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The modeling of laboratory information systems in higher education based on enterprise architecture planning (EAP) for optimizing monitoring and equipment maintenance

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Abstract: The laboratory is a place to conduct scientific research, experiments, measurements, or scientific training. FMIPA UNNES has several laboratories distributed in each department to support student lectures. Through the implementation of practicum in the laboratory, students are expected to be able to find a concept, and foster scientific attitudes, and critical thinking skills. Good laboratory management is expected to be able to utilize laboratory resources effectively and efficiently. Laboratory equipment must be ensured to function properly and be ready to be used for practicum. To support this, it is necessary to monitor the condition of the equipment and immediately repair the equipment if any damage is found. The current obstacle is monitoring tool repairs manually, so there are shortcomings such as poor documentation, and equipment conditions that cannot be monitored online. In this study, an information system for monitoring the maintenance of laboratory equipment in the departments in the FMIPA UNNES environment will be built. The research method begins with a literature study, initial data collection and observation, EAP-based system design, system testing, system analysis, and system evaluation. This study uses the SDLC (System Development Life Cycle) approach which is used to develop a product for the Monitoring Information System for the Maintenance of Laboratory Equipment. Testing is done using black box testing. From the results of development and testing, it can be concluded that the system can be used to simplify the process of managing laboratory equipment with a UAT value of 88% suitable for use.

Keywords: EAP, information system, laboratory, maintenance, optimization

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Introduction

A laboratory is a place to conduct scientific research, experiments, measurements, or scientific training. Now lab management has followed technological developments, through the application of information systems. This is because technology can facilitate human work. One of them is the existence of digital applications. Applications have various capabilities to help human work, ranging from office applications to management, personal, entertainment, and other fields of human work. With this equipment, human tasks become easier, faster, more thorough, and more efficient [1].

The implementation of lecture practicum in the laboratory is expected so that students can find a concept, and foster scientific attitudes, and critical thinking skills. So laboratory management needs to be empowered effectively and efficiently [2]. Laboratory equipment must be ensured to function properly and be ready to be used for practicum. To support this, it is necessary to monitor the maintenance of the equipment systematically. The current obstacle is that monitoring of tool repair is done manually, so there are shortcomings such as poor documentation, and the condition of the equipment that cannot be monitored online [3].

Currently, the FMIPA UNNES laboratory does not yet have an information system that can monitor the maintenance of laboratory equipment, starting from the condition of laboratory equipment to the repair process if there is damage [4]. Therefore, this study aims to create and implement an information system for monitoring the maintenance of laboratory equipment in the Department of Mathematics and Natural Sciences UNNES. Based on the description of the importance of laboratories to supporting lectures, the authors initiated the idea of researching the Development of Information Systems for Monitoring Laboratory Equipment Maintenance [5]. This is in line with the recommendation of the Minister of PANRB, which implies the use of IT and modern tools in completing work [6].

This monitoring system aims to create an information system that can perform two purposes at once, namely preventing laboratory equipment from being lost or damaged and making it easier for laboratory technicians to carry out maintenance of laboratory equipment [7].

Methodology

The stages in this research are data collection, analysis and design, stages of developing laboratory systems, and testing information systems [8]. The stage of data collection is done by using the method of interview and observation [9]. Interviews were conducted with lecturers, students, and department managers, to obtain an overview of the needs and flow of laboratory management. Meanwhile, observations were made by observing what data would be used in the management of laboratory equipment, borrowing, and processing laboratory equipment at FMIPA UNNES [10].

At the system design stage, it is carried out using the Waterfall method. The Waterfall method is a sequential software development method and consists of five interrelated and influencing stages [11]. In this method, there are several stages, namely the analysis, design, implementation/coding, testing/verification, and maintenance stages. The stages of the Waterfall method are shown in Figure 1.

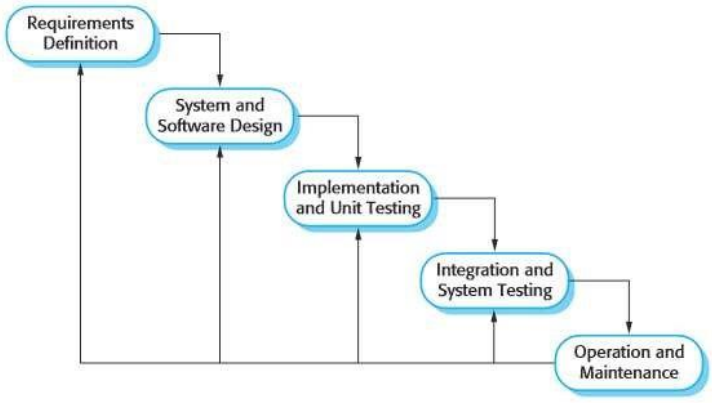

Figure 1. Waterfall Method

At the system design stage, it will produce a design for the database using ERD and DFD to describe the system framework that will later be built making it easier for the process of making the system needed by the user [12]. The development stage is by implementing the results of the design carried out. The process of developing information systems using the CodeIgniter Framework with the programming languages used are PHP and JavaScript. The next stage of this research is testing information systems. Testing using the Black Box Testing method. This test is carried out to find out what deficiencies and errors are in the system [13]. The system will be tested by conducting experiments directly by the user. Tests that will be carried out are using black box testing and Mean Opinion Score. Black-box testing is a testing process by checking one by one the functions that have been created, and whether they have been made in accordance with user requirements [14]. The Mean Opinion Score test is carried out by involving several respondents to try to use the system, then asking them to assess with a range of 1 to 4. Where a value of 1 represents the worst value and a value of 4 represents the best value. Then the

average rating of all respondents is calculated so that the Mean Opinion Score value is obtained from the system [15].

Development of information systems using the CodeIgniter Framework with the programming languages used are PHP and JavaScript. The next stage of this research is testing information systems. Testing using the Black Box Testing method. This test is carried out to find out what deficiencies and errors are in the system [16]. The system will be tested by conducting experiments directly by the user. Tests that will be carried out are using black box testing and Mean Opinion Score. Black-box testing is a testing process by checking one by one the functions that have been created, and whether they have been made in accordance with user requirements [17]. The Mean Opinion Score test is carried out by involving several respondents to try to use the system, then asking them to assess with a range of 1 to 4. Where a value of 1 represents the worst value and a value of 4 represents the best value. Then the average rating of all respondents is calculated so that the Mean Opinion Score value is obtained from the system [18].

Enterprise Architecture is a logical organization for the main business processes and Information Technology capabilities that reflect the need for integration and standardization of the company's operating model based on the Center for Information Systems Research [19]. Enterprise Architecture is a set of principles, methods, and models used in the design and realization of a company's organizational structure, business processes, information systems, and infrastructure [20]. Based on the description above, it can be concluded that enterprise architecture is the principles, methods, and models used in the design and realization of a company's organizational structure, business processes, information systems, and infrastructure. Enterprise Architecture Planning is a process of defining the architecture for the use of information to support the business and planning to implement the architecture [21], [22], [23].

Enterprise Architecture Planning methodologies and models are an early part of a major body of Enterprise Architecture knowledge that is still relevant and has influenced many frameworks, methodologies, and best practices in the public and private sectors [24], [25]. In this journal the research methodology used will be adapted to the architectural modeling steps in the EAP, namely planning initiation, business modeling, current system architecture and technology, development of enterprise architecture models in the form of data architecture, application architecture, technology architecture, and implementation [26].

Results and Discussions

The result of this research is an information system for the management of laboratory equipment. This system can be used to simplify the process of data collection, borrowing, and also processing the value of laboratory equipment results. The modeling steps in the EAP are steps that can be taken in building a blueprint for architecture. Following the steps in the EAP concept, it will be used to model the laboratory system at FMIPA UNNES.

A. Initiation of Planning

The users of this system are Department Lab Admin, tasked with inputting lab asset data in their respective departments, including conditions and suggestions for repairing tools. Faculty Admin, Faculty admin is tasked with making decisions about whether to approve or postpone the proposed tool repair. Finance Admin, tasked with approving budget allocations/ceilings.

The initial stage of the EAP is planning initialization, which defines the organization as an object by describing the organization's vision and mission which is linked to the vision of the information system planning so that the development of the architecture can be carried out in accordance with business objectives. In accordance with its existence as a university, the core business of a university consists of three main components, namely: education and teaching, community service, and research which is called the tri dharma of higher education. By providing educational services to the community to produce graduates who will be returned to the community.

Determining the future vision and mission is very necessary as a guideline for determining various IT strategies needed to support the vision and mission. The selection of the planning methodology approach will determine the results of the blueprint that will be made. The vision and mission of FMIPA UNNES are as follows.

The vision of FMIPA UNNES is to become a Faculty of Mathematics and Natural Sciences with a conservation perspective with an international reputation. The mission of FMIPA UNNES is to first organize and develop mathematics and natural science education in superior educational and non-educational programs with conservation insight and international reputation. Second, develop and create science and technology in the fields of mathematics and natural sciences, as well as civilizations with conservation insight and international reputation. Third, disseminate science and technology in the fields of mathematics and natural sciences with conservation insight and with an international reputation. Fourth, build and develop institutional cooperation in supporting the institutional strengthening of international reputation.

The goal of FMIPA UNNES is to produce human resources of MIPA that are superior at the international level. Produce MIPA science and education with superior conservation insight. Providing modern professional services in the field of Mathematics and Natural Sciences and education to the community, and implementing cooperation in the field of Mathematics and Natural Sciences to support the strengthening of institutions of international reputation.

B. Business Modeling

The organizational structure within universities is the main basis for conducting business modeling. The organizational structure will show what parts will be handled by a university. So the determination of the organizational structure will be very decisive in the business modeling step. As a higher education institution, it runs the Tri Dharma of higher education, namely education, research, and community service. So the main activities of higher education are grouped into the fields of Education, Research, and Community Service. This paper will only discuss the fields of education and research, especially laboratories, not including community service. Based on the value chain concept, the main functional areas for the education model in higher education can generally be grouped into main activities and supporting activities. The main activities consist of student admissions, academic operations, and graduation. Meanwhile, supporting activities consist of activities related to resource management (general), financial management, planning and information systems, and publishing and publication. Figure 2 shows the value chain for a university's education and research model.

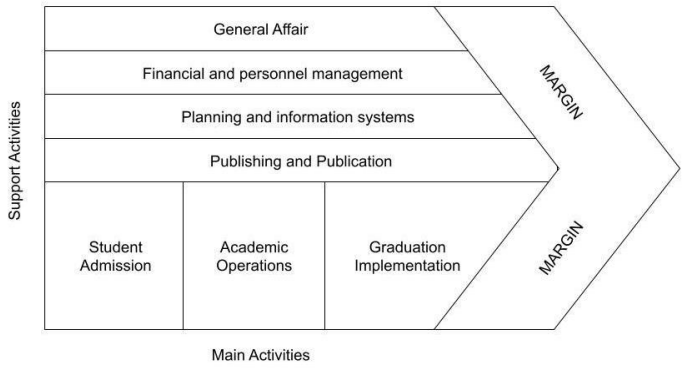

Figure 2. The laboratory value chain is in academic operations

Each of the main activities can be described. First, student admissions are all activities starting from the process of new student admissions, and selection of new student administration. Second, academic operations are all activities related to teaching and learning activities during the student's academic period. Third, graduation is an activity to release students academically at the end of student studies.

Each of the supporting activities can be described. First, the general division is the part responsible for the smooth operation of educational facilities and has carried out the development of infrastructure from year to year, both physical facilities and facilities to support educational activities. Second, finance and staffing are activities related to financial management, determination of investment budgets and determination of needs, and monitoring and allocation of human resources. Third, planning and information systems are activities related to the management and development of information system equipment and networks. Fourth,

publishing and publication are activities related to the management and publication of journals, bulletins, and student textbooks.

After initiating the organization's business function areas by utilizing Potter's value chain, it is possible to arrange the decomposition structure of the business functions using a function hierarchy chart. In accordance with the scope and limitations of this journal, the functions that are decomposed are those related to academics as the main functions with elaboration on student admissions, academic operations, graduation implementation, general division, financial and staffing management, planning and information systems, as well as publishing and publications. It can be depicted in Table 1.

Table 1. Details of Business Activities in Higher Education

Activity	Detailed activities
Student Admission	1. Student admission planning 2. Implementation of Selection 3. Implementation of Selection 4. Re-registration of new students
Academic Operations	1. Planning the implementation of academic activities 2. Re-registration 3. Study process 4. Laboratory Use 5. Re-registration of new students 6. Evaluation process 7. Implementation of student academic leave 8. Student final exam
Financial and personnel management	1. Budgeting 2. Budget allocation 3. Monitoring and evaluation 4. Budget revision 5. Financial accounting system 6. Employee development planning 7. Payment calculation 8. Employee performance evaluation
Graduation Implementation	1. Determination of graduation requirements 2. Diploma making 3. Generating transcripts of grades
Planning and information systems	1. Implementation of information system administration 2. Information system administration reporting 3. Development of software or information systems
General Affair	1. Implementation of the procurement of facilities and infrastructure 2. Implementation of inventory management 3. Supervision and evaluation of the use of facilities and infrastructure 4. Office inventory reporting
Publishing and Publication	1. Implementation of journal administration 2. Implementation of bulletin administration 3. Implementation of textbook administration

Figure 3 below shows the relationship between stakeholders and the main and supporting business functions in a university.

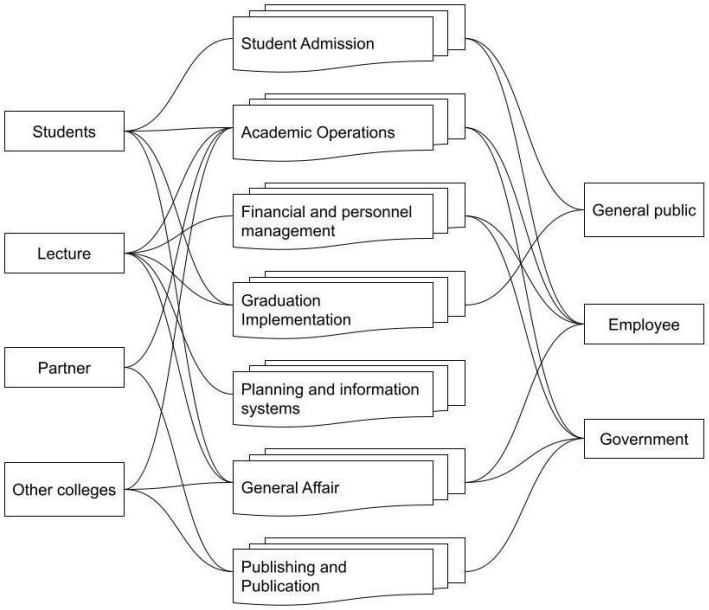

Figure 3. The main stakeholders of higher education

C. System Architecture and Technology

The current information system and technology provide an overview of the current state of information technology and systems, the development of information technology, and the desire and direction of information technology development in universities today. In this step, several things need to be considered and used as the main key in conducting the analysis, namely, the first condition of the organization, the second direction of information technology development strategy, and the third condition of the current information system and technology.

D. Development of enterprise architecture model

In building an architectural model, the first thing to do is create a data architecture. The data architecture that will be defined this time is the definition of the data usage that will be used in the application architecture later, which will be delivered at this stage according to the EAP stage in the data architecture.

An entity candidate is an entity that will be part of the enterprise architecture planning so that the determination can be based on the condition of the main business functions in the previously defined value chain, thus the entity that will be defined as a business entity, and based on the business entity data entities will be defined. In accordance with the condition of the value chain, the list of business entities and data in Table 2 that can be identified is as follows:

Table 2. Entity list

Business Entity	Data Entity
Tool Repair Entity	1. Tool Entity 2. Period Entity 3. Date Entity 4. Urgency Entity 5. Entity Status
Tool/ Material Lending Entity	1. Tool Entity 2. Course Entities 3. Class Entities 4. Major Entity 5. Lecture Room Entities
Loan Repayment Entity	1. Tool Entity 2. Course Entities 3. Class Entities 4. Lecturer Entity

	5. Rombel's Entity
Practicum Entity	1. Tool Entity 2. Space Entity 3. Entity Type Practicum 4. Lecturer Entity 5. Entity Status
Transaction Recap Entity	1. Tool Entity 2. Lecturer Entity 3. Course Entities

To describe the relationship between entities, the conceptual depiction of the relationship will use the Entity-Relationship (E-R) diagram. Laboratory E-R Diagram is a logical data conceptual model that shows the relationship between entities in laboratories in universities. The last stage in modeling the architecture is defining the technology architecture. The EAP concept defines technology requirements that need to be provided in the business environment to run a data architecture that can manage data based on the application architecture, in other words, the technology architecture is an infrastructure requirement that must be provided to support the running of data and applications used by the organization. The principles and technology platforms were created to identify the main types of technology platforms needed to support shared data and application environments in universities. This principle is determined by considering trends and developments in information technology, business models, data architecture, application architecture, existing systems, and technologies as well as requests and findings from businesspeople within the organization. Table 3 will show the technology platforms that can be used to support data and applications in universities.

Table 3. Platform/technology architecture

Principle Area	Description
Operating system	The selected operating system is portable (can run on multiple platforms), scalable (can run on small to large-scale computers, interoperable (can run in heterogeneous environments), compatible (maintains existing software investments and allows technological advances to be applied to the environment).
Hardware	Hardware must be reliable and highly available and support future technologies
Communication and Network	The network environment is provided with sufficient bandwidth and a set of standard protocols to support network services and real-time access to information.
Application	All application designs should be modular and should be testable.
Database Management	The database model used is a relational database which is relatively easier to understand and more popular.
Security	Security requirements include secrecy (requirements in information systems that can only be read), availability (needs that information resources can only be obtained and used by authorized users), and integrity (needs that information resources can only be modified and maintained by authorized units).

E. Implementation and Testing

The laboratory system development stage is the implementation stage of the design stage. At this stage of development, it is done by coding the required pages on the laboratory system using the CodeIgniter framework. Figure 4 shows the results of the login page development, this page is an implementation of the login page mock-up. The login page is a page that is used to verify users, there are username and password inputs that must be filled in by

system users to be able to enter the system, if the username and password inputs do not match then the user cannot enter the system.

Figure 4. Login page

Admin users who have entered the correct username and password will enter the admin page. Figure 5 is a view of the admin page (Admin Data). This page is the result of the implementation of the mock-up of the Admin Page Mock-up. On the admin data page, admin users can view, add, change information, and can delete admin data.

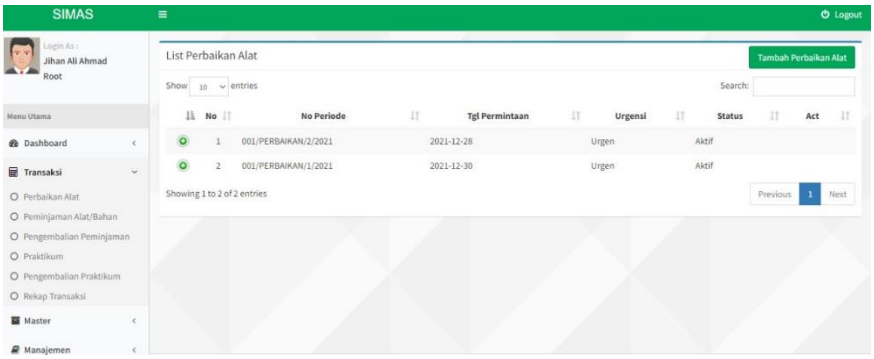

Figure 5. Admin Pages

The system testing stage or testing is the stage carried out to match and observe the results of the implementation that has been carried out. System testing or testing carried out in this study using the black box method and Mean Opinion Score. The testing process with the black box method is carried out by testing one by one the functions that have been made whether they are in accordance with user requirements and whether the output of these functions is in accordance with what is expected, while for MOS testing is carried out by subjective assessment of the quality associated with the system. The results of the tests carried out on the Website-based Pendadaran Information System using the Mean Opinion Score test method based on the User Acceptance Test (UAT) can be seen in Table 4.

Table 4. Eligibility Result by Expert

Code	Rating Indicator	Result
A1	Attractive Laboratory System Design	93%
A2	Laboratory System Color Match	87%
A3	Component Location in Laboratory System Appropriately	93%
A4	Laboratory System Size Appropriate	67%
A5	Easy-to-Use Laboratory System	93%
A6	Laboratory System Convenient to Use	87%
A7	Color on Laboratory System Clear	93%
A8	The image on Laboratory System Clear	87%

We also present expert validity data in the graph of each component, which can be seen in Figure 6.

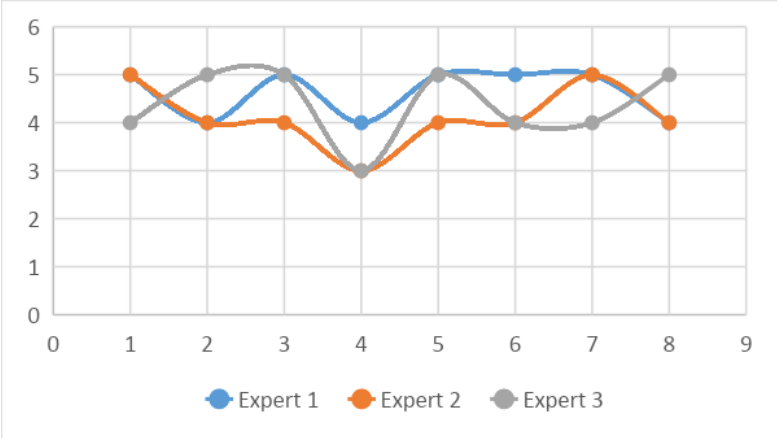

Figure 6. Expert validity of each component

Based on tool validation by UAT experts selected by the research team to validate the laboratory system for system validation sheets, the results of product feasibility from experts show valid and very valid results, starting from A1 with 93% results, and A2 with 87% results. A3 results in 93%, A4 results in 67%, A5 results in 93%, A6 results in 87%, A7 results in 93%, and A8 results in 87%, if the overall validity component is obtained on average, 88% of the products are very valid. These results can be presented in the form of Table 4 and Figure 6.

Conclusion

Based on the results of the study, it can be concluded that the use of laboratory systems for monitoring and maintenance in laboratory management has proven to be very valid. Before implementing the Laboratory System Identification Method laboratory tools and materials used were still manual. Enterprise Architecture Planning (EAP) is an effective approach to modeling laboratory information systems in higher education. EAP helps align the business and technology within the laboratory information system, making it easier to monitor and maintain equipment. Monitoring and maintenance of laboratory equipment play a critical role in ensuring the quality of collected data. EAP helps ensure that laboratory equipment is functioning properly and strengthens the laboratory information system. Modeling becomes an effective tool for applying the EAP concept in laboratory information systems. Modeling helps align the business and technology goals of the organization with the laboratory information system, ensuring the quality of collected data. The implementation of EAP in laboratory information systems in higher education has the potential to increase efficiency and effectiveness in monitoring and maintenance of equipment. It helps ensure that collected data is accurate and of high quality, making it easier to process analysis and make decisions. After implementing the EAP method, the laboratory system is safer, and access to tools and materials can be monitored properly. Test the validity of the laboratory system for monitoring and maintenance, with an average validity of the expert team reaching 88% Based on tool validation by UAT experts.

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