✓	
23	Logout	Redirected to login page	Display login page	Login page not displayed	✓	

5 CONCLUSION

Based on a comprehensive analysis of the study results, it can be concluded that the BedFinder application plays a significant role in strengthening coordination mechanisms within hospitals. The findings demonstrate that the application effectively transforms inpatient room availability management into a more efficient, responsive, and accurate process by integrating real-time information. The application possesses advanced capabilities to monitor, track, and manage the status of inpatient rooms and beds, thereby enabling hospital management to obtain up-to-date insights into patient distribution. This, in turn, supports the strategic allocation of essential healthcare resources, including medical equipment and personnel, with a high level of accuracy, thereby minimizing the risk of misallocation and ensuring optimal utilization of hospital infrastructure.

Additionally, BedFinder introduces a structured framework for scheduling patient visits. This feature systematically organizes visitation patterns to reduce overcrowding, support disease prevention protocols, and create a conducive environment for patient recovery and well-being. The integrated scheduling system further strengthens infection control measures and contributes to enhancing the overall experience of both patients and visitors.

Furthermore, this study highlights the role of BedFinder in reinforcing healthcare governance by integrating room coordination, patient flow management, and visitation scheduling into a unified digital platform. Such integration streamlines internal workflows while aligning with key principles of healthcare service management efficiency, patient-centered care, and sustainable support through digital technology.

In conclusion, the findings confirm that BedFinder represents a relevant, practical, and effective technological solution to address the challenges of modern healthcare services, particularly in managing critical patient visits. Its implementation provides a strategic pathway toward improved hospital governance, optimized resource management, and enhanced quality and safety of healthcare delivery.

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Development of Website-Based Outsourcing Services Negotiation System Using Extreme Programming Method at PT. XYZ

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Abstract

This study develops a Website-Based Outsourcing Services Negotiation System for PT XYZ, addressing the company's reliance on manual communication and document exchange, which previously caused delays and data inconsistencies. The system streamlines client registration, service submission, negotiation, and invoice generation. Extreme Programming (XP) was selected for its iterative adaptability to evolving user requirements, focusing on rapid prototyping, continuous feedback, and incremental improvement. An object-oriented design approach ensures modularity and maintainability, while black box testing validates functional accuracy. After deployment, negotiation process time was reduced by 35%, communication response time by 42%, and documentation completeness reached 100%, significantly enhancing operational efficiency, transparency, and record reliability. These measurable improvements demonstrate the system's role in accelerating PT XYZ's digital transformation and establishing a more structured, evidence-driven outsourcing negotiation process.

Keywords: Outsourcing Service, Website-Based System, Extreme Programming, Object Oriented Programming, Black Box Testing

1 INTRODUCTION

In the era of digital transformation, the adoption of digitalization in business processes has become an inevitable need for companies looking to improve operational efficiency, information transparency, and service acceleration. One sector that has been significantly impacted by this development is the outsourcing service industry. Although the problem statement outlines the general need for a digital outsourcing negotiation system, the specific context at PT XYZ reveals more pressing operational challenges. The company currently relies on manual communication channels such as email, phone calls, and in person meetings for negotiation processes, resulting in prolonged approval times, inconsistent documentation, and difficulties in tracking negotiation history.

Additionally, the absence of a centralized digital platform leads to frequent miscommunication between departments, reduced transparency in pricing discussions, and increased administrative workload. These inefficiencies hinder the company's responsiveness to client requests and limit its ability to compete with industry peers that have already adopted integrated digital solutions (Huang et al., 2021). Addressing these business and operational constraints forms a clear research gap, underscoring the practical relevance of developing a website based outsourcing services negotiation system tailored to PT XYZ's needs. One effective solution to overcome this problem is the development of a web-based negotiation information system. Such a system can simplify the entire process, from client registration and negotiation submission to service data processing and invoicing.

A web-based platform offers accessibility, time efficiency, and can be developed with an interface customized to the user's needs (Setyawati, 2021).

Adopting an appropriate system development methodology is essential to ensure the resulting software effectively meets user needs. Extreme Programming (XP), one of the Agile methods, offers an iterative and flexible approach that is highly suitable for systems requiring close user collaboration and frequent adjustments (Fatoni & Irawan, 2019). In the context of a web-based outsourcing negotiation system, XP's short iterations, continuous testing, and rapid adaptability are advantageous in addressing dynamic requirements. Practices such as daily stand ups and sprint reviews help minimize communication gaps in dispersed projects, while user story mapping and backlog grooming can be automated to manage priorities effectively. Furthermore, continuous integration ensures that code development remains aligned with negotiated agreements (Lamada et al., 2023).

By integrating the adaptive strengths of Extreme Programming (XP) with a web-based platform, this study introduces a negotiation system tailored to real-time outsourcing collaboration. Unlike conventional approaches, it directly addresses dynamic communication needs, enhancing operational efficiency while contributing a practical model for continuous digital transformation in service-based processes.

2 LITERATURE REVIEW

The literature review in this study serves as a theoretical and conceptual basis to support the development of a website-based outsourcing service negotiation system using the Extreme Programming (XP) method. It critically examines prior works to identify relevant findings, limitations, and opportunities that this research aims to address.

2.1 Digital Transformation

Digital transformation has become a key driver of innovation in information systems, where technology is used to create new value and improve operational efficiency. According to (Verhoef et al., 2021), emphasize that transformation is not only about digitizing processes, but also about building integrated and adaptive digital systems. In the context of outsourcing services, digitization enables faster communication and higher transparency between clients and providers. Prior works, such as (Setyawati, 2021), have demonstrated the advantages of web-based systems in providing real-time access and systematic documentation. However, most of these studies focus on general service management without detailing negotiation-specific workflows or the integration of agile methods. This study addresses that gap by combining web-based platforms with an agile methodology tailored to outsourcing negotiations.

2.2 Negotiation in an Outsourcing System

Negotiation is central to establishing agreements in outsourcing, covering service scope, pricing, performance standards, and contract terms (Hou et al., 2021). Previous studies highlight the importance of strategic preparation and transparent communication in achieving a win-win outcome. While these works describe the theoretical and procedural aspects of negotiation, they often lack concrete technological implementations that support real-time, traceable negotiations. This research advances the field by embedding these negotiation principles into a digital platform, enabling structured interactions and automatic documentation.

2.3 Extreme Programming (XP)

Extreme Programming (XP) is known for short iterations, close user collaboration, and rapid adaptability (Shrivastava et al., 2021). This method has proven to be effective in adaptive and efficient software development, especially on projects that require rapid response to changing user

needs (Widhiastuti et al., 2023). Prior implementations, such as (Lamada et al., 2023), have successfully applied XP in web based project management, improving responsiveness to changing requirements. However, these applications generally target broader project management contexts and do not address the specific needs of outsourcing negotiations. This study builds on these strengths by adapting XP practices daily stand ups, sprint reviews, and continuous integration to reduce communication gaps and ensure alignment between negotiated agreements and implemented system features.

2.4 Object-Oriented Programming

Object-Oriented Programming (OOP) promotes modularity, reusability, and maintainability (Issyatirrahim et al., 2024). Previous research demonstrates that OOP facilitates scalable designs and easier error detection. In the context of negotiation systems, however, OOP's potential for modular workflow handling has rarely been explored. This research leverages OOP to design reusable modules for user management, negotiation handling, and documentation, enabling a flexible and secure role-based access structure.

2.5 Unified Modeling Language (UML)

UML diagrams provide a standardized way to visualize system requirements and design (Siska Narulita et al., 2024). While prior works have demonstrated UML's value in system design, few have shown its integration with agile methods for iterative refinement. This study applies UML not only for initial modeling but also as a living document updated through XP iterations, ensuring that system design evolves alongside stakeholder feedback.

2.6 Black Box Testing

Black Box Testing evaluates system functionality from the user's perspective without inspecting the source code (Putri et al., 2024). To ensure reliability, testing was performed on all core modules with a defined number of test cases, repeated at least three times under varying input conditions, and considered successful if 100% of critical cases passed without errors (Sitio et al., 2023). This approach was applied in each XP iteration to detect and resolve discrepancies early.

2.7 Synthesis and Research Gap

From the reviewed literature, several patterns emerge:

1. Digital transformation and web-based systems improve efficiency and transparency, but prior studies seldom focus on outsourcing negotiations.
2. Negotiation theory is well-documented, yet its integration into adaptive, real-time digital tools remains limited.
3. XP and OOP have been applied in various contexts, but their combined use for negotiation-specific workflows is rare.
4. UML and Black Box Testing are established tools, but their iterative application within negotiation systems is underexplored.

By addressing these gaps, this study contributes both theoretically and practically: it offers a negotiation system specifically tailored to outsourcing services, integrates agile and modular development principles, and provides an iterative, test-driven framework that ensures the system evolves in step with business needs.

3 RESEARCH METHODS

This research adopts the Extreme Programming (XP) approach as the primary methodology to develop a web based outsourcing service negotiation system at PT XYZ. XP was selected over other Agile methods, such as Scrum and Kanban, due to its strong emphasis on short development cycles, continuous feedback, and direct collaboration with end-users. These characteristics align with PT XYZ's operational challenges, which include frequent changes in negotiation terms, the need for rapid iteration to accommodate client feedback, and the importance of maintaining traceable documentation in a dynamic outsourcing environment.

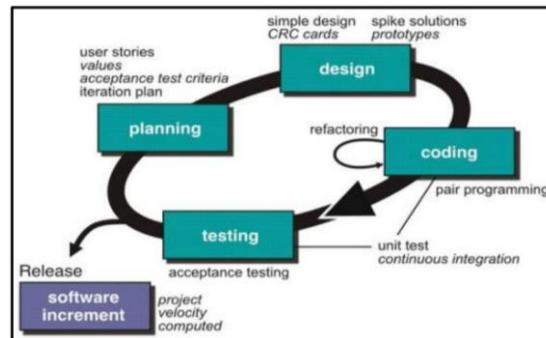


Figure 1. SDLC Extreme Programming

What follows is an explanation of each stage of extreme programming:

1. **Planning**
In the planning game, developers and stakeholders collaborated to identify and prioritize system requirements in the form of user stories. For the negotiation system, high-priority stories included client registration, service request submission, negotiation revision handling, and invoice generation. This stage ensured that the system scope directly reflected the critical functions required to address PT XYZ's negotiation workflow inefficiencies.
2. **Design**
System design translated user stories into UML diagrams, including Use Case, Sequence, and Class Diagrams, to represent workflows and system structure. The negotiation module, for example, was designed with flexible iteration loops to support back-and-forth revisions between clients and operations managers, a feature identified as essential in stakeholder interviews. Simple design principles were applied to maintain clarity and adaptability.
3. **Coding**
The coding phase implemented features according to the agreed design, using PHP for rapid, maintainable development. Pair programming was applied to the negotiation and invoice modules, as these were mission-critical features that required both accuracy and reliability. This approach improved code quality and allowed for early detection of logic discrepancies, especially in price calculation and approval workflows.
4. **Testing**
Testing was conducted using the Black Box Testing method, focusing on verifying functional behavior against defined acceptance criteria. For the negotiation system, test cases included verifying price revision handling, invoice generation accuracy, and role-based access control. Each test case was executed at least three times under different input conditions, with a success threshold of 100% for all critical cases. Any failures triggered immediate corrective actions within the same XP iteration.

4 RESULTS AND DISCUSSION

The development of the Website-Based Outsourcing Service Negotiation System at PT XYZ was conducted in accordance with the principles of Extreme Programming (XP) methodology. This section not only reports the procedural steps taken but also provides a comparative analysis of the system's capabilities against prior studies, highlighting its novelty and contributions to both practice and literature.

4.1 User Stories and Functional Requirements

These user stories were prioritized to focus on modules critical to PT XYZ's operations, such as multi-iteration negotiation handling, automated documentation, and integrated invoicing. Unlike (Setyawati, 2021), whose work addressed general service management, this study's user stories specifically addressed real-time negotiation loops and traceability, filling a gap in the literature on outsourcing-specific systems. The main actors identified in this system are:

1. Client (who submits outsourcing service requests),
2. Administrator (who manages services, responses, and invoices),
3. Operations Manager (who oversees negotiation and approval flow).

Table 1. List of user stories

No	User Stories
1	As a client, I want to register and log in so that I can access the negotiation system.
2	As a client, I want to submit a service request so that I can initiate outsourcing negotiations
3	As a client, I want to view and edit my request before finalizing it.
4	As an admin, I want to receive service submissions and respond with an initial offer.
5	As an operations manager, I want to approve or decline negotiation submitted.
6	As a client, I want to receive notifications and reply to offers so that the negotiation process is interactive.
7	As a client, admin, and operations manager. I want to see the negotiation history for transparency.
8	As an admin, I want to generate and send invoices once the negotiation is completed.
9	As a client, I want to download the invoice as proof of agreement.

After making a list of user stories, then determine the functional requirements of this system. The functional requirements determined are as follows:

Table 2. Functional Requirements Table

No	Functional Requirement	Description
FR1	User Authentication	The system must support client, admin and operations manager login with role-based access.
FR2	Service Request Form	Clients must be able to fill and submit a service negotiation form (with date, type of service, description).
FR3	Response Module	Operations manager must be able to view requests and reply with service terms and prices.

No	Functional Requirement	Description
FR4	Negotiation Threading	Both parties can send and receive messages/offers in a structured conversation thread.
FR5	Notification System	The system should send email or in-app alerts for status changes.
FR6	Invoice Generation	Admin can issue invoices after both parties agree.
FR7	Document Management	Clients can download or archive submitted requests and invoices.
FR8	Monitoring	Admin can view a summary of ongoing negotiations and statuses.

This structured set of user stories and functional requirements ensured that the system addresses real business processes and supports interactive and traceable negotiation flows, rather than just static submissions.

4.2 System Development Process

At this initial stage, system requirements were collected in the form of user stories through interviews and discussions with key stakeholders, including the outsourcing service manager and administrative staff.

1. Planning

These user stories were compiled into a product backlog and prioritized according to business importance and technical feasibility. This stage aimed to define clear functional expectations, such as: Client registration and login, Service submission, Service period selection, Cost estimation (RAB), Negotiation, Invoice generation and notification. This approach mirrors Agile best practices in (Lamada et al., 2023) but differs in its targeted prioritization of negotiation workflows essential in addressing PT XYZ's documented issues of prolonged approval times and miscommunication.

2. Design Stage

The negotiation module was explicitly designed with back and forth revision loops to accommodate multiple agreement cycles, an aspect absent in prior general project management systems.

a. Use case diagram

The Use Case Diagram below illustrates the interaction between three main external actors and the Outsourcing Services Negotiation System, namely the Client, Operations Manager, and Administrator. This diagram is organized to represent the main business processes that occur in digitally applying for and negotiating outsourcing services.

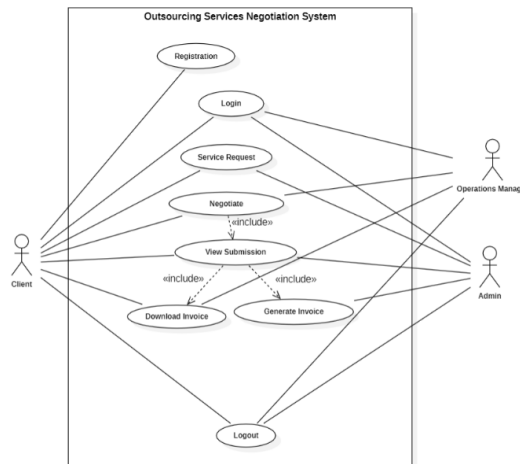


Figure 2. Use case diagram

Overall, this diagram shows how the developed system is able to facilitate the process of applying, negotiating, and administering outsourcing services in an integrated manner, while supporting the flexibility of user roles in a safe and efficient digital service ecosystem.

To understand the functional requirements and interactions between users and the system, a use case model was developed to describe how each actor communicates with the system components. The system is designed to facilitate end-to-end outsourcing service negotiations in a structured and traceable manner. Table III outlines the primary use cases identified in the system, along with the respective actors involved and a brief description of each function. This modeling approach helps define the scope of the system and ensures that all business processes are covered effectively.

The use case descriptions presented in the table illustrate the core activities performed by each actor, including clients, administrators, and operations managers. These activities range from user authentication to service submission, negotiation, and document handling. The inclusion of shared components such as the View Submission use case within multiple workflows highlights the modularity and reuse of system functions. This comprehensive model serves as the foundation for further design phases, including interface prototyping and system implementation.

Table 3. Use case description

No	Use Case	Actor	Description
1	Registration	Client	Allows new clients to create an account and gain access to the system for submitting outsourcing service requests
2	Login	Client, Administrator, Operations Manager	Authenticates users before they can access system features. Each actor has role-based access rights.
3	Service Request	Client, Administrator	The client submits a service request by filling out a form with service details. The administrator receives and verifies the request as part of the negotiation process.
4	Negotiate	Client, Administrator, Operations Manager	A structured negotiation process involving price, service scope, and delivery time, in which all actors participate to reach an agreement.

No	Use Case	Actor	Description
5	View Submission	Client, Administrator, Operations Manager	Displays submitted data, status updates, and negotiation history. This use case is included in multiple other use cases via <<include>> relationships.
6	Generate Invoice	Administrator	The administrator creates and uploads an invoice based on the agreement reached in the negotiation. This use case includes View Submission.
7	Download Invoice	Client, Operations Manager	Allows users to access and download the final invoice as an official document for payment or archiving. This use case includes View Submission.
8	Logout	Client, Administrator, Operations Manager	Ends the current user session and logs the user out securely from the system.

b. Activity diagram

To further illustrate the system’s workflow, an activity diagram was developed to represent the sequence of actions and decision points involved in processing an outsourcing service request. This diagram visualizes the interactions among the system components and actors starting from client registration through negotiation and ending with invoice generation. By mapping out the flow of activities, the diagram provides insight into the dynamic behavior of the system and supports the identification of potential bottlenecks or redundancies.

This diagram illustrates the sequential flow of user registration and login activities. The process begins with the client opening the respective page and inputting data. The system then performs validation, determines whether the input is valid or invalid, and provides appropriate feedback. If valid, the user either completes the registration or is redirected to the dashboard upon successful login.

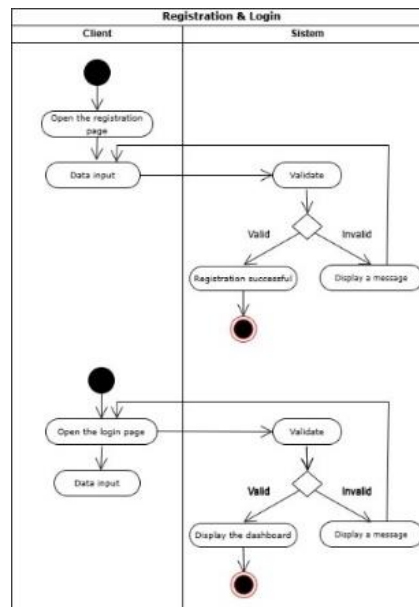


Figure 3. Activity diagram registration & login

After the authentication process is completed through login or registration, the next primary interaction performed by the client is submitting a service request. This function serves as the entry point for initiating the outsourcing service process. To represent this interaction, an activity diagram for the Service Request process is presented, outlining the sequence of activities carried out by the client, system, and administrator. The diagram illustrates how the system receives input, validates request data, and manages approval or revision feedback.

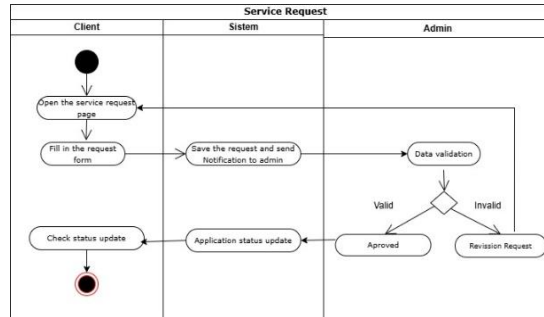


Figure 4. Activity diagram service request

Once a service request has been submitted and approved by the administrator, the process moves into the negotiation phase. This phase is essential for aligning expectations between the client and the operations manager regarding the scope, duration, and pricing of the requested service. It begins with the Operations Manager opening the negotiation page and filling out the RAB form. The system sends the service details and RAB to the client, who then reviews and either processes the terms or submits a revision. If a revision is received, the manager checks it and decides whether to approve or decline. The loop continues until a final agreement is reached.

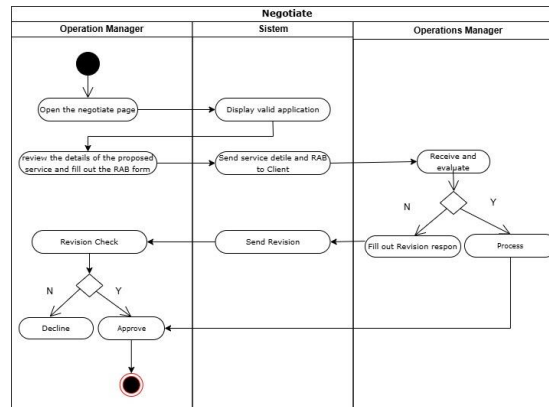


Figure 5. Activity diagram negotiate

After the negotiation process has reached a mutual agreement, the system proceeds to the final administrative stages, including viewing the finalized submission, generating the invoice, and allowing users to download the invoice as official documentation. The following activity diagram illustrates this post-negotiation workflow, showing how the client, administrator, and operations manager interact with the system to complete the service transaction.

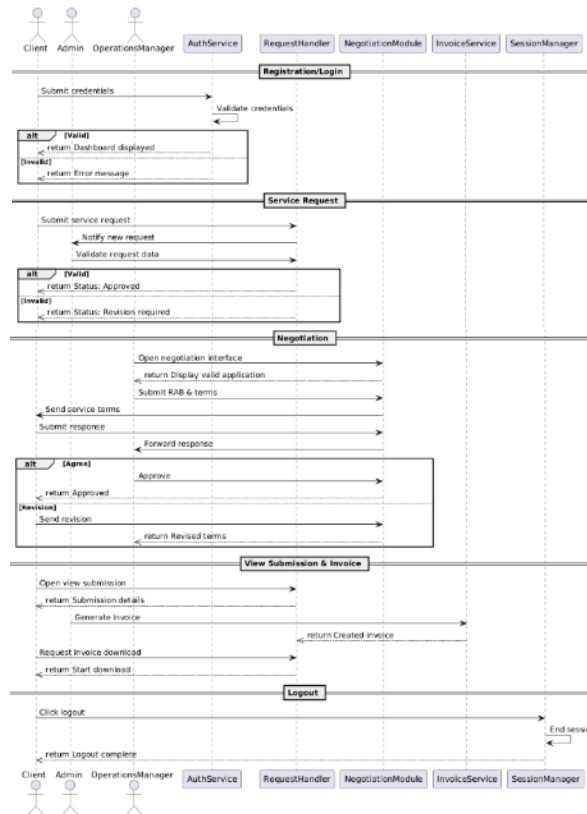


Figure 8. Sequence diagram

This sequence diagram clarifies the interaction flow and role distribution among various actors and services within the system architecture. By modeling time-based message exchanges, it helps ensure that the system design aligns with the intended business logic and supports a clear implementation roadmap for developers.

d. Class diagram

The following class diagram is used to illustrate the static structure of the Outsourcing Services Negotiation system, including class relationships and the primary responsibilities of each entity. The diagram includes eight main classes, such as User, AuthService, SessionManager, RequestHandler, NegotiationModule, and InvoiceService. The User class serves as a central entity representing different user roles client, admin, and operations manager distinguished through the role attribute. Relationships among classes are annotated with multiplicity to show the cardinality of interactions.

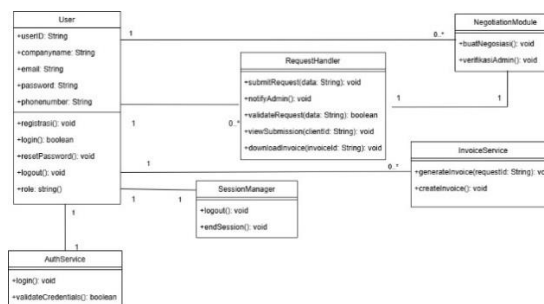


Figure 9. Class diagram

This class diagram facilitates the understanding of the systems structure from an object-oriented programming perspective. With clearly defined responsibilities and multiplicity relationships between classes, it provides a solid foundation for implementing modular and structured system logic. The model also supports future development through a flexible role based access control approach.

e. Mockup design

In the design of the Outsourcing Services Negotiation system, the user interface (UI) plays a vital role in supporting effective and intuitive user interaction. To visualize and validate the system functionality, mockups were developed to reflect the intended user experience. This article presents three primary screens: the login page, dashboard, and negotiation form.

First, the Login mockup illustrates the entry point into the system. It includes fields for username/email and password. The layout is intentionally simple and responsive to accommodate all user roles (client, admin, and operations manager).

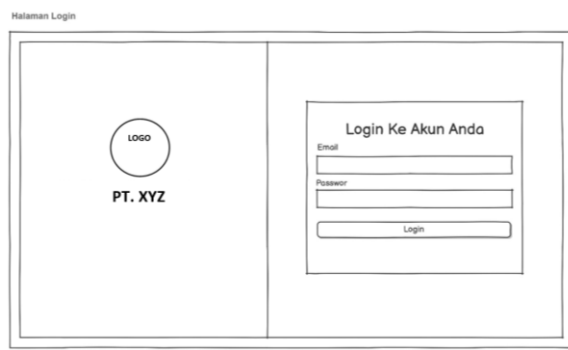


Figure 10. Login form design

Second, the Dashboard interface provides a role based navigation experience. The design supports direct access to essential system functions with minimal visual clutter.

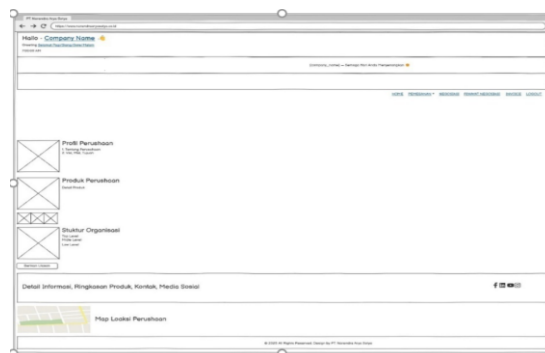


Figure 11. Dashboard design

Third, the Negotiation Form mockup facilitates interaction between the client and the operations manager. This interface allows users to review service details, submit revisions, or approve proposed terms. Fields for inputting service scope, duration, and cost are presented clearly to support transparent and efficient decision-making.

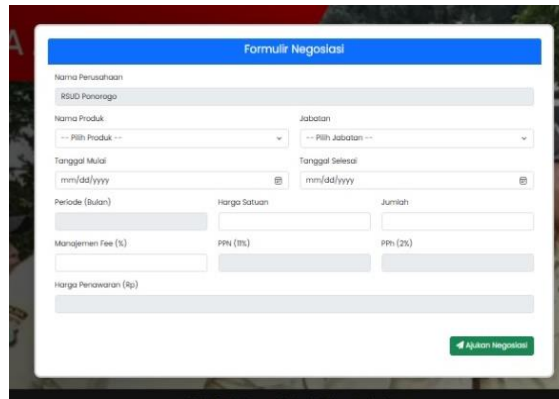


Figure 14. Negotiate page

4. Testing Stage

To ensure that all system functionalities operated in accordance with user requirements, the system underwent Black Box Testing. This method evaluates the output of each function based on given inputs, without inspecting the internal code structure. Testing was conducted on key modules including login, service request, negotiation, invoice generation, and logout. In addition to qualitative verification, quantitative performance metrics were recorded to strengthen the evaluation. These included execution time for each function and error rates during repeated trials. Testing was performed three times for each module under varied but valid input conditions.

Table 4. Black box testing

Test Case	Input	Expected Output	Actual Output	Execution Time (seconds)	Error Rate (%)
Login	Valid username/ password	Access granted	Access granted	1.2	0
Service Request	Valid service data	Service request stored	Service request stored	3.5	0
Negotiation	Price and duration proposal	Negotiation terms updated	Negotiation terms updated	5.0	0
Invoice Generation	Approved negotiation details	Invoice generated	Invoice generated	2.8	0
Logout	Logout request	Session ended	Session ended	1.0	0

Based on the testing results conducted using the Black Box Testing method, all core features of the system have demonstrated behavior consistent with the expected specifications. Each module, from user authentication to invoice download, functioned correctly and no anomalies were found under different input scenarios. This indicates that the system successfully meets the functional requirements and is suitable for deployment in an operational environment. The successful test outcomes also reflect that the system development process was carried out systematically and adhered to sound software engineering principles.

5 CONCLUSION

Manual negotiation process as outlined in the research objectives and problem statement in the introduction. The system was designed to transform the negotiation process between clients, administrators, and operations managers into a systematic, interactive, and traceable digital workflow. The adoption of XP allowed for a flexible, collaborative, and iterative development process, enabling rapid adaptation to evolving user needs.

Through an object-oriented programming approach, the system achieves a modular structure and effective role-based access management. The resulting prototype integrates a user-friendly login page, dashboard, and negotiation form, all designed to enhance usability. Black Box Testing demonstrated that all system functions operated according to specifications with zero anomalies, confirming that the system is ready for operational deployment. This outcome aligns with the study's objective to improve

Both efficiency and transparency in outsourcing service negotiations. Despite these achievements, the research has limitations. The evaluation was conducted within a controlled testing environment, without performance benchmarking against comparable systems or stress-testing under high-load conditions. Furthermore, user feedback was limited to internal stakeholders, which may restrict generalizability.

For future work, it is recommended to expand the evaluation scope to include larger-scale operational environments and diverse user groups, integrate quantitative performance benchmarks, and explore comparative studies with alternative Agile methodologies. System enhancements could include API integration for digital signatures, automated notifications via email or WhatsApp, and advanced security measures such as end-to-end encryption and detailed audit trails. These developments would not only strengthen the system's practical value but also contribute to academic knowledge on the application of Agile methods in digital negotiation systems.

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Leveraging Employee Digital Skills to Accelerate Digital Transformation and Achieve Organization Competitive Advantage

(An Empirical Study on Digital Capability Assessment Across Early Childhood, Primary, Junior, and Senior High School Levels)

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Abstract

Digital transformation in education has become an urgent necessity in the post-COVID-19 era, as remote learning accelerated large-scale technology adoption. Yet, digital skill gaps among education employees remain a critical barrier, particularly in Indonesia with its limited infrastructure. This study aims to assess the digital skills of 824 employees in XYZ Educational Organization, spanning early childhood to senior high school levels. Using an adapted UNESCO Global Framework of Reference on Digital Literacy Skills, five core competencies are measured. Data were collected via surveys and analyzed to identify gaps across educational levels. The findings are expected to provide milestone-based recommendations to accelerate multi-level digital transformation, improve collaboration, enhance data management efficiency, strengthen cybersecurity, and boost school competitiveness in the digital era.

Keywords: Digital Skill, Educational Technology, Information Security Awareness, Privacy Awareness, Digital Literacy

1 INTRODUCTION

Digital transformation in education has become an urgent need in the post-COVID-19 era, when distance learning forced schools to adopt technology widely. Globally, UNESCO notes that the pandemic sped up the digitalization of education but also increased gaps in access and digital skills, especially in developing nations. In Indonesia, the pandemic caused over 530,000 schools to close in 2020, leading to a quick move to online learning that highlighted reliance on digital infrastructure (UNICEF, 2021). This shift not only changed teaching methods but also stressed the importance of digital skills among education workers, like teachers and staff, as a key factor in institutional competitiveness. According to the World Bank (2021a), only 30% of rural schools in Indonesia have reliable internet, which hampers technology use and worsens educational inequalities.

The urgency of this research stems from how digital skills can transform education, from individual employees to entire organizations, thereby boosting schools' competitiveness in the digital age. Post-pandemic studies indicate that digital transformation in Indonesian education has advanced rapidly since 2012, especially after COVID-19, with an emphasis on online platforms and learning. Innovations (Fuadiy et al., 2025) However, without sufficient digital skills, educational institutions risk falling behind in curriculum innovation, data management, and global collaboration. Frameworks like the Resource-Based View (RBV) suggest that digital skills as internal resources can become a competitive advantage, allowing schools to attract more students, improve graduate

quality, and adapt to technological changes change (Barney, 1991). In the Indonesian context, digitalization of education is essential to support Sustainable Development Goal (SDG) 4 on quality education, where technology acts as a catalyst (UNESCO, 2018).

Despite these advancements, there are significant gaps in digital skills among teachers and education staff in Indonesia. Research indicates that teachers' digital literacy is at a "fairly good" level, but variations across provinces and education levels remain high, with key factors including lack of infrastructure, training, and educational focus. According to International Labour Organization (2022), Indonesia faces a shortage of 15,000-20,000 ICT specialists in creative sectors, including education, which impedes technology adaptation. Additionally, only 30% of students achieve minimum proficiency in reading, which indirectly affects the development of teachers' digital skills (Smeru Research Institute, 2022). The lack of training support during the digital transition post-pandemic has further exacerbated this issue, where teachers often struggle to integrate technology into teaching (World Bank, 2021b).

In the XYZ Educational Organization, which oversees various levels of primary and secondary education with a total of 1,157 employees, similar issues have been observed during initial assessments: uneven digital skills across different levels (e.g., TK/PAUD lower than SMA/SMK), which hampers multi-level digital transformation. This causes inefficiencies in collaboration, data management, and cybersecurity, ultimately reducing the organization's competitiveness in attracting students and fostering innovation.

The aim of this research is to evaluate the digital skills of XYZ employees to support multi-level digital transformation, from fundamental abilities to organizational competitiveness. The method used is a modification of the UNESCO Global Framework of Reference on Digital Literacy Skills, which includes seven core competencies such as device operation, information literacy, communication, content creation, safety, problem-solving, and career skills, adapted into five main competencies tailored to the XYZ context. This research plan includes assessment instruments tailored to the organization's needs, data collection through questionnaire distribution, data analysis to determine the value of digital capabilities and to identify competency areas that need to be improved, and formulation of recommendations for a 5-year sustainable program to make employee digital capabilities a competitive advantage for the organization.

2 LITERATURE REVIEW

This research utilizes the Digital Literacy Framework proposed by UNESCO (2018) as its main conceptual foundation for evaluating respondents' digital capabilities. The framework consists of 7 competency areas from those in areas numbered 0 to 6. This study uses 5 of the 7 proposed competency areas, namely areas 0 to 5 as described in the methodology section. In addition, this study also adjusts the sub-competency section in each competency to the context or needs of the XYZ organization which is the location of the case study. Before going into the details of the adjusted competencies and sub-competencies, this Literature Review section will first describe the competency areas proposed by UNESCO as follows:

- Area 0 - Device and Software Operation. This section delves into the user's fundamental ability to manage essential hardware and software required for their work.
- Area 1 - Information and Data Literacy. This focus ensures individuals possess the skills to locate, assess, and manage information effectively within online platforms.
- Area 2 - Communication and Collaboration. This area examines the potential to work together with others via digital means, fostering the exchange of ideas, coordinating tasks, and achieving shared objectives.
- Area 3 - Digital Content Creation. Here, the emphasis lies on the ability to develop and adapt digital material, with a keen understanding of copyright and licensing considerations.

- Area 4 - Safety. This aspect addresses the capacity to protect devices, data, personal information, and privacy within digital settings.
- Area 5 - Problem Solving. This area explores the skill to identify needs and challenges, tackling conceptual difficulties and real-world digital scenarios, while leveraging tools to improve processes and outcomes.
- Area 6 - Career Related Competencies. This focus highlights the aptitude to apply advanced digital technologies and to understand, evaluate, and analyze specialized data and content relevant to a specific field.

Considering these competencies as interconnected rather than isolated abilities, the UNESCO framework provides a broad perspective on digital literacy, blending technical expertise with the ethical and mindful use of digital tools. Within this study, the framework serves as a foundation for setting measurement standards and steering the evaluation process, allowing for adaptations that reflect the organization's practical needs and goals.

3 RESEARCH METHODOLOGY

This study followed a structured methodology consisting of six interrelated stages, as illustrated in Figure 1. The process began with the identification of digital capability standards for employees and concluded with the preparation of the final research report. In addition to outlining the research stages, this section explains the scope of the study, the instruments developed, and the data analysis techniques applied. The six research stages are as follows:

1. Research on Employee Capability Standards

At this stage, our main objective was to determine which indicators could best capture an individual's level of digital skills. To support this effort, we referred to the UNESCO Global Framework of Reference on Digital Literacy Skills, a model that identifies seven broad areas of competence (discussed further in Chapter 2). We selected this framework because of its strong international reputation and its ability to encompass the diverse dimensions of digital literacy. By grounding our work in a globally recognized standard, we were able not only to ensure the credibility of our approach but also to position our results in relation to international benchmarks. The insights gathered during this stage became an essential foundation for the development of the assessment tool in the next phase of the study, ensuring that the instrument would be both comprehensive and contextually meaningful.



Figure 1. Research Stages

2. Development of Assessment Instrument

In the second stage, we worked on designing an instrument to assess employees' digital competencies in a way that was both structured and practical. The instrument was organized into a series of indicators, each supported by guiding questions that could capture different aspects of digital literacy. At the outset, we drew inspiration from UNESCO's Global Framework of Reference on Digital Literacy Skills (2018), which identifies seven broad areas of competence (see Chapter 2 – Literature Review). While this served as a valuable reference, we also recognized that not every element of the framework was fully aligned with the organization's immediate context. After several rounds of internal discussions and a review of the organization's strategic objectives, we agreed to exclude two areas—Problem-Solving and Career-Related Competences. These domains, although important in a broader sense, were judged to be less applicable to the current digital environment of the organization. By narrowing the scope in this way, we ensured that the instrument would remain focused, relevant, and directly supportive of the organization's ongoing digital initiatives, rather than introducing measures that might not yield meaningful insights at this stage. Consequently, we focused on five main areas: Devices and Software Operations, Information and Data Literacy, Communication and Collaboration, Digital Content Creation, and Safety & Privacy.

Moreover, the specific sub-competencies associated with these areas were not taken directly from UNESCO's framework. Instead, we tailored and redefined them to better reflect the unique digital skills necessary for our organization. This customization was based on qualitative feedback gathered from interviews with both our IT and Education units, ensuring the sub-competencies accurately represented the operational context and skill needs. We included a mapping in Table 1 that shows the relationship between the original UNESCO competencies and our adapted sub-competencies used in this study.

I created the assessment tool by developing questions that align with the various indicators of each sub-competency I mentioned earlier. This preparation was crucial to make sure that when we move on to collecting data, we can accurately and consistently measure the digital competencies of the respondents.

Table 1. Proposed Instrument Digital Competencies

Core Competency (UNESCO, 2018)	Proposed (Sub-Competency)
Devices and software operations	Connecting to the internet
	Connecting speakers and webcams
	Downloading applications
Information and Data Literacy	Searching for information on Google
	Evaluating the credibility of information
	Identifying online scams
	Downloading documents
	Performing copy-and-paste operations
Communication and Collaboration	Using email
	Creating meeting links
	Using collaborative applications
	Crediting authors appropriately
	Posting job-related content
Digital Content Creation	Creating presentation materials
	Processing data
	Writing reports
	Storing files
	Understanding content licensing

Core Competency (UNESCO, 2018)	Proposed (Sub-Competency)
Safety & Privacy	Using character combinations for passwords
	Managing account passwords
	Identifying unreliable sources
	Sharing personal data securely

3. Data Collection

The data collection stage involved determining the research population and selecting an appropriate sample size to ensure representative results. The population in this study comprised all employees of the Basic and Secondary Education Institution within Organization XYZ, totaling 1,157 individuals. To determine the minimum sample size required, the Slovin's formula (Slovin, 1960) was applied:

$$n = \frac{N}{1+N(d)^2} \quad (1)$$

where:

- N = population size
- d = margin of error
- n = required sample size

Using Slovin's formula, and substituting $N = 1,157$ with $d = 0.10$ (10% margin of error), the minimum sample size was calculated as 795 participants. In practice, responses were obtained from 824 employees, surpassing the minimum requirement. This larger sample helped strengthen the reliability and accuracy of the results. The sampling approach was designed to include perspectives from personnel across all schools under the management of Organization XYZ, providing a broad and representative overview of their digital capabilities.

4. Data Processing

- Validity Test

To verify that the questionnaire effectively measured the intended constructs (Sekaran & Bougie, 2016), Pearson's Product-Moment correlation was applied using the formula shown below:

$$r_{XY} = \frac{N \sum XY - (\sum X)(\sum Y)}{\sqrt{(N \sum X^2 - (\sum X)^2)(N \sum Y^2 - (\sum Y)^2)}} \quad (2)$$

Decision criteria:

The instrument is deemed valid if the computed r value exceeds the r table value, where the r table is determined according to Pearson's correlation table based on the sample size.

- Reliability Test

Reliability was examined to determine the internal consistency of the questionnaire. Cronbach's Alpha (Sekaran & Bougie, 2016) was applied using the formula shown below:

$$r_{11} = \left[\frac{k}{k-1} \right] - \left[1 - \frac{\sum ab^2}{at^2} \right] \quad (3)$$

Decision criteria:

An instrument was judged reliable when its Cronbach's alpha was at least 0.70.

- **Digital Literacy Level Calculation**
Respondents' digital literacy levels were determined by calculating the average of their responses on a Likert scale, defined as follows:
1 = Strongly Disagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree
For each indicator, we summed all individual scores and divided by the number of respondents to obtain a mean; higher means indicate stronger digital literacy within the group.
5. **Formulation of Recommendations**
At this stage we drafted targeted program proposals to strengthen employees' digital competencies. The design was guided by the analysis results so that the actions address observed skill gaps, support adaptation to technological change, and encourage a culture of continuous learning. The recommendations are intended to help staff use current digital tools effectively while preparing for future developments.
 6. **Report Writing and Revision**
The final step was to assemble the research report by integrating findings and analyses from the preceding stages. We iteratively reviewed and edited the manuscript to improve clarity, accuracy, and coherence. This process ensured that the final document aligned with the study objectives, was accessible to the intended audience, and was ready for submission to relevant stakeholders.

4 RESULTS AND DISCUSSIONS

4.1 Instrument Validity and Reliability

The validity check encompassed all questionnaire items administered at every educational stage, ranging from kindergarten and early childhood programs to senior high and vocational schools. Using Pearson's correlation coefficient, all items achieved calculated R values higher than their respective R table thresholds, confirming that the instruments effectively measure the intended constructs of digital capability. This demonstrates that each question item is statistically valid and suitable for use in the assessment. Reliability testing was conducted through Cronbach's Alpha, with 0.700 set as the minimum acceptable coefficient. The results show that every educational level recorded values above this standard, ranging from 0.786 in primary schools to 0.894 in senior high/vocational schools. These results indicate a high level of internal consistency across the instrument, reinforcing its dependability for evaluating digital capability within the organization.

4.2 Digital Capability Conditions of Employees

The measurement results of employees' digital capabilities in organization XYZ, as illustrated in *Figure 1*, indicate that of the five competency levels assessed, four fall into the Good category (score ≥ 4.00) and one is in the Moderate category (3.00–3.99). This assessment involved a total of 824 respondents, representing 72% of the overall employee population across educational levels.

Level 1 (Basic Computer and Software Operation) achieved the highest average score at 4.45, followed by Level 2 (Information and Data Literacy) with 4.34, Level 4 (Digital Content Creation) with 4.20, and Level 3 (Communication and Collaboration) with 4.11—all within the Good range. Although Levels 3 and 4 meet the Good category threshold, several sub-competencies within these levels remain in the Moderate range, indicating uneven mastery across certain skills. Level 5 (Security and Privacy) recorded a score of 3.81, placing it in the Moderate category and highlighting the need to strengthen awareness and practices regarding data protection and privacy. Overall, *Figure*

I reflects that while core digital capabilities are generally satisfactory, targeted initiatives in security and privacy are essential to supporting the organization’s digital transformation objectives.

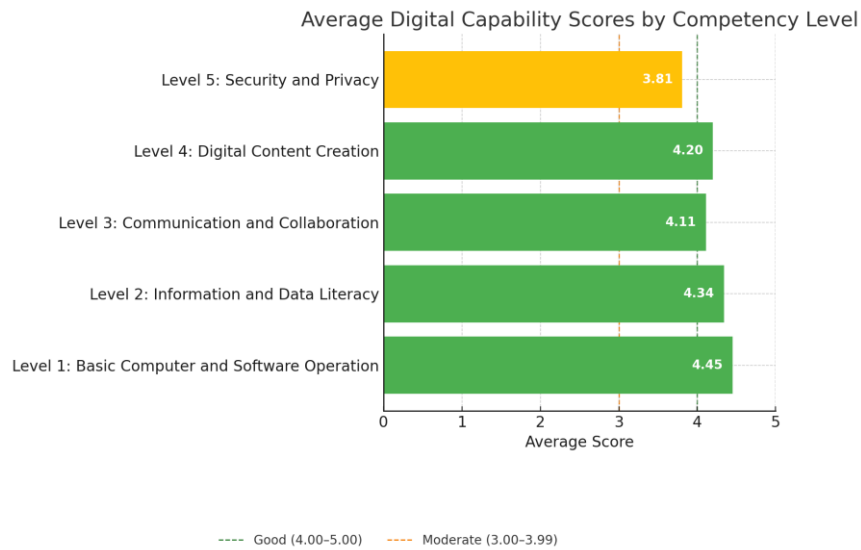


Figure 2. *Digital Capability Conditions of Employees Based on Five Competency Levels*

4.3 Average Digital Capability by Education Institution Levels

Figure 3 presents the average digital capability scores across four educational levels within organization XYZ, based on responses from 824 employees (72% of the total population). Primary school employees achieved the highest average score (4.34), closely followed by senior high/vocational school employees (4.32) and junior high school employees (4.27), all within the *Good* category (≥ 4.00). Kindergarten/early childhood education employees scored lower at 3.77, placing them in the *Moderate* category (3.00–3.99).

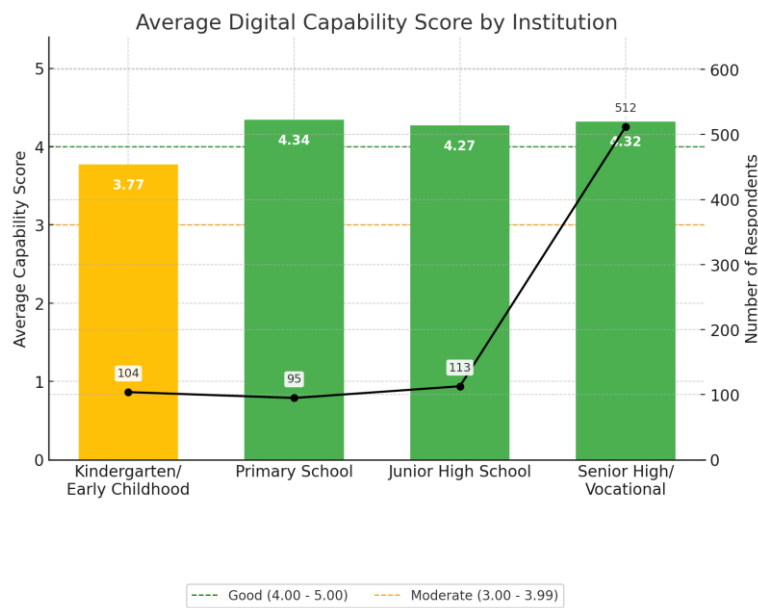


Figure 3. *Average Digital Capability and Respondent Distribution by Education Institution Levels*

The higher scores at the primary, junior high, and senior high/vocational levels suggest greater familiarity with digital tools, potentially due to more frequent integration of technology in daily work processes and job requirements. Conversely, the lower score in kindergarten/early childhood education may reflect limited exposure to advanced digital applications, as the teaching context and operational needs often prioritize face-to-face interaction and basic administrative tools over more complex digital systems. These variations highlight the need for differentiated digital capability development programs. Specifically, targeted training for kindergarten/early childhood staff could help bridge the gap, ensuring consistent competency levels across all educational stages. Addressing this disparity will support a more balanced and cohesive digital transformation across the organization's diverse institutions.

4.4 Detailed Digital Capability by Competency Level and Institution

The detailed breakdown of digital capability scores by competency level and institution, as shown in *Table 2*, reveals notable variations across educational levels in organization XYZ. In Level 1 (*Basic Computer and Software Operation*), all institutions perform in the *Good* category, with primary schools achieving the highest score (4.67), followed by junior high schools and senior high/vocational schools (both 4.54), and kindergarten/early childhood education at 4.05. For Level 2 (*Information and Data Literacy*), primary schools again lead with 4.51, closely followed by senior high/vocational schools (4.45) and junior high schools (4.44), while kindergarten/early childhood education scores 3.95 (*Moderate*).

In Level 3 (*Communication and Collaboration*), primary schools (4.24), junior high schools (4.26), and senior high/vocational schools (4.32) remain in the *Good* category, whereas kindergarten/early childhood education is at 3.62 (*Moderate*). A similar pattern appears in Level 4 (*Digital Content Creation*), with primary schools scoring 4.52, senior high/vocational schools 4.33, junior high schools 4.32, and kindergarten/early childhood education 3.62. Scores for Level 5 (*Security and Privacy*) are relatively lower across all institutions, ranging from 3.67 in kindergarten/early childhood education to 3.99 in senior high/vocational schools, placing them in the *Moderate* category. Overall, *Table 2* demonstrates that while core digital competencies (Levels 1–4) are well-developed across most institutions, there is a clear need for targeted improvement in security awareness and data protection where several institutions remain in *Moderate* or *Poor* categories.

Table 2. Digital Capability Scores by Competency Level and Institution

Competency Level	Kindergarten / Early Childhood Education (TK/PAUD)	Primary School (SD)	Junior High School (SMP)	Senior High / Vocational School (SMA/SMK)
Level 1: Basic Computer and Software Operation	4.05	4.67	4.54	4.54
Level 2: Information and Data Literacy	3.95	4.51	4.44	4.45
Level 3: Communication and Collaboration	3.62	4.24	4.26	4.32
Level 4: Digital Content Creation	3.62	4.52	4.32	4.33
Level 5: Security and Privacy	3.67	3.78	3.82	3.99

4.5 Milestone-Based Recommendations for Digital Capability Development

The milestone frameworks for each educational level in organization XYZ provide a strategic roadmap for progressively enhancing digital capabilities over a five-year period. *Figure 4 illustrates the milestone for kindergarten/early childhood (TK/PAUD), beginning with Building Foundation Skills in Year 1, progressing through Strengthening Foundation Skills in Year 2, and achieving Digital Creator status by Year 3. In Years 4 and 5, the focus shifts towards Initiating Digital Literacy for Competitive Advantage and fostering a Digital Mindset, which is essential for adapting to emerging technologies and preparing for advanced competencies.*

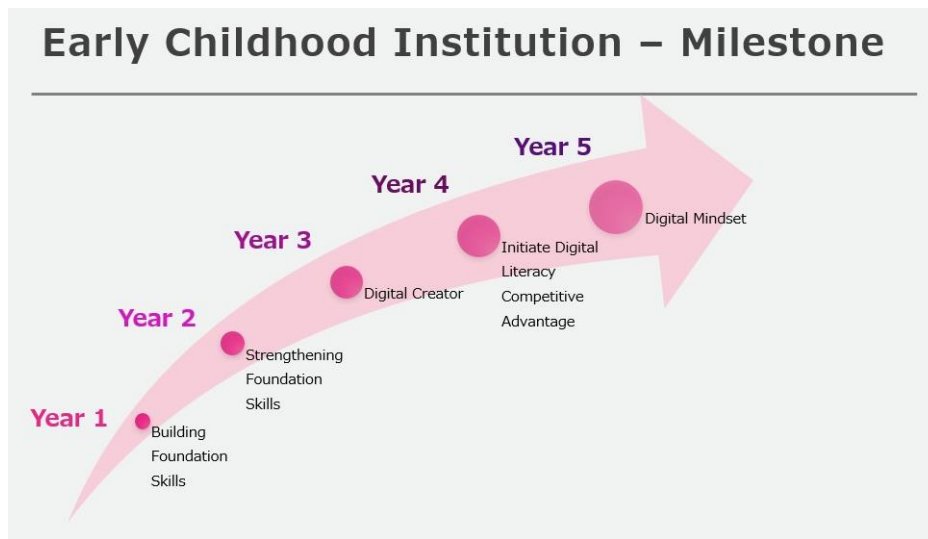


Figure 4. *Early Childhood Institution Digital Capability Milestone*

Similarly, *Figure 5 presents the milestone path for primary school, junior high school, and senior high/vocational institutions. Here, the journey starts with Strengthening the Basics in Year 1, moving to Specialization and Growth in Year 2, and advancing to Initiating Digital Literacy for Competitive Advantage by Year 3. By the fourth year, the emphasis shifts toward cultivating a strong digital mindset, setting the stage for attaining mastery and driving innovation in the fifth year. This planned progression is intended to equip the institution with a competitive advantage, allowing it to stand out and maintain relevance within the education sector.*

Drawing from these milestones, the development of digital capabilities should follow a structured, multi-stage plan aligned with the outlined framework. In early childhood education, emphasis needs to be placed on building essential operational competencies, followed by the gradual integration of creative and collaborative activities. At the primary, junior high, and senior high or vocational stages, development efforts should prioritize building deeper areas of specialization, encouraging a culture of innovative thinking, and strengthening the ability to solve complex problems within digital contexts. Each stage should be supported by clearly defined key performance indicators (KPIs) to facilitate systematic tracking and ensure that progress remains consistent with both short-term objectives and long-term strategic goals.

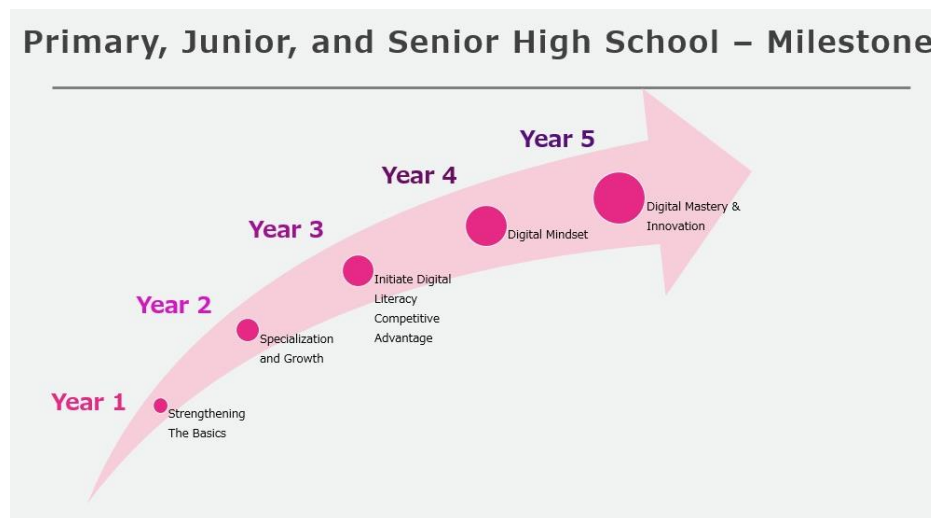


Figure 5. Primary, Junior, and Senior High School Digital Capability Milestone

5 CONCLUSIONS

The evaluation of employees' digital capabilities in organization XYZ shows that four of the five assessed competency levels are classified as Good, while one falls into the Moderate category. Foundational skills such as basic computer operations, information and data literacy, communication and collaboration, and digital content creation are generally well-developed across most educational levels. In contrast, competencies related to security and privacy show notable weaknesses. The gap is most evident in kindergarten/early childhood education, where the overall capability score is lower.

These findings indicate the need for a structured, phased development strategy that reflects the distinct needs of each educational level. For early childhood education, the primary focus should be on building a solid foundation in essential digital skills, followed by the gradual integration of creative and collaborative competencies. At the primary, junior high, and senior high/vocational levels, the emphasis should be on specialization, innovation, and advanced problem-solving, alongside the cultivation of a digital mindset.

The implementation of these recommendations should be guided by clearly defined key performance indicators for each milestone stage, as outlined in the proposed development roadmap. Continuous monitoring and evaluation will be essential to ensure that progress remains aligned with the organization's operational needs and long-term strategic vision. Strengthening weaker domains, particularly in technical management and security, will be critical to achieving a balanced and sustainable digital capability framework across all educational levels.

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Implementation of the Sugeno Fuzzy Algorithm for a Dynamic Scoring System in an Educational Game on Fraction and Decimal Operations

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Abstract

Technology in education provides opportunities for independent learning through diverse media, and educational games have emerged as powerful tools to enhance motivation and comprehension. However, traditional assessment in mathematics often relies on binary *right-or-wrong* evaluation, limiting fairness and overlooking students' learning processes. This study introduces an Android-based educational game on fraction and decimal operations that integrates the Sugeno Fuzzy Algorithm for dynamic scoring. Unlike previous applications that primarily used fuzzy logic for reward allocation, this approach incorporates three input variables correct answers, time, and remaining lives to generate a more holistic evaluation of student performance. The game was developed using the Game Development Life Cycle (GDLC) framework and tested with 24 sixth-grade students at SDN 17 Kuningan. Results show that the fuzzy-based scoring system was perceived as fairer by students and contributed to improved understanding of fraction and decimal operations. The broader contribution of this research lies in demonstrating how fuzzy logic can be embedded into educational games to support adaptive and equitable assessment. Limitations include the small sample size and the context-specific design of fuzzy rules, which call for further research with larger populations and more diverse subjects.

Keywords: Dynamic scoring, educational games, Sugeno Fuzzy Algorithm, fractions and decimals, adaptive assessment.

1 INTRODUCTION

The utilization of technology as a learning medium provides opportunities for students to engage in independent learning and access more diverse learning resources, thereby enhancing both their motivation and academic performance. Technological advancements have given rise to innovative and creative learning models within the educational process (Effendi & Wahidy, 2019). Among these, educational games are considered one of the most engaging tools, as they combine technological features with enjoyable learning methods. Educational games have been reported to improve students' motivation and learning outcomes by providing interactive and enjoyable learning experiences (Oktiviani et al., 2017) Furthermore, learning media allow students to participate more actively and independently, leading to better comprehension of subject matter (Nuraini, I., Sutarna, & Narimo, 2019). The integration of technology into educational games allows students to learn while playing, making the learning process more engaging and effective.

However, based on interviews with the homeroom teacher of class 6B at SDN 17 Kuningan, mathematics lessons are still predominantly delivered through lecture-based instruction, with textbooks serving as the primary learning media. Such limitations restrict both the delivery and comprehension of material, resulting in passive student engagement and reduced motivation to learn. This condition directly impacts students' understanding of mathematics and leads to suboptimal achievement, as reflected in the finding that only 37.5% of students achieved scores above the minimum competency standard (Adrillian et al., 2024). Moreover, assessments in mathematics are often limited to binary right-or-wrong evaluations, without considering other aspects of students' learning processes. These challenges contribute to students' perception of mathematics as a difficult and less appealing subject.

Dynamic assessment has been suggested as an alternative that can enhance critical thinking and more fairly reflect students' learning progress (Situngkir et al., 2023). In this context, several prior studies have utilized the Sugeno Fuzzy Algorithm within educational and serious games. For instance, Astriningrum, et al., (2017) developed the *Marine Ecosystem Hero* game using Sugeno Fuzzy to calculate scores based on time and points. While their approach demonstrated the algorithm's applicability, it was limited to a narrow set of input variables and did not capture broader learning performance. Similarly, Oktavia dan Maulidi (2019) applied Sugeno Fuzzy in the *Aku Bisa* game for early childhood sexual education, where rewards were determined using three inputs (score, lives, time). Although the design provided adaptive rewards, the scoring system remained reward-oriented rather than supporting cognitive assessment. More recently, Sanjaya et al., (2022) implemented Sugeno Fuzzy in a mobile platformer game to assign bonuses from inputs such as points and lives. Their focus was primarily on maintaining engagement, but the scoring mechanism did not integrate deeper educational objectives.

From these studies, it is evident that while Sugeno Fuzzy has been applied in educational and gamified contexts, most implementations remain limited to reward allocation and rely on a restricted set of variables. Few have explored its use in supporting dynamic scoring systems that comprehensively reflect students' performance across multiple dimensions of learning. Recent works in game-based learning emphasize the importance of adaptive assessment mechanisms that consider time, accuracy, and consistency to better support personalized learning. For instance, adaptive scaffolding in game-based learning has been shown to influence accuracy, completion time, and systematicity, illustrating how multiple performance metrics can be integrated into adaptive systems (Bolsinova et al., 2022). Similarly, adaptive gamified assessments adjust task difficulty based on knowledge rating derived from both accuracy and response time, enabling continuous personalization of learning scenarios (Papadimitriou et al., 2019). Moreover, systematic reviews of adaptive game-based learning demonstrate that personalized educational games those adjusting in real time to learner behavior can significantly enhance student motivation, engagement, and performance (S. Zhu et al., 2023). Yet, integration of such approaches in mathematics education, and particularly in topics such as fractions and decimals, remains under-explored.

Therefore, the present study addresses this gap by applying the Sugeno Fuzzy Algorithm for *dynamic scoring* in an Android-based educational game focused on fraction and decimal operations. Unlike prior works, this research integrates three input variables correct answers, time, and lives (hearts)—to generate a more holistic score that reflects both accuracy and learning process. The game is specifically designed for grade 6B students at SDN 17 Kuningan and aims to provide an alternative interactive medium that enhances students' motivation and comprehension of mathematical concepts. Beyond entertainment, the integration of dynamic scoring is expected to foster fairer assessment, improve learning engagement, and serve as a practical teaching aid for educators.

2 Literature Review

2.1 Educational Games

A game is generally defined as a structured form of play governed by specific rules that allow players to win or lose Gunawan et al., (2021). In educational contexts, games are designed not merely for entertainment but to integrate learning objectives with gameplay, creating interactive and enjoyable experiences. Prior research highlights that educational games can foster engagement and improve comprehension due to the integration of challenge, feedback, and active participation (Dony Novalindry, 2013). However, many early implementations of educational games emphasized entertainment value more than adaptive learning features, leading to limited impact on deeper cognitive outcomes (Hamari et al., 2016);(Friel et al., 2009). More recent studies stress the importance of adaptive mechanisms, such as dynamic feedback and personalized scoring, to enhance the educational effectiveness of game-based learning (S. Zhu et al., 2023). This study builds upon such findings by embedding a dynamic scoring system using the Sugeno Fuzzy Algorithm, aiming to move beyond static right-or-wrong evaluations and foster fairer, multidimensional assessment.

2.2 Sugeno Fuzzy Algorithm

The Sugeno Fuzzy Method was introduced by Takagi, Sugeno, and Kang in 1985 (Chast, 2002). *Sugeno Fuzzy is a fuzzy logic method that employs IF–THEN rules for decision-making. There are two main models of the Sugeno method, described as follows:*

a. Zero-order Sugeno Fuzzy Model

In general, the Zero-order Sugeno Fuzzy model is expressed as:

$$IF (x_1 \text{ is } A_1) \text{ AND } (x_2 \text{ is } A_2) \dots (x_n \text{ is } A_n) \text{ THEN } z = k \quad (1)$$

where x_i is the i -th fuzzy set as the antecedent, and k is a constant representing the consequent.

b. First-Order Sugeno Fuzzy Model

In general, the First-Order Sugeno Fuzzy model is expressed as:

$$IF (x_1 \text{ is } A_1) \text{ AND } (x_2 \text{ is } A_2) \dots (x_n \text{ is } A_n) \text{ THEN } z = p_1x_1 + p_2x_2 + \dots + p_nx_n + q \quad (2)$$

where A_i is the i -th fuzzy set as the antecedent, p_i is the i -th constant, and q is also a constant in the consequent.

2.3 Mathematics

Mathematics is one of the core subjects taught at all levels of education, from elementary school to higher education. It is a compulsory field of study. As stated by Farhana et al. (Farhana et al., 2022). "Mathematics is a deductive, axiomatic, formal, and abstract science that uses symbolic language. Therefore, it is crucial to introduce mathematics to children as early as elementary school." This importance stems from the fact that mathematics functions not only as a scientific discipline but also as a foundational tool for understanding various other fields of study.

2.4 Game Development Life Cycle (GDLC)

The Game Development Life Cycle (GDLC) is a game development process that follows an iterative approach consisting of six phases: concept initiation, pre-production, production, testing, beta, and release (Krisdiawan, 2018).

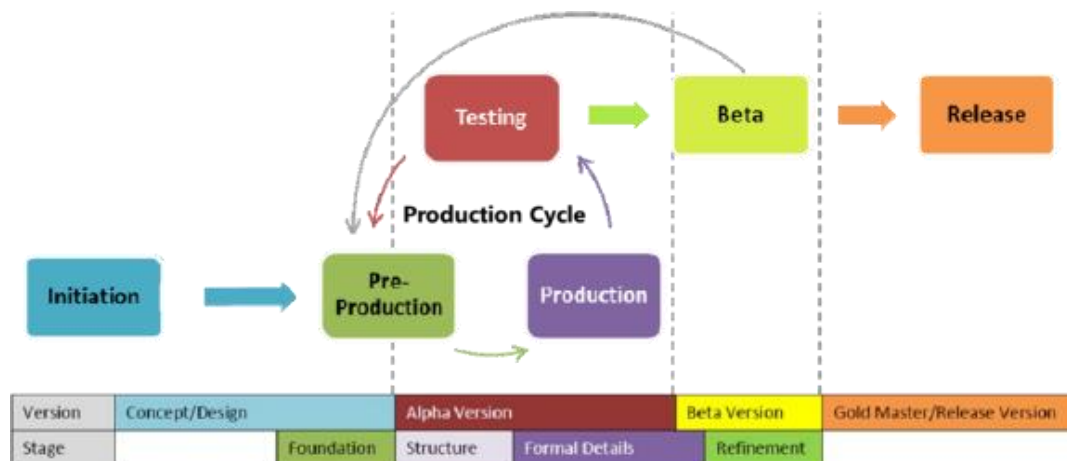


Figure 1. GDLC Stages

3 Research Methodology

The research method employed in this study for developing the mathematics educational game is based on the Game Development Life Cycle (GDLC) model. The problem-solving approach utilizes the Sugeno Fuzzy Algorithm, while the system design is carried out using the Unified Modeling Language (UML). The research object is class 6B of SDN 17 Kuningan, located at Jl. Siliwangi, Purwawinangun, Kuningan, Kabupaten Kuningan.

3.1 Data Collection Methods

a. Observation

The observation process was conducted by directly monitoring the teaching and learning activities in class 6B of SDN 17 Kuningan. In addition, the researchers administered a pre-test consisting of 10 questions and distributed questionnaires to 24 students in class 6B to identify learning difficulties faced by the students.

b. Interview

The interview process was conducted directly with the informant, Mr. Nunu Nugraha, S.Pd., the homeroom teacher of class 6B as well as the mathematics teacher for the class. This interview provided information regarding the learning process, the teaching media used, and the challenges encountered during lessons.

c. Literature Study

A literature review was conducted by reading and analyzing various references relevant to the research topic from different types of scientific publications, textbooks, journal articles, and other credible sources related to the study, such as those discussing the Sugeno Fuzzy Algorithm, GDLC, and game development.

3.2 Problem-Solving Method

The Sugeno Fuzzy Algorithm was implemented to enable dynamic scoring within the game. The Sugeno Fuzzy Method was first introduced by Takagi, Sugeno, and Kang in 1985 (Chast, 2002). It is a fuzzy logic method that uses IF–THEN rules for decision-making. In this study, the Sugeno Fuzzy Algorithm is applied to dynamic assessment within the game by considering multiple performance indicators in the scoring process.

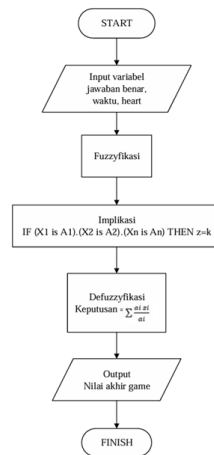


Figure 2. Flowchart of the Sugeno Fuzzy Algorithm used in this study

1. Input Variable : In this study, three determining input variables are used: correct answers, time, and heart. Additionally, one output variable is used, namely the score.
2. Linguistic Values
 - a. Linguistic values for the *correct answers* variable: **low, medium, high**.
 - b. Linguistic values for the *time* variable: **slow, moderate, fast**.
 - c. Linguistic values for the *heart* variable: **few, moderate, many**.
 - d. Linguistic values for the *score* output variable: **A, B, C**.
3. **Fuzzy Rules and Membership Functions**
 The rules were constructed in collaboration with the mathematics teacher to reflect realistic evaluation criteria. For example:
 - IF correct answers are *high* AND time is *fast* AND heart is *many* THEN score = *A*.
 - IF correct answers are *medium* AND time is *moderate* AND heart is *few* THEN score = *B*.
 - IF correct answers are *low* AND time is *slow* AND heart is *few* THEN score = *C*.
 Membership functions for each variable (correct answers, time, heart) were designed using **trapezoidal and triangular functions** due to their simplicity and suitability for representing linguistic values.
4. Fuzzification
 Fuzzification is the initial stage in the fuzzy logic process, in which crisp sets are transformed into fuzzy sets with continuous membership values [4].
 - a. Fuzzy set for correct answers
 Figure 3 illustrates the membership function for the correct answers variable:

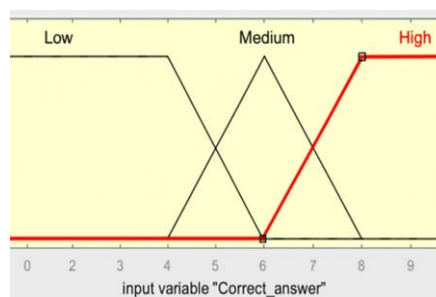


Figure 3. Membership function of correct answer

$$\text{Less : Trapezoid: } \mu(x) = \begin{cases} 1; & x \leq 4 \\ \frac{6-x}{6-4}; & 4 < x \leq 6 \\ 0; & x \geq 6 \end{cases} \quad (3)$$

$$\text{Medium : Triangle : } \mu(x) = \begin{cases} 0; & x \leq 4 \text{ atau } x > 8 \\ \frac{x-4}{6-4}; & 4 < x \leq 6 \\ \frac{8-x}{8-6}; & 6 < x \leq 8 \\ 1; & x = 6 \end{cases} \quad (4)$$

$$\text{Many : Trapeziums : } \mu(x) = \begin{cases} 0; & x \leq 6 \\ \frac{x-6}{8-6}; & 6 < x \leq 8 \\ 1; & x \geq 8 \end{cases} \quad (5)$$

b. Time Fuzzy Set

Figure 4 below is the membership function of the Time variable:

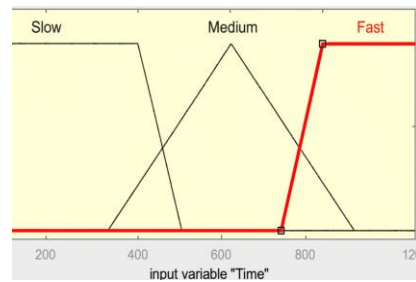


Figure 4 Time membership function

$$\text{Slow : Trapezoid : } \mu(x) = \begin{cases} 1; & x \leq 400 \\ \frac{500-x}{500-400}; & 400 < x \leq 500 \\ 0; & x \geq 500 \end{cases} \quad (6)$$

$$\text{Medium : Triangle : } \mu(x) = \begin{cases} 0; & x \leq 400 \text{ atau } x \geq 1000 \\ \frac{x-400}{700-400}; & 400 < x \leq 700 \\ \frac{1000-x}{1000-700}; & 700 < x \leq 1000 \\ 1; & x = 700 \end{cases} \quad (7)$$

$$\text{Fast : Trapezoid : } \mu(x) = \begin{cases} 0; & x \leq 900 \\ \frac{x-900}{1000-900}; & 900 \leq x \leq 1000 \\ 1; & x \geq 1000 \end{cases} \quad (8)$$

c. Fuzzy Heart Set

Figure 5 below is the membership function of the Heart variable:

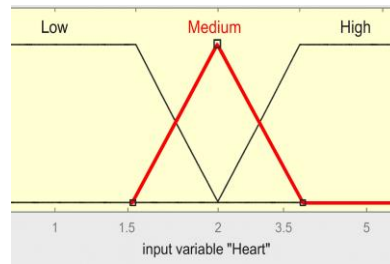


Figure 5 Heart membership function

$$Little : Trapezoid: \mu(x) = \begin{cases} 1; & x \leq 2 \\ \frac{3-x}{3-2}; & 2 < x \leq 3 \\ 0; & x \geq 3 \end{cases} \quad (9)$$

$$Medium : Triangle: \mu(x) = \begin{cases} 0; & x \leq 2 \text{ atau } x \geq 4 \\ \frac{x-2}{3-2}; & 2 < x \leq 3 \\ \frac{4-x}{4-3}; & 3 < x \leq 4 \\ 1; & x = 3 \end{cases} \quad (10)$$

$$Many : Trapeziums : \mu(x) = \begin{cases} 0; & x \leq 3 \\ \frac{x-3}{4-3}; & 3 \leq x \leq 4 \\ 1; & x \geq 4 \end{cases} \quad (11)$$

5. Defuzzification

In the Sugeno method, the defuzzification process is carried out using the Average method with the following formula.:

$$Z^* = \frac{\sum a_i z_i}{\sum a_i} \quad (12)$$

3.3 System Development Methods

The system development method used in this research is the Game Development Life Cycle (GDLC) method. GDLC consists of 6 stages, namely:(Krisdiawan, 2018)

- a. Initialization
 At this stage, the researcher collected data through observations, interviews, questionnaires, and pretests with students. Afterward, the researcher determined the game concept to suit user needs.
- b. Pre-Production
 At this stage, the researcher revised the game design and created a game prototype. Pre-production ended when the revisions or changes to the game design were approved and documented in the GDD.
- c. Production
 At the production stage, the researcher created assets using Adobe Illustrator, wrote program code using C# and PHP, and developed the game using Unity.
- d. Testing
 At this stage, the researcher tested the game's functions. The researcher conducted black-box and white-box testing of the game. The results would determine whether it was time to advance to the next phase (Beta) or repeat the production cycle.

- e. Beta
Beta is the phase for conducting third-party or external testing, known as beta testing. The author conducted testing using User Acceptance Tests (UAT) with students and homeroom teachers of Grade 6B SDN 17 Kuningan.
- f. Release
At this stage, the game has been successfully developed and has completed alpha and beta testing. At this stage, the game is ready for use by students.

4 RESULT AND DISCUSSION

4.1 Game Design Document (GDD)

1. Game Layout Chart

The image shows the flow structure of the game in a game layout chart that depicts the overall navigation from the beginning to the end of the game. Figure 6 below is the game layout chart for this game.

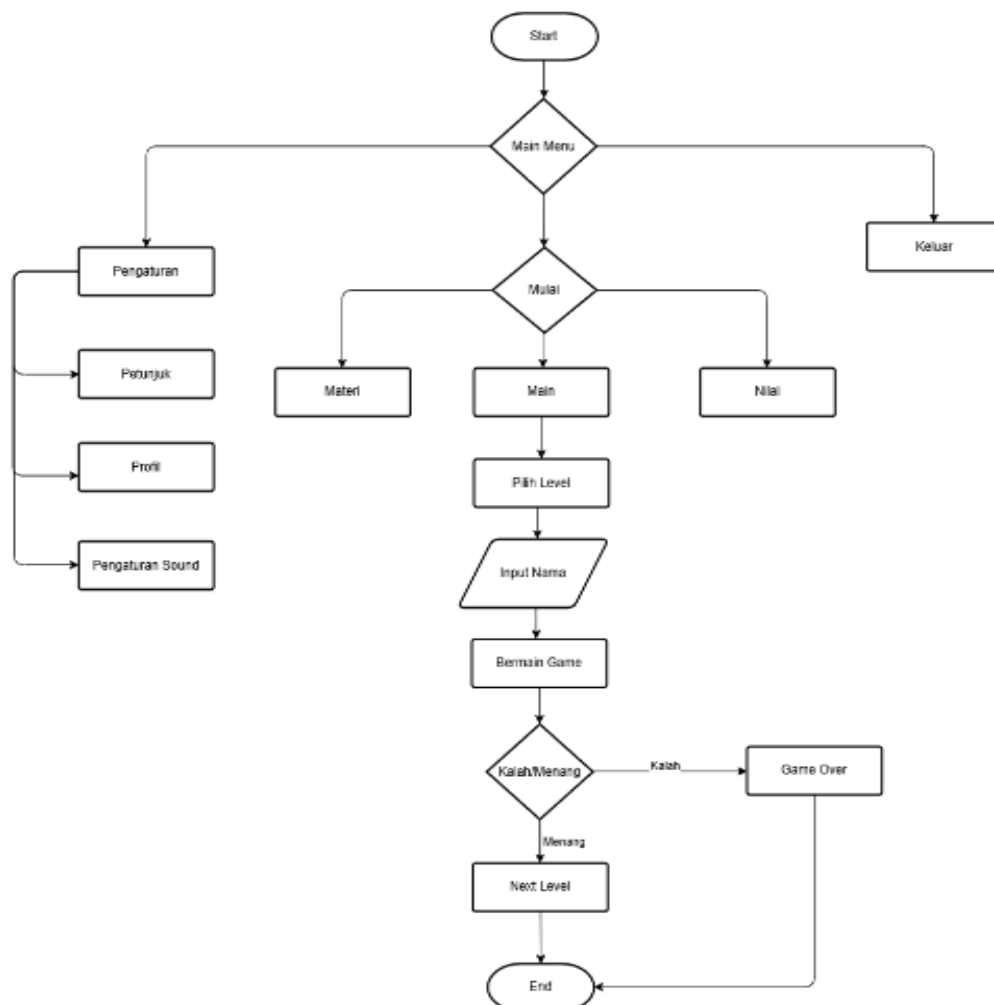

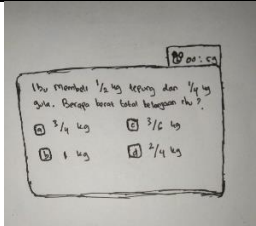


Figure 6. Game layout chart

2. Storyboard

Table 1. Storyboard

No	Scene game	Information
1.		Level 1 is set in summer. The interface features controls for moving left and right, jumping, and sliding. Players must avoid enemies and cliffs to avoid losing lives. Additionally, 10 paper scrolls appear throughout the adventure, displaying random fraction operation problems, which players must answer correctly to avoid losing lives. At the end, a finish board indicates successful completion and displays a panel containing the game's results.
2.		The question panel will appear when the player touches the rolled paper object. The questions displayed are random. The question panel consists of the question text, buttons a, b, c, d, and a timer.

4.2 Unified Modelling Language (UML)

Figure 7.(a) below is a use case of the educational game that was created, which involves 2 actors, namely students and teachers, while Figure 7.(b) is a class diagram of the educational game that was created.

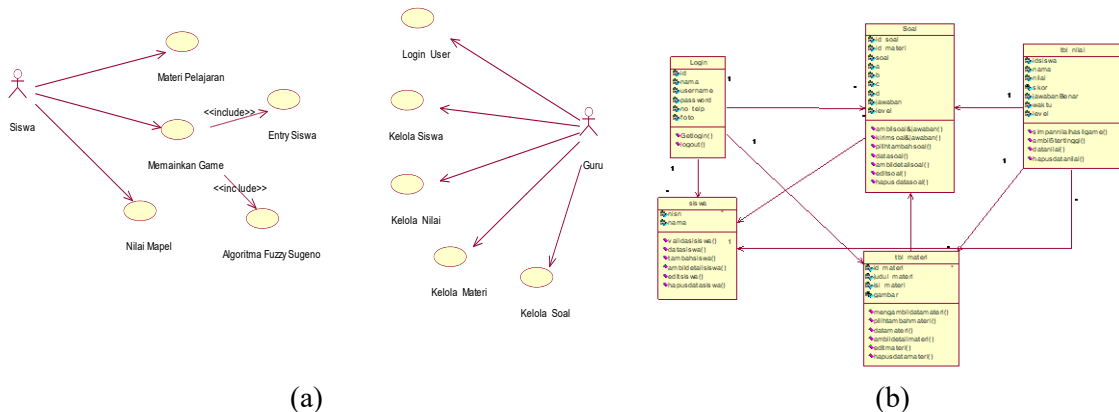


Figure 7. (a) Use case diagram; (b) Class diagram

Figure 8.(a) below illustrates the flow of activities carried out by the actor (student) when playing the game depicted in the activity diagram. Figure 8.(b) below is a sequence diagram of playing the game that illustrates the flow of communication between the main objects in the system during the actor's interaction process with the game.

4.3 Interface Game

1. Main Menu and Menu Interface

Figure 9.(a) is the initial page that will appear when the player enters the application. Meanwhile, Figure 9.(b) is the page that appears when the player selects the start menu on the main menu page.

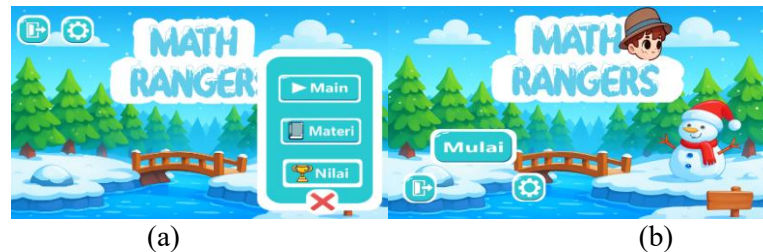


Figure 9. (a) Menu interface; Menu interface (b)

2. Game Play Interface & Question Display

Figure 10.(a) is the game play page, this page appears when the player selects the main menu and selects a level and then enters a name. Then Figure 10.(b) is the question display page, this page appears when the player touches the game question object while playing the game.

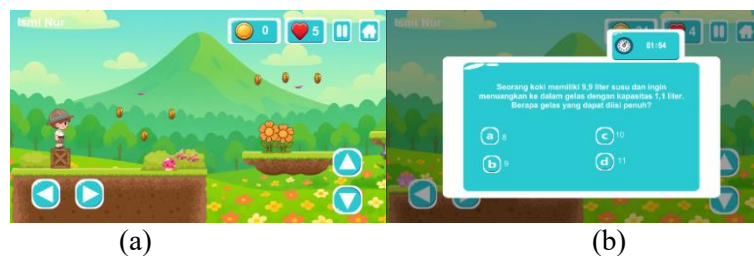


Figure 10. (a) Main game interface; (b) Question display interface

3. Score and Value Results Interface

Figure 11.(a) is the score results page that appears when a player successfully completes the game and reaches the finish line. Figure 11.(b) is the score page, which displays the five highest scores from all students. This page appears when a player selects the score menu on the menu page.

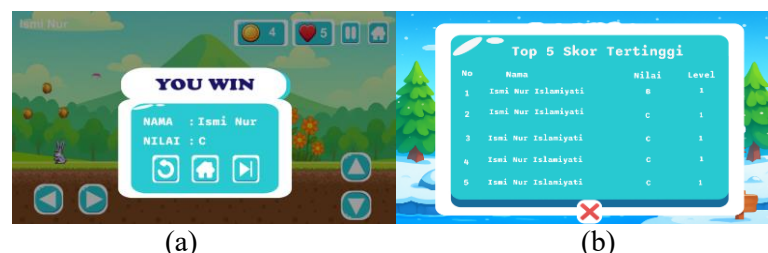


Figure 11. (a) Score result interface; (b) Value interface

4. Material Interface & Teacher Dashboard

Figure 12.a is the page that appears when a player selects the material menu on the menu page. Figure 12.b, on the other hand, shows the teacher dashboard; this page is not in-game and can only be accessed by teachers.

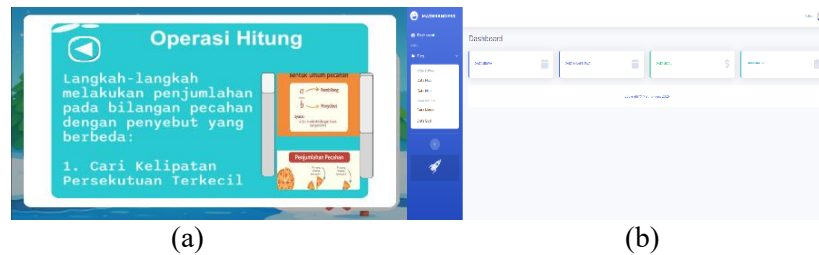


Figure 12. Material interface and teacher dashboard interface

4.4 Blackbox Testing

The results of blackbox testing (Table 2) confirm that all core features of the game functioned as designed. This indicates that the system architecture developed using GDLC and UML diagrams was successfully implemented without major technical errors. Likewise, whitebox testing confirmed that the internal logic of the fuzzy membership functions operated according to specification. These findings provide assurance that the algorithmic implementation of the Sugeno Fuzzy method was technically sound, allowing us to focus the analysis on its pedagogical impact.

Table 2. Blackbox testing

Button Function	Testing Scenarios	Expected Results	Result
Begin	Player presses the Start button	The system displays the game menu page	Valid
Material	Player presses Material button	The system displays the material list page	Valid
Main	Player presses Play button	The system displays the select level page	Valid
Finish	Players touch the finish	The system calculates the value and displays the score results page	Valid
Value	Player presses the value button	The system displays the highest 5 rated pages	Valid
Setting	Player presses the settings button	The system displays the game settings page	Valid

From the tests that have been carried out, it was found that all the functionality of the features in the game are running according to the initial design.

4.5 Whitebox Testing

White box testing is a test that is carried out by looking into the modules and codes in the application. (Krisdiawan, 2018). *Whitebox testing is performed to ensure that the program's logic flows according to the structure and conditions specified in the code. The following is an example of source code used in whitebox testing:*

1. `public float[] GetjawabanBenar(float jawabanbenar){`
2. `if (jawabanbenar <= 4) {`
3. `jawabanBenarkurang = 1;}`
4. `else if (jawabanbenar > 4 && jawabanbenar <= 6){`
5. `jawabanBenarkurang = (6 - jawabanbenar) / (6 - 4); }`
6. `else if (jawabanbenar >= 6){`

```

7. jawabanBenarkurang = 0;}
8. if (jawabanbenar > 4 && jawabanbenar <= 6){
9. jawabanBenarsedang = (jawabanbenar - 4) / (6 - 4)}
10. else if (jawabanbenar > 6 && jawabanbenar <= 8){
11. jawabanBenarsedang = (8 - jawabanbenar) / (8 - 6);}
12. else if (jawabanbenar == 6){
13. jawabanBenarsedang = 1; }
14. else{
15. jawabanBenarsedang = 0;}
16. if (jawabanbenar > 6 && jawabanbenar <= 8){
17. jawabanBenarbanyak = (jawabanbenar - 6) / (8 - 6);}
18. else if (jawabanbenar > 8){
19. jawabanBenarbanyak = 1;}
20. else{
21. jawabanBenarbanyak = 0;}
22. return new float[] { jawabanBenarkurang, jawabanBenarsedang, jawabanBenarbanyak };

```

Based on the code example above, the following calculations are obtained:

$V(G)$ = cyclomatic complexity

E = Total number of edges

N = Total number of nodes

$V(G) = E - N + 2$

$V(G) 33 - 25 + 2 = 10$

4.6 User Acceptance Test (UAT)

To find out the respondents' responses to the mathematics educational game that had been made, a test was carried out on 24 students. The assessment uses the Likert scale which consists of five answer choices, namely Strongly Agree is given a weight of 5, Agree is given a weight of 4, Neutral is given a weight of 3, Disagree is given a weight of 2, and Strongly Disagree is given a weight of 1.

Table 4. UAT Results

No	Question	Answer					Result
		Strongly agree x_5	Agree x_4	Neutral x_3	Disagree x_2	Strongly Disagree x_1	
1.	This educational game is easy to use	70	28	9	0	0	107
2.	The menus and buttons in this game are clear and easy to use	55	40	9	0	0	104
3.	This educational game is interesting and makes you more motivated to learn	85	8	15	0	0	108
4.	The questions and materials in this game are the same as the teachers teach in class	70	32	6	0	0	108

No	Question	Answer					Result
		Strongly agree x_5	Agree x_4	Neutral x_3	Disagree x_2	Strongly Disagree x_1	
5.	This educational game can help you understand the basic operation of fractions and decimals	85	4	3	0	0	92
6.	This educational game can be used as an alternative learning medium in schools	95	16	3	0	0	114
7.	The final game score is in accordance with how you play and answer questions	110	4	3	0	0	117
Total							750

From 3 teacher respondents and 24 student respondents, the total weight was obtained: 750. The expected score or maximum score is as follows: Students: $24 \times 7 \times 5 = 840$, Then the percentage value is as follows :

$$\text{Percentage of Eligibility (\%)} = \frac{(\text{Corps of test results})}{(\text{Expected score})} \times 100\%$$

$$\text{Percentage of Eligibility (\%)} = \frac{750}{840} \times 100\%$$

$$\text{Percentage of Eligibility (\%)} = 89,28\%$$

The User Acceptance Test yielded an average feasibility score of **89.28%**, suggesting that students and teachers perceived the game as both engaging and suitable as a learning tool. As shown in Table 4, the highest agreement (117 total score) was on the item *“The final game score is in accordance with how you play and answer questions.”* This result is particularly significant, as it demonstrates that students perceived the **fuzzy-based scoring system** as fair and reflective of their performance. Unlike traditional binary scoring, the fuzzy system incorporated accuracy, response time, and remaining lives, allowing for a more nuanced evaluation.

This multidimensional approach reduced frustration among students who answered correctly but took slightly longer or lost lives. For instance, students who showed persistence despite mistakes could still achieve an intermediate score (B), rather than being penalized with a low score (C). Such fairness is aligned with the principles of **dynamic assessment** (Situngkir et al., 2023), which emphasizes evaluating learning processes rather than just outcomes.

4.7 Pre-Test and Post-Test Testing

This Pre-test and Post-Test test is carried out to measure the level of students' understanding of fractional and decimal operation materials before and after using this educational game. This pre-test and post-test were carried out to 24 students in grade 6b of SDN 17 Kuningan which consisted of 10 essay questions which were done within 20 minutes using the same questions, the results of this test can be seen in Figure 13.

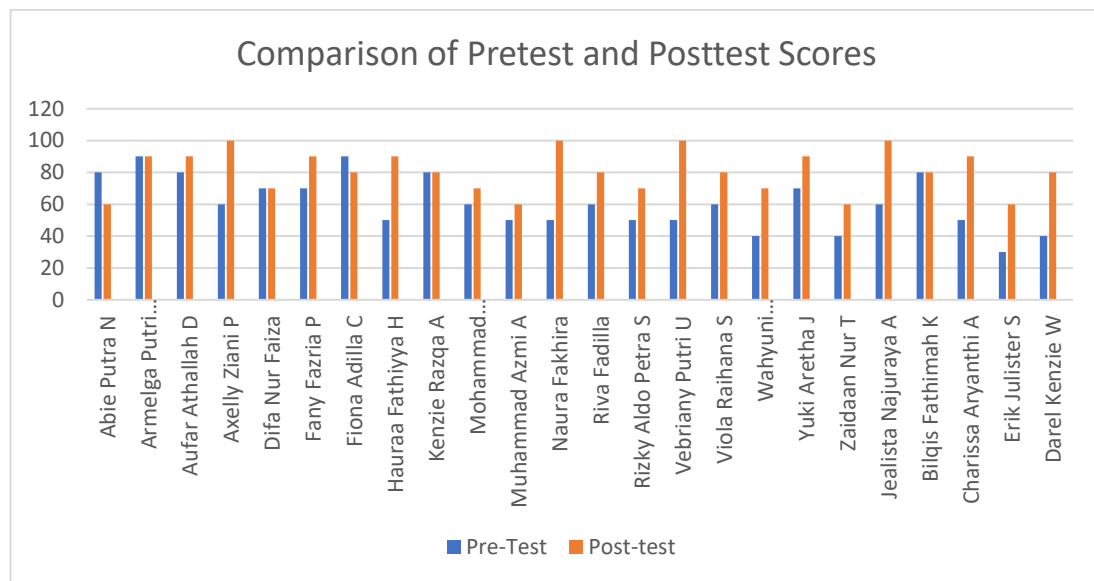


Figure 13. Comparison of pre-test and post-test

The pre-test and post-test comparison (Figure 13) shows a **20% increase in students' average scores** after playing the game. This improvement suggests that integrating mathematics exercises into game-based scenarios enhanced understanding of fractions and decimals. Importantly, the fuzzy scoring mechanism contributed to this outcome by maintaining motivation: students reported higher willingness to reattempt problems knowing that partial effort (time and persistence) was also valued in their final score. This reflects findings from prior studies that adaptive scoring can sustain engagement and promote deeper learning (Bolsinova et al., 2022; Z. Zhu & Zhu, 2022).

5 CONCLUSION

This study demonstrates that integrating the Sugeno Fuzzy Algorithm into an Android-based educational game provides an effective approach for implementing dynamic scoring in mathematics learning, particularly on fractions and decimals. Beyond its technical success, the game highlights the pedagogical potential of fuzzy-based assessment to deliver fairer evaluations by considering accuracy, time efficiency, and consistency. This multidimensional scoring approach represents a meaningful shift from conventional binary assessments, offering learners feedback that values both outcomes and processes.

The broader implication of this research lies in its contribution to the field of **adaptive game-based learning**, where assessment is increasingly recognized not only as a measure of achievement but also as a tool to sustain motivation and enhance learning engagement. For educators, the developed game provides a practical model of how fuzzy logic can be embedded in classroom practice as an alternative formative assessment tool.

Nevertheless, the study is not without limitations. The relatively small sample size (24 students in a single school) restricts the generalizability of the findings. In addition, the fuzzy rules and membership functions were designed with teacher input, which, while contextually valid, may limit transferability to broader populations. External factors such as teacher support and the novelty of digital games may also have influenced the results.

Future research should expand testing to larger and more diverse samples, explore the integration of data-driven tuning techniques such as **Adaptive Neuro-Fuzzy Inference System (ANFIS)** to refine scoring rules, and apply the model to other mathematical topics or subject areas. Comparative studies with other adaptive scoring approaches, such as Mamdani or machine learning-

based assessment, would further strengthen the evidence base for dynamic scoring in educational games.

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Enhancing English Vocabulary Learning with Fisher-Yates Shuffle Algorithm

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Abstract

The limited penetration of educational games compared to other genres highlights the need for more engaging digital learning tools, particularly for English as a Foreign Language (EFL) learning at the elementary level. This study developed an Android-based educational game that applies the Fisher-Yates Shuffle algorithm to support vocabulary and phrase mastery among Grade III students. The algorithm was employed to generate fair, unpredictable, and varied challenges by randomizing letters and words while integrating distractor elements to increase cognitive demand. The development process followed the Game Development Life Cycle (GDLC) framework, and the game was tested with 47 students at SDN 2 Pamulihan, Indonesia. Evaluation included a User Acceptance Test (UAT) and pre-post comprehension tests. Results showed high feasibility, with an overall acceptance rate of 86.06%. Moreover, significant learning gains were observed: vocabulary scores improved by 33%, phrase construction by 51.5%, and overall comprehension by 40.8%. These findings demonstrate that algorithmic randomization combined with gamification and contextualized materials enhances motivation and language acquisition. The study contributes by linking algorithm-driven fairness to measurable educational outcomes, offering evidence that adaptive educational games can complement classroom instruction in EFL learning.

Keywords: Educational game, Fisher-Yates Shuffle, English vocabulary, gamification, EFL learning.

1 INTRODUCTION

Educational games remain underrepresented in comparison to other mobile game genres on app distribution platforms. For instance, according to (Nauval et al., 2022a), educational games on Google Play total only 28,693 titles, while arcade, puzzle, and casual genres each surpass 50,000 titles. This disparity suggests that the educational game genre has not been fully leveraged, despite its potential to transform learning experiences, particularly in domains such as English vocabulary and phrase mastery for elementary school students.

Although vocabulary (and phrase) acquisition is central to language learning as it supports reading, listening, speaking, and writing (Baiq Siti Humaeratul Azizah et al., 2024) many classrooms still rely on conventional learning media, such as textbooks and workbooks, which offer limited interactivity and repetitive exercises (Anisa & Mega Febriani S, 2022). Existing digital tools or language-learning apps frequently reuse fixed question banks or rely on rote drills, leading to predictable patterns that can reduce student engagement and hinder long-term retention. In many such tools, the sequencing or ordering of vocabulary items is static or pseudo-random, which may allow learners to anticipate patterns and memorize positions rather than truly internalizing the language content.

At SD Negeri 2 Pamulihan, Cipicung District, Kuningan Regency, English is taught from grades I to VI, covering basic vocabulary, phrase construction, and simple sentence structures. However, based on observations and interviews with the English teacher (Ono Sudarsono, M.Pd.), Grade III students still struggle with converting scrambled letters into words and arranged words into meaningful phrases. These difficulties indicate that the existing media (textbook, handouts) fail to provide sufficient variation, repetition, and adaptive challenge to sustain learning.

Given these limitations, an interactive and engaging medium is needed one that prevents repetition, maintains fairness, and adapts challenge to the learner. In this work, we propose an Android-based educational game to assist students in arranging vocabulary and phrases in a fun, gamified environment. To generate non-repetitive, fair, and unpredictable challenge sequences, the game leverages the Fisher-Yates Shuffle algorithm, a widely used method for unbiased shuffling with time efficiency. By randomizing the positions of letters and words each time, the game reduces (Mery, 2024; Saokani et al., 2023) the chance that students memorize fixed patterns and encourage genuine problem solving.

Prior research has applied Fisher-Yates Shuffle in educational games in diverse contexts. For instance, (Krisdiawan & Ramdhany, 2018) used this algorithm in a mobile game for animal recognition in elementary contexts. (Pratama et al., 2024) applied it in their Things Bedroom game, reporting that 94% of users passed UAT testing. These precedents validate the technical feasibility of algorithmic shuffling in educational media, but they often stop short of rigorous pedagogical evaluation (e.g. using pre–post tests or field trials with EFL learners).

Meanwhile, many language learning apps or digital tools do not incorporate truly randomized ordering of stimuli or adaptive mechanisms. This limitation reduces their ability to maintain engagement or to prevent learners from overfitting to patterns. Thus, a gap remains: very few studies combine algorithmic randomness (via Fisher-Yates Shuffle) with empirical evaluation (pre–post tests, UAT) in the context of English vocabulary and phrase learning for elementary students.

To bridge that gap, this study is guided by the following objectives and research questions / hypotheses:

1. Objectives:
 - a. Develop an Android-based educational game that supports students in interactively arranging English vocabulary and phrases.
 - b. Enhance learner engagement and comprehension through an immersive, playful experience.
 - c. Apply Fisher-Yates Shuffle to randomize letters and words, producing varied and unpredictable challenges that promote deeper understanding.
2. Research Questions / Hypotheses:

RQ1: Does using an educational game with Fisher-Yates-based randomization lead to a statistically significant improvement in students' vocabulary and phrase comprehension (pre-test vs post-test)?

RQ2: Is the Android game media rated as acceptable and usable (via UAT) by the students, in terms of interface, usability, content, and learning experience?

H1: Students who use the Fisher-Yates Shuffle-powered game will show greater gain scores in vocabulary and phrase tests than what is predicted by traditional methods.

H2: The game will achieve an acceptability rating of $\geq 80\%$ in UAT (considered very feasible for classroom use).

This study is expected to make both a technical contribution (demonstrating how Fisher-Yates Shuffle can be integrated with distractor logic in language games) and a pedagogical advance (evidence of learning gain in real classroom context). Practically, the game can serve as a motivating tool for students and as a dynamic evaluative alternative for teachers, aligning with curriculum needs in SD-level English education.

2 LITERATURE REVIEW

To situate this research within existing scholarship, several studies on educational games and the implementation of the Fisher-Yates Shuffle algorithm are compared. The following table presents a summary of prior works, their methods, findings, and limitations.

Table 1. Comparison of Previous Studies on Educational Games Using Fisher-Yates Shuffle

<i>Author & Year</i>	<i>Context & Method</i>	<i>Findings</i>	<i>Limitations</i>	<i>Gap Addressed by This Study</i>
Ramadhan (2022) (Ramadhan, 2022)	Developed hijaiyah letter game with Fisher-Yates Shuffle; evaluated usability.	Increased game variation and user motivation.	Focused only on religious content; no empirical test of learning outcomes.	Extends algorithm application to English learning and measures pre-post learning gains.
Nauval et al. (2022) (Nauval et al., 2022b)	Android-based game for cultural learning; Unity engine.	Increased motivation and engagement.	Randomization relied on pseudo-random logic; evaluation limited to engagement.	Uses Fisher-Yates Shuffle for unbiased randomization and evaluates comprehension gains.
Mery (2024) (Mery, 2024)	Web-based educational game using Fisher-Yates Shuffle.	Demonstrated fairness and efficiency of algorithm.	Focused only on technical performance; no pedagogical evaluation.	Links algorithmic fairness to cognitive engagement in language learning.
Saokani et al. (2023) (Saokani et al., 2023)	Compared Fisher-Yates vs Linear Congruent in Nahwu learning media.	Fisher-Yates produced fairer randomization.	Evaluation was purely algorithmic; no user learning measurement.	Combines algorithm validation with empirical classroom testing.
Azizah et al. (2024) (Baiq Siti Humaeratul Azizah et al., 2024)	Meta-analysis of gamified tools (Wordwall, scramble, crossword).	Gamification improves vocabulary acquisition.	Tools relied on static content; lacked dynamic randomization.	Introduces algorithm-driven variety to sustain engagement.
Pratama, Krisdiawan, & Yulyanto (2024) (Pratama et al., 2024)	Developed "Things Bedroom" game with Fisher-Yates Shuffle; UAT tested.	Achieved 94% user acceptance.	Did not measure learning improvement, only usability.	Evaluates both usability and learning outcomes simultaneously.
Krisdiawan & Ramdhany (2018) (Krisdiawan & Ramdhany, 2018)	Animal recognition game with Fisher-Yates Shuffle.	Demonstrated algorithm's applicability to educational games.	Evaluation descriptive; no rigorous testing.	Advances to structured GDLC methodology with pre-post empirical validation.

From table 1, several critical points emerge:

1. **Scope Limitation** Most prior works applied Fisher-Yates Shuffle to **narrow domains** (e.g., hijaiyah letters, cultural learning, object recognition), whereas English vocabulary and phrase learning essential for early foreign language acquisition remains underexplored.
2. **Evaluation Limitation** Many studies emphasized **usability** e.g., UAT ratings in (Pratama et al., 2024) or **technical fairness** (Mery, 2024; Saokani et al., 2023), but rarely measured **learning gains** through pre–post testing, leaving uncertain the real educational effectiveness.
3. **Algorithmic Novelty** While Fisher-Yates Shuffle has been shown to produce unbiased randomization, previous works did not explicitly link this property to **pedagogical impact**, such as preventing rote memorization and sustaining cognitive engagement.
4. **Methodological Rigor** Prior studies often lacked structured development frameworks, focusing on ad hoc implementations. Few works adopted comprehensive methodologies such as the **Game Development Life Cycle (GDLC)**, which ensures systematic design, testing, and release.

Given these limitations, the present study contributes by:

1. Targeting **English vocabulary and phrase mastery** at the elementary level, a domain critical for foundational language acquisition.
2. Combining **algorithmic fairness (Fisher-Yates Shuffle)** with **structured design (GDLC)**.
3. Conducting both **UAT** and **pre–post testing**, ensuring evaluation covers usability and measurable learning gains.
4. Providing empirical evidence that algorithmic randomization not only improves fairness but also enhances learner engagement and comprehension.

Thus, this research fills an important gap by integrating **technical innovation** with **pedagogical validation**, offering a model for future educational game development that balances usability, fairness, and learning effectiveness.

3 RESEARCH METHODS

3.1 Data Collection Method

The study employed four data collection techniques to ensure triangulation and reliability of findings:

1. **Literature Study** – A comprehensive review of books, journals, and articles related to the Fisher-Yates Shuffle algorithm, Android-based educational games, and vocabulary/phrase learning strategies was conducted to establish a theoretical foundation.
2. **Observation** – Classroom observations at *SDN 2 Pamulihan* documented the teaching practices and learning difficulties faced by Grade III students in vocabulary and phrase construction.
3. **Interview** – Semi-structured interviews with the English teacher (*Ono Sudarsono, M.Pd.*) were conducted to gain insights into existing instructional methods, challenges, and expectations for supplementary media.
4. **Questionnaires and Tests** – The research applied **pre-tests and post-tests** to measure vocabulary and phrase comprehension before and after game use. Additionally, a **User Acceptance Test (UAT)** questionnaire evaluated usability, interface, and learning experience. The participants were 47 Grade III students.

3.2 Instrument Validity and Reliability

1. **Content validity** was established by involving two language experts and one instructional technology expert to review the test items and questionnaires.
2. **Reliability** was verified using Cronbach's Alpha on the UAT questionnaire ($\alpha \geq 0.80$, indicating high reliability).

3. The pre-test and post-test items were piloted in a parallel class, achieving item difficulty within acceptable ranges (0.30–0.70) and discrimination indices above 0.25.

3.3 System Development Methods

The development model used is the **Game Development Life Cycle (GDLC)**, which includes initiation, pre-production, production, alpha testing, beta testing, and final release (Krisdiawan, 2018; Krisdiawan & Darsanto, 2019).

GDLC was selected because it provides a structured, iterative framework tailored for game projects, unlike traditional software models (e.g., Waterfall). GDLC emphasizes prototyping, user testing, and refinement, which are critical in educational games where usability, engagement, and learning impact must be continuously validated. This method ensures that feedback from students (the end-users) directly informs design refinements.

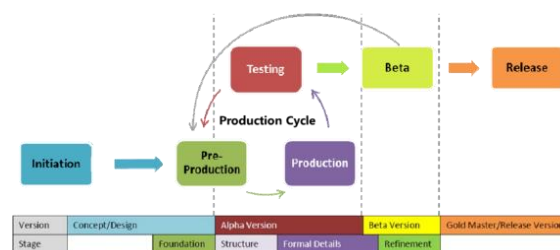


Figure 1. GDLC Stages

The main stages include:

1. **Initiation** – Problem identification (low vocabulary/phrase mastery) and needs analysis.
2. **Pre-Production** – Game design planning (mechanics, characters, levels, challenges).
3. **Production** – Development of features such as randomized word/letter challenges, scoring, and feedback system.
4. **Alpha Testing** – Internal testing of algorithms and interface.
5. **Beta Testing** – External testing with target users for usability and feedback
6. **Final Release** – Deployment of the improved version for classroom use.

3.4 Problem Solving Methods

The **Fisher-Yates Shuffle algorithm** was implemented to randomize letters and words in vocabulary and phrase tasks. To increase cognitive challenge, **distractor elements** were deliberately inserted:

1. For **vocabulary tasks**: additional vowels and consonants were added to prevent students from merely relying on memorization. Random letters from vowel categories (a, e, i, o, u) and consonants (other than vowels) are added as distractions in the vocabulary rearrangement process.
2. For **phrase tasks**: extra words were inserted to make phrase construction more cognitively demanding. Several additional words taken from the question input data were included to increase the complexity of the phrase arrangement.

This design ensures that each challenge requires deeper processing and discourages simple pattern recognition. Once the shuffle elements are combined with the main vocabulary or phrase into a single array, the Fisher-Yates Shuffle algorithm is applied to generate a random sequence used in the gameplay. Here is a flowchart of the Fisher-Yates Shuffle algorithm:

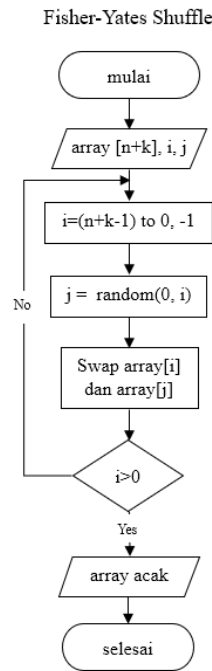


Figure 2. Flowchart Algorithm Fisher-Yates Shuffle
 Source: Andriyat Rio & Sugiharto Tito, 2025

Based on Figure 2, the Fisher Yates algorithm flowchart above, the pseudocode and natural language can be explained as follows:

Table 2. Natural Language and Pseudocode Fisher-Yates Shuffle

Natural Language of the Fisher-Yates Shuffle	Pseudocode of the Fisher-Yates Shuffle
<ol style="list-style-type: none"> 1. Start 2. Get the main vocabulary/phrase (n) 3. Get the letter/word suffix from the question input (k) 4. Combine into Array[n + k] 5. Initialize: Provide an array [n + k] and variables i and j. 6. Loop from i = (n + k - 1) to 0: Start from the last element and work backward to the first element. 7. Randomly select j between 0 and i. 8. Swap: Swap elements in array[i] with array[j]. 9. Condition i > 0: If i > 0, return to the process of selecting j and swapping elements. If i = 0, the loop stops and the array is completely randomized. 10. Display the random array. 11. Done. 	<pre> function fisherYatesShuffle(array A): n ← length(A) for i from n-1 downto 1: j ← random integer between 0 and i swap A[i] with A[j] return A </pre>

Table 3. Vocabulary Letter Randomization Results

<i>Range(i)</i>	<i>Roll(j)</i>	<i>Scratch</i>	<i>Result</i>
		S, M, A, L, L, E, R	
<i>l-7</i>	3 (A)	S, M, L, L, E, R	A
<i>l-6</i>	6 (E)	S, M, R, L, L,	E, A
<i>l-5</i>	4 (L)	S, M, R, L	L, E, A
<i>l-4</i>	1 (S)	M, R, L	S, L, E, A
<i>l-3</i>	2 (M)	L, R	M, S, L, E, A
<i>l-2</i>	2 (R)	L	R, M, S, L, E, A
Randomization Results			L R M S L E A

Table 4. Results of Randomization of Phrases

<i>Range(i)</i>	<i>Roll(j)</i>	<i>Scratch</i>	<i>Result</i>
		The, classroom, is, dirty, and, narrow, beautiful, quickly	
<i>l-8</i>	3 (is)	The, classroom, dirty, and, narrow, beautiful, quickly	is
<i>l-7</i>	6 (narrow)	The, classroom, quickly, dirty, and, beautiful	narrow, is
<i>l-6</i>	2 (classroom)	The, quickly, dirty, and, beautiful	classroom, narrow, is
<i>l-5</i>	4 (dirty)	The, beautiful, quickly, and	dirty, classroom, narrow, is
<i>l-4</i>	1 (The)	beautiful, quickly, and	The, dirty, classroom, narrow, is
<i>l-3</i>	2 (beautiful)	and, quickly	beautiful, The, dirty, classroom, narrow, is
<i>l-2</i>	2 (quickly)	and	quickly, beautiful, The, dirty, classroom, narrow, is
Randomization Results			and, quickly, beautiful, The, dirty, classroom, narrow, is

Table 2 (Vocabulary Letter Randomization Results) and Table 3 (Phrase Word Randomization Results) present the results of the implementation of the Fisher-Yates Shuffle algorithm in the letter and word randomization process. In Table 1, the process of randomizing letters from vocabulary that has been added with two letters of trickery, such as in the word small with the letters e and r added. All letters, including trickery, are then randomized without repetition of positions to form varied answer choices. Table 3 shows the results of word randomization from simple phrases or sentences that have also been added to two tricky words, namely beautiful and quickly, then randomized using the same algorithm. The results in both tables showed that the Fisher-Yates algorithm was able to generate a fair and unpredictable random distribution, thus enriching the variety of answer choices in each game session and increasing cognitive challenges for students.

The algorithm guarantees unbiased shuffling, ensuring that every permutation has an equal probability of occurrence (Mery, 2024). Combined with distractors, this creates varied and unpredictable challenges, fostering higher-order cognitive engagement such as analysis and problem-solving.

4 RESULTS AND DISCUSSION

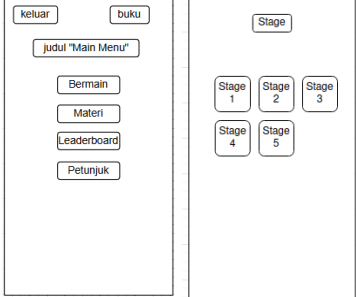
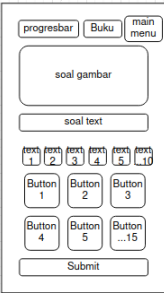
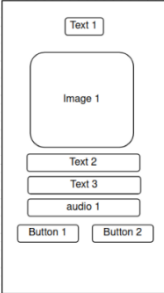
4.1 Proposed System Analysis

The proposed system analysis includes Game Design Document (GDD) of the educational game to be developed, as follows:

Game Design Document (GDD)

a. Storyboard

Table 5. Storyboard

Information	Scene
<p>After login, you will be redirected to the Main Menu with:</p> <ol style="list-style-type: none"> 1. Exit (quit game) 2. Play (start game) 3. Materials (study & get books) 4. Leaderboard (view scores) 5. Instructions (how to play) 6. Books (life) 7. Title <p>Choosing Easy/Medium/Hard directs you to the Stage Page, with 5 stages per level.</p>	
<p>After selecting a stage, you enter the Gameplay page with an interactive interface to compose vocabulary/phrases. It includes a progress bar, book-shaped lives, and navigation to the main menu. Questions appear as images and text, while answers use input fields with randomized options (Fisher-Yates Shuffle). The result is locked by pressing Submit.</p>	
<p>The Material Page displays vocabulary/phrases with text, image, spelling, translation, and (for vocabulary) pronunciation audio. Navigation uses back/next buttons, and as gamification, users earn 1 life per minute of reading or after a listening session.</p>	

b. Game Layout Chart

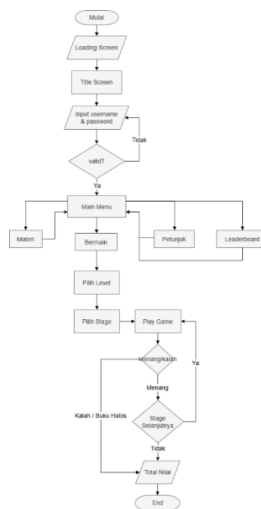


Figure 3. Game Layout Chart

2. Class Diagram and Sequence Diagram Play Game

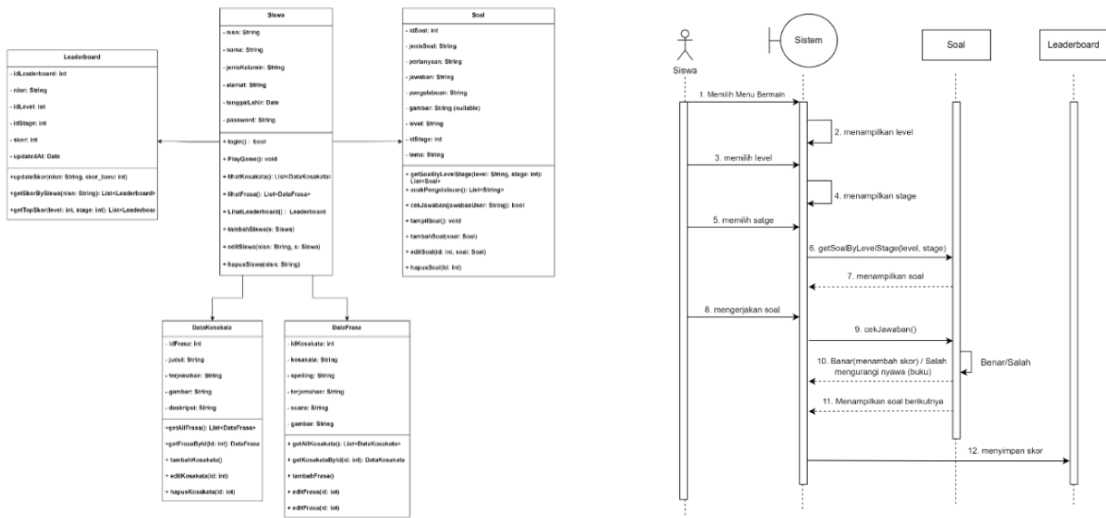
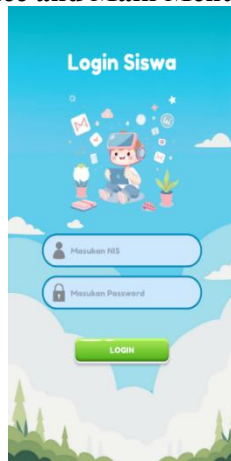


Figure 6. (a) Class Diagram; (b) Sequence Diagram Play Game

The Class Diagram (a) illustrates the structural design of the system by depicting the relationships among classes that collectively support the functionality of the educational game. In contrast, the Gameplay Sequence Diagram (b) demonstrates the dynamic interactions between student actors and system components throughout the gameplay process.

3. Interface Game

a. Login Interface and Main Menu



(a) Interface Login

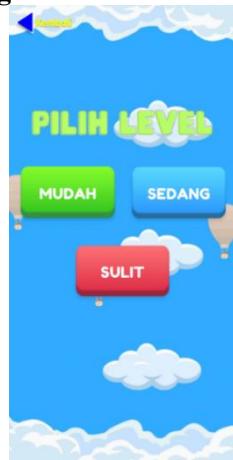


(b) Interface Main Menu

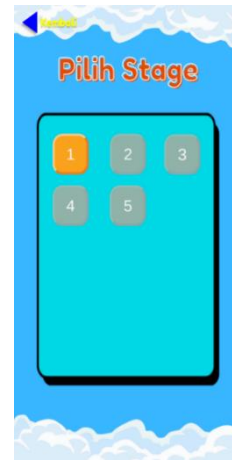
Figure 7. (a) Interface Login; (b) Interface Main Menu

Figure 7(a) presents the login interface, functioning as the application’s home page where users enter their NISN and password for authentication, ensuring access only for registered users. Figure 7(b) displays the main menu interface shown after successful login, serving as the central navigation hub with features including exit, total scores, books, play, leaderboard, materials, and information.

b. Level and Stage Interface



(a) Interface Level



(b) Interface Stages

Figure 8. (a) Interface Level; (b) Interface Stages

Figure 8(a) illustrates the level selection interface accessed from the play menu, where users choose among three difficulty levels—Easy, Medium, and Hard—based on their ability or learning progress. Subsequently, Figure 8(b) presents the stage selection interface, comprising five sequential stages beginning from Stage 1.

c. Gameplay Interface, Game Win, and Game Over



(a) Interface Gameplay



(b) Interface Game Win

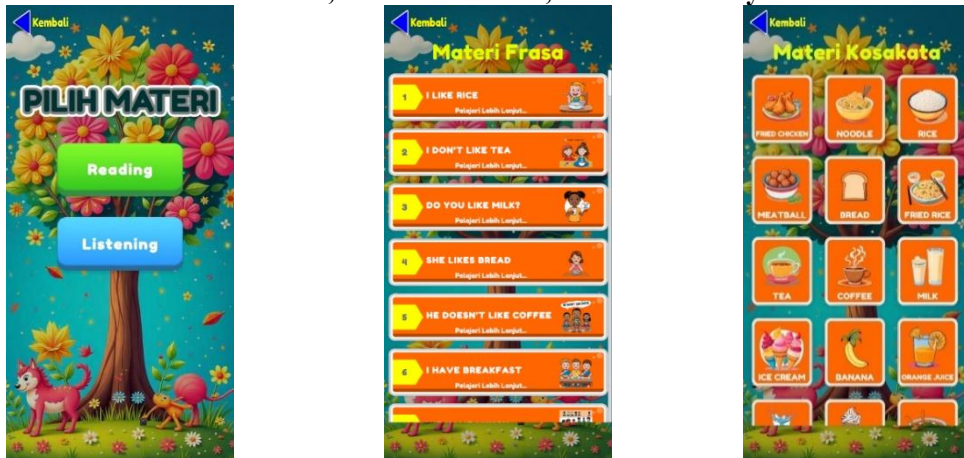


(c) Interface Game Over

Figure 9. (a) Interface Gameplay; (b) Interface Game Win; (c) Interface Game Over

Figure (a) illustrates the gameplay interface, which serves as the main workspace containing questions (text or images), life indicators, time, scores, and interactive components such as answer options and a submit button. Figure (b) presents the Game Win interface, displayed after completing all problems in a stage, showing the score with options to continue or return to the main menu. Conversely, Figure (c) depicts the Game Over interface, appearing when lives are exhausted or the stage is not completed, providing final score information and navigation choices.

d. Material Menu Interface, Phrase Material, and Vocabulary Material



(a) Material Menu Interface (b) Phrase Material Interface (c) Vocabulary Material Interface
 Figure 10. (a) Material Menu Interface; (b) Phrase Material Interface; (c) Vocabulary Material Interface

Figure 10(a) presents the material menu interface, offering access to two learning modes: Reading (phrases) and Listening (vocabulary). Figures 10(b) and 10(c) display the respective material lists, containing collections of phrases or vocabulary accompanied by illustrations to support contextual understanding.

e. Detailed Interface of Reading, Listening, and Leaderboard Materials



(a) Detail Reading Interface (b) Detail Listening Interface (c) Leaderboard Interface
 Figure 11. (a) Detail Reading Interface; (b) Detail Listening Interface; (c) Leaderboard Interface

Figure 11(a) illustrates the Reading material interface, consisting of phrase text, supporting images, and book rewards upon completion. Figure 11(b) depicts the Listening material interface, presenting vocabulary with audio, illustrations, and a book reward after the session. Figure 11(c) shows the leaderboard interface, a ranking table based on total scores designed to motivate users through competitive achievement monitoring.

4.3 User Acceptance Test

The User Acceptance Test (UAT) involved 47 Grade III students and evaluated four dimensions: Display, Learning Process, Material, and Comprehension Improvement, using 14

questionnaire items. The overall feasibility rate reached 86.06%, which falls into the “very feasible” category for classroom adoption.

Table 6. Respondents' Statements and Answers (Students)

No	Statement	Answer			
		Strongly agree	Agree	DisAgree	Strongly Disagree
A. Display					
1	The app's interface is attractive and fun to use.	29	15	1	2
2	In-app navigation is easy to understand and use.	27	19	1	
3	The writing and images in this game are easy to read and understand.	26	20	1	
B. Learning Process					
4	This game helps me in understanding English vocabulary.	27	18	2	
5	This game helps me in understanding English phrases.	23	20	3	1
6	This game can be used for learning, not just for playing.	23	20	2	2
7	The questions in this game are according to my difficulty level.	23	21	3	
8	The time given when working on the question is according to the level of difficulty of the question	22	24	1	
C. Material					
9	The reading material (Phrases) in this game is easy to understand.	22	20	3	2
10	The listening material (Vocabulary) in this game is easy to understand.	26	18	3	
11	The sound of in-game material is audible.	23	20	3	1
D. Increased Understanding					
12	This game increased my motivation to learn more English vocabulary and phrases.	22	22	2	1
13	This game improved my understanding of English vocabulary and phrases.	25	19	2	1
14	I became more able to compose words and sentences after playing this game.	22	23	2	

Table 7. Summary of Results UAT

<i>Dimension</i>	<i>Avg. Score (%)</i>	<i>Key Insights</i>
<i>Display</i>	88.3	Attractive, child-friendly, easy navigation; reduced extraneous cognitive load.
<i>Learning Process</i>	85.7	Level calibration matched skills; aligned with flow theory for engagement.
<i>Material</i>	84.9	Contextual and curriculum-aligned; clear sound and visuals.
<i>Comprehension Improvement</i>	85.5	Boosted motivation and ability to compose words/phrases.

Based on the data obtained from UAT, the following results were obtained:

- a. **Display (88.3%)** Students strongly agreed that the interface was attractive, fun, and easy to navigate. This suggests that the game's **child-friendly design** reduced extraneous cognitive load and supported intuitive interaction. High ratings in this aspect are consistent with (Pratama et al., 2024), who also found that appealing visual design contributed to a 94% acceptance rate in their "Things Bedroom" game. However, unlike that study, the present work extends beyond usability by linking interface satisfaction to learning outcomes through pre–posttests.
- b. **Learning Process (85.74%)** Students agreed that the game facilitated understanding vocabulary and phrases, provided challenges aligned with their abilities, and offered time allocation consistent with difficulty levels. This indicates that the **difficulty calibration and level system** successfully maintained engagement, aligning with flow theory which posits that learners are most engaged when challenges match their skill level. This finding reinforces (Baiq Siti Humaeratul Azizah et al., 2024), who reported that gamification elements (scramble, crossword, Wordwall) enhanced vocabulary mastery, although those tools relied on static content rather than algorithmic variety.
- c. **Material (84.9%)** Respondents found the reading and listening materials accessible and clear, with audible sound quality. The use of **contextual vocabulary and simple phrases** aligned with the curriculum likely supported comprehension. While earlier studies (Mery, 2024; Ramadhan, 2022) demonstrated the technical feasibility of Fisher-Yates Shuffle in educational games, they did not explicitly examine material relevance. Our findings suggest that **curriculum alignment combined with randomization** increases both usability and perceived usefulness.
- d. **Comprehension Improvement (85.5%)** Students reported that the game improved their motivation and ability to compose words and sentences. This subjective perception aligns with objective evidence from the comprehension test (see §4.5), where mean scores increased significantly. Motivation is a key mediator in learning effectiveness: games that students find enjoyable encourage repeated practice, which in turn strengthens vocabulary acquisition.

High acceptance is explained by (a) fair/randomized challenges via Fisher-Yates Shuffle, (b) gamification (lives, scores, leaderboards), (c) contextual materials, and (d) balanced difficulty. Similar to (Pratama et al., 2024), high usability was confirmed, but unlike previous works, this study connects UAT with measurable learning outcomes.

Limitations of UAT results. Although high scores (>84%) across all aspects demonstrate feasibility, UAT data represent **subjective perceptions** and may be influenced by novelty effects (students' excitement about trying a new game). In addition, the study was conducted in a **single school with 47 respondents**, which limits generalizability. Further replication across diverse contexts and longer exposure would strengthen external validity.

4.4 Comprehension Test Response

The **pre–post test** revealed significant improvements:

Table 8. Comprehension Test Response

<i>Aspect</i>	<i>Pre-Test (Mean)</i>	<i>Post-Test (Mean)</i>	<i>Gain</i>	<i>% Increase</i>
<i>Vocabulary</i>	28.94	38.50	+9.56	+33%
<i>Phrase Construction</i>	21.06	31.90	+10.84	+51.5%
<i>Total Score</i>	50.00	70.40	+20.40	+40.8%

The improvement can be influenced by several factors including Fisher-Yates Shuffle ensures fair/random tasks, Distractors increase cognitive engagement, Gamification encourages repeated practice, Contextual content strengthens semantic associations.

Comparison with prior studies: Gains (+40.8%) exceed typical improvements (20–30%) in gamified vocabulary studies (Baiq Siti Humaeratul Azizah et al., 2024). Unlike (Pratama et al., 2024) who only measured usability, this study links usability with significant learning impact.

Limitations: One-group design (no control), limited sample, short-term gains only, and lack of reported effect size (t-test, Cohen's d).

Implications: The integration of **algorithmic randomization, gamification, and contextual content** significantly enhanced vocabulary and phrase mastery, offering an empirically validated model for technology-based language learning.

5 CONCLUSION

This study developed and evaluated an Android-based educational game designed to improve English vocabulary and phrase mastery among elementary school students, utilizing the Fisher-Yates Shuffle algorithm to generate fair and varied challenges. The integration of algorithmic randomization, distractor-based tasks, and gamification elements resulted in both high user acceptance and measurable learning improvements.

The User Acceptance Test (UAT) involving 47 Grade III students yielded an overall feasibility score of 86.06%, indicating that the game was perceived as highly engaging, usable, and relevant to learning needs. More importantly, comprehension test results demonstrated substantial learning gains: vocabulary scores increased by 33%, phrase construction improved by 51.5%, and overall comprehension rose by 40.8%. These findings suggest that the combination of algorithmic fairness, contextualized materials, and gamified reinforcement not only sustains student motivation but also enhances language acquisition more effectively than static, conventional methods.

Compared with prior studies that primarily focused on usability or technical implementation, this research provides empirical evidence linking algorithmic shuffling to improved learning outcomes in English as a Foreign Language (EFL) contexts. This strengthens the claim that algorithm-driven educational games can complement teacher-led instruction by offering personalized, varied, and cognitively stimulating learning opportunities.

Nevertheless, several limitations must be acknowledged. The study was conducted in a single school with a relatively small sample size, and the evaluation was limited to short-term outcomes. Longitudinal studies with larger and more diverse samples are needed to confirm the long-term effectiveness and generalizability of this approach. Additionally, future research should incorporate statistical effect size analysis and controlled experimental designs to strengthen causal inferences.

In conclusion, this study contributes to the growing body of evidence supporting the role of serious games in language education. By demonstrating how the Fisher-Yates Shuffle algorithm can create fairness and variety in vocabulary and phrase learning, it provides a novel direction for the design of adaptive and engaging digital learning tools.

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