ISSN 2614-0047

Digitalization of information systems and educational laboratory management in higher education institutions

Rochmad Fauzi [a,1,*], Harits Ar Rosyid [a,2], Heru Wahyu Herwanto [a,3]

[a] Department of Electrical Engineering and Informatics, Faculty of Engineering, Universitas Negeri Malang, Indonesia
[1] rochmad.fauzi@um.ac.id; [2] harits.ar.ft@um.ac.id; [3] heru_wh@um.ac.id
* corresponding author

ARTICLE INFO

Article history
Received May 28, 2024
Revised October 18, 2024
Accepted December 7, 2024

Keywords
Digitalization
Educational laboratory anagement
SIONLAP
Higher education institutions

ABSTRACT

This study aims to develop an Information and Educational Laboratory Management System application based on SIONLAP. SIONLAP is designed and developed following educational institution elements' duties, needs, and functions. The system is developed to convert manual procedures, forms, and workflows into digital formats. Workflow processes can be optimized and automated through the implementation of SIONLAP. Documents and records generated by SIONLAP will be in digital data form, which can facilitate data processing and strategic analysis for planning, organizing, implementing, documenting, monitoring, reporting, evaluating, and developing educational laboratories, thereby improving management and continuous services in support of the implementation of the Tri Dharma of Higher Education. The research method refers to the waterfall method, with testing using the black box method. The results of the SIONLAP 2.0 application research show that it 1) provides more user-friendly user access management capabilities to facilitate users in higher education institutions with multi-role functions; 2) simplifies the data management and information workflow of equipment inventory; and 3) offers a laboratory asset rental feature as a means for higher education institutions to generate revenue from their laboratory assets.

1. Introduction

Education is a deliberate and meticulously structured endeavor to nurture a conducive learning milieu and process [1], [2]. Among educational providers, higher education institutions play a pivotal role in fostering the development of highly competent and competitive human resources. They furnish students with a spectrum of competencies encompassing knowledge, skills, autonomy, and attitudes indispensable for discovering, cultivating, and applying science, technology, and art to fulfill personal, societal, industrial, national, and state exigencies [3].

An indispensable facet of the educational continuum is the laboratory, outfitted with requisite amenities and infrastructure [4]. Within these laboratories, students translate theoretical knowledge acquired in classrooms into practical realms, conduct experiments, and cultivate essential practical skills vital for professional life. Hands-on laboratory experiences enable students to delve deeper into subjects, hone technical proficiencies, and grasp concepts more quickly. Consequently, student engagement in laboratory pursuits not only enriches their learning journey but also fortifies their readiness to navigate the complexities of societal and professional demands.

Efficient, dependable, systematic, and integrated management and administration are imperative to optimize laboratory functionalities. This holistic approach endeavors to cater to the requisites of planning, organizing, executing, documenting, overseeing, reporting, and evolving laboratories, which are pivotal for the academic community, educational staff, and policymakers in higher

education institutions [5]–[8]. Research underscores the pivotal role of educational laboratories in enhancing educational quality [9], [10]. However, laboratory management grapples with an array of challenges that can impede efficiency, efficacy, and service quality [11]–[14].

Identified challenges in laboratory management encompass a myriad of issues, including limited human resource ratios, misaligned personnel rotations, manual management utilizing paper and Word/excel applications, lack of integrated management, incongruous mapping and scheduling of practicum courses, and absence of an integrated information system facilitating the needs of laboratory managers and users, thus hampering connectivity and integration of laboratory information.

Previous research has highlighted gaps in a system that lacks integration and fails to meet educational requirements [15]–[18]. The Online Laboratory Information System (SIONLAP) examination reveals a comprehensive framework comprising seven user access rights. These rights are meticulously designed and developed based on the needs, primary responsibilities, and functions of educational institution constituents, including Administrators, Laboratory Heads, Laboratory Chairs, PLP/Technicians/Laboratory Assistants, Assistants, Lecturers, and Students.

SIONLAP is adept at managing and amalgamating data, information, and online laboratory services within the departmental purview, spanning manager data, lecturer data for practicum courses, equipment data, material data, inventory, SOP, practicum modules, activity schedules, thesis/final project data, feedback, statistics documents on equipment material usage, documents on equipment material conditions, announcements, equipment and material borrowing, proposals for equipment material procurement based on practicum module development and laboratory enhancement, and monitoring and air quality control of laboratory rooms across all laboratories within the department, utilizing features such as the Internet of Things and wireless sensor networks.

As of 2024, over 130 SIONLAP licenses have been embraced by educational institutions across diverse regions in Indonesia, encompassing higher education, polytechnics, and high schools.

2. Method

The chosen methodology for this research is the waterfall method [19], [20], a well-established and structured approach in system development characterized by a linear and sequential progression through defined phases. The waterfall method delineates distinct stages that guide the progression of the development process, as illustrated in Fig. 1.

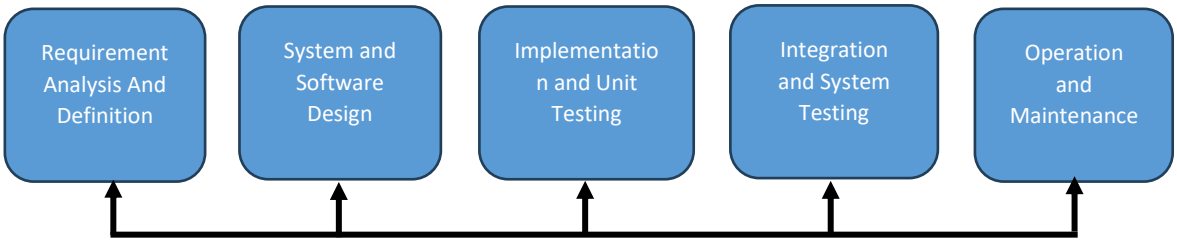

Fig. 1. Waterfall Method (Ian Sommerville, 2011)

2.1. Requirements Analysis And Definition

In requirements analysis and definition, the research embarks on a comprehensive journey to gather and analyze system requirements and specifications tailored specifically for SIONLAP users [21]. This pivotal phase is the bedrock upon which the subsequent development stages are built, emphasizing a meticulous approach to understanding user needs and expectations. A multifaceted approach is adopted, encompassing various activities such as interviews, dissemination efforts, discussions, and surveys meticulously conducted among SIONLAP users within higher education institutions and polytechnics across Indonesia.

These activities serve as invaluable conduits for eliciting firsthand insights and perspectives from end-users, enabling a holistic understanding of their experiences, challenges, and aspirations concerning SIONLAP. Through structured interviews, researchers delve into the nuanced intricacies of user interactions with the system, identifying pain points, preferences, and areas for improvement. Dissemination efforts disseminate information about the research endeavor, inviting participation and feedback from diverse stakeholders within the educational landscape.

Furthermore, discussions provide a collaborative platform for stakeholders to engage in dialogue, exchange ideas, and offer insights into the functionalities and features they deem essential for an optimal user experience with SIONLAP. Surveys offer a structured mechanism for collecting quantitative data, allowing researchers to gauge user satisfaction levels, identify patterns, and prioritize requirements based on user feedback. By integrating these diverse methodologies, the research endeavors to construct a comprehensive and nuanced understanding of user requirements, laying a robust foundation for subsequent stages of system development.

2.2. System and Software Design

In System and Software Design, the research focuses on translating the established requirements into a tangible architecture for SIONLAP [22]. This pivotal phase bridges conceptualization and implementation, laying the groundwork for developing a robust and user-centric software system. Building upon the comprehensive understanding garnered during the Requirements Analysis phase, the design process endeavors to encapsulate the essence of user needs and expectations within the architectural framework.

Central to this endeavor is the identification and depiction of the fundamental abstractions of the software system. Through a meticulous analysis of user requirements, researchers aim to delineate the core components and functionalities that constitute the essence of SIONLAP. This process involves distilling complex user needs into tangible design elements, ensuring that the resulting architecture aligns seamlessly with user expectations. Additionally, the design phase encompasses delineating key features and access rights, providing a blueprint for developing a comprehensive and user-centric system.

Furthermore, the design process endeavors to strike a delicate balance between functionality and usability, ensuring that the resulting architecture meets the functional requirements and offers an intuitive and seamless user experience. Through iterative design iterations and feedback loops, researchers strive to refine and optimize the architectural framework, incorporating user feedback and insights to enhance the design iteratively. By adopting a user-centric approach to design, the research aims to create an architecture that addresses the immediate needs of users and anticipates future requirements and scalability needs, laying the foundation for a robust and adaptable software system.

2.3. Implementation and Unit Testing

In the Implementation and Unit Testing phase, the meticulously crafted architecture design of SIONLAP transitions into tangible program units through the implementation process [23]. This pivotal stage marks the transformation of conceptual designs into functional software components, breathing life into the envisioned system. Leveraging the insights gleaned from the design phase, developers embark on the coding process, translating architectural blueprints into executable code that forms the backbone of SIONLAP.

Following the implementation of program units, rigorous testing ensues to validate the functionality and integrity of the developed software. Unit testing, a cornerstone of the testing process, examines individual software units in isolation, ensuring that each component operates as intended and meets specified requirements. Through a battery of test cases and scenarios, developers meticulously scrutinize the behavior and performance of program units, identifying and rectifying any discrepancies or defects that may impede functionality.

Furthermore, integration testing plays a pivotal role in assessing the interoperability and cohesion of individual program units when integrated into a unified system. This process systematically integrates program units to evaluate their collective behavior and functionality as a cohesive whole. By simulating real-world usage scenarios and interactions, integration testing aims to uncover any inconsistencies or compatibility issues that may arise when different components interact. Through iterative testing cycles and feedback-driven refinements, developers strive to ensure that the developed software aligns seamlessly with the specified specifications and user expectations, laying the groundwork for subsequent system deployment and operation stages.

2.4. Integration and System Testing

In the Integration and System Testing phase, the disparate components of the SIONLAP system converge to form a cohesive whole, undergoing comprehensive testing to evaluate their collective functionality and performance [24]. This pivotal stage marks the culmination of the development

process, where individual program units are seamlessly integrated to create a unified system. Through meticulous testing protocols and procedures, developers aim to ensure that the integration process proceeds smoothly and that the resulting system aligns seamlessly with user expectations.

Central to this endeavor is validating system interoperability and cohesion, ensuring that different components interact harmoniously to deliver the intended functionality. Integration testing encompasses scenarios and uses cases, simulating real-world interactions to assess the system's behavior under varying conditions. By subjecting the integrated system to a battery of test cases and scenarios, developers aim to identify and rectify any inconsistencies or compatibility issues that may arise during the integration process.

Furthermore, system testing delves into broader aspects of system functionality and performance, evaluating the system against predefined criteria and specifications. Through comprehensive testing protocols, developers aim to ascertain that the integrated system operates smoothly, reliably, and following user expectations. This encompasses rigorous performance, stress, and usability testing to ensure that the system can withstand varying loads and usage scenarios while delivering an intuitive and seamless user experience. By conducting thorough integration and system testing, developers endeavor to instill confidence in the reliability and functionality of the SIONLAP system, laying the groundwork for its successful deployment and operation in real-world environments.

2.5. Operation and Maintenance

In the final stage of Operation and Maintenance, the culmination of rigorous development efforts is realized as the SIONLAP system is primed for user operation and sustained maintenance [25]. This pivotal phase marks the transition from development to deployment, where the focus shifts toward ensuring the system's ongoing reliability, performance, and adaptability. At the heart of this stage lies the commitment to delivering a robust and user-centric solution that meets the evolving needs of stakeholders within the educational landscape.

Maintenance activities encompass a comprehensive review and inspection of every facet of the SIONLAP system, aimed at identifying any residual errors or discrepancies that may have eluded detection during earlier stages of development. Developers strive to rectify any lingering issues through meticulous error correction and debugging, ensuring the system operates seamlessly and reliably in real-world environments. Moreover, maintenance efforts extend beyond error correction to encompass system unit implementation improvements and enhancements designed to optimize system performance and functionality.

Furthermore, maintenance activities are informed by a keen understanding of user feedback and evolving requirements, driving iterative enhancements and adjustments to the system. This iterative approach to maintenance ensures that the SIONLAP system remains aligned with the dynamic needs and expectations of users, fostering a culture of continuous improvement and innovation. By prioritizing user satisfaction and system reliability, stakeholders can confidently leverage the SIONLAP system to enhance educational experiences and outcomes, driving positive impacts across the educational landscape.

Through ongoing maintenance efforts, the SIONLAP system evolves into a resilient and adaptive solution, capable of supporting the diverse needs of stakeholders and fostering a culture of excellence within educational institutions.

3. Results and Discussion

Based on the analysis of user experiences [17] and dissemination during training workshops and national seminars on SIONLAP in Indonesia, several user requirements have been identified, including (1) user-friendly user access management.

This should facilitate users with multiple roles, such as PLP/Technicians/Laboratory Assistants and educators (for example, PLP/Technicians/Laboratory Assistants who also act as instructors, as well as students); (2) simplification of equipment inventory data management and information flow; (3) the need for institutions to generate revenue from laboratory assets. Table 1 shows the SIONLAP 2.0 user access rights design.

Table.1 Design of SIONLAP 2.0 user access rights

Menu	Submenu	1	2	3	4	5	6	7
Master	Agency, Slider, Province, Semester	√						
	SIMAK Category, Item Category, Item, Unit	√						
	User Level, Identification Number Category	√						
	Lab Type, Funding Source, Subject, Obstacle Category, Work Category, FAQ		√					
Manage	User	√						
	Announcement	√	√					
	Laboratory (Lab Information, Lab Schedule, Lab Work, Lab Problems, Lab Guest Book, Stock Opname, Muasi Stock)		√					
	Laboratorium→ Module					√		
	Works					√	√	√
Submission	Object Submission		√	√	√	√	√	√
	Submission Period		√					
Transaction	New Transaction		√	√	√	√	√	√
	Transaction Status		√	√	√	√	√	√
	Dependent		√	√	√	√	√	√
Obstacles	List of Constraints					√	√	√
Guest Book						√	√	√
Lab List	Details, Inventory, Additional Inventory, Transactions, Dependents, Module, Schedule, Constraints, Works, Guestbook			√	√			
	Module						√	

The design of the SIONLAP 2.0 application is based on the analysis of user needs and specifications. The SIONLAP 2.0 system design follows a mockup approach featuring a left sidebar, top navigation, and centered content theme. The mockup wireframe developed is divided into three main groups: Fig. 2 represents the wireframe layout for managerial users (Admin, Lab Head, and Lab Chair).

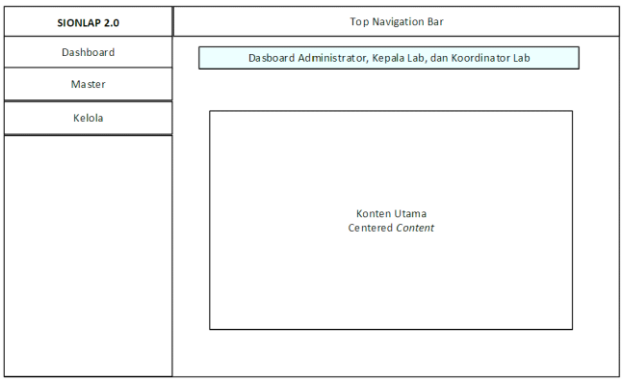

Fig. 2. Mockup of Administrator, Lab Head, and Lab Coordinator

Fig. 3 represents operational management users (PLP/Technician/Lab Assistant).

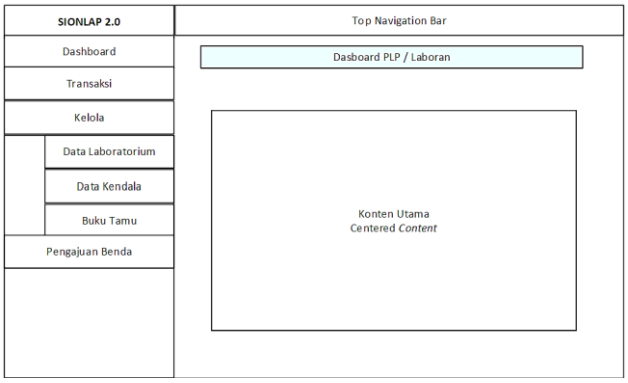

Fig. 3. PLP/Laboran Mockup

Fig. 4, it represents general users (Lecturers, Assistants, and Students).

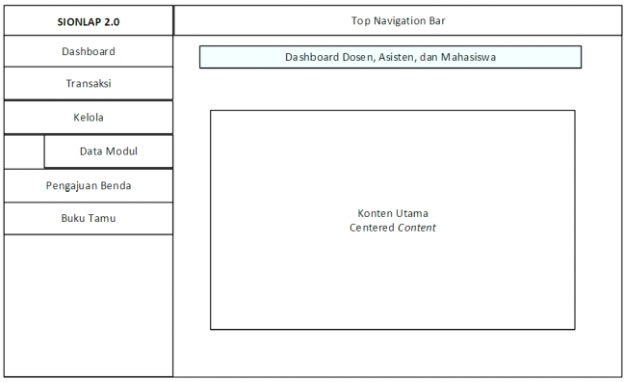

Fig. 4. Lecturer, Assistant, and Student Mockups

Realization is done by coding the program based on the SIONLAP architecture design and testing it in program units to ensure that the developed software aligns with the specified specifications. Application testing is conducted using the black box method.

Fig. 5 depicts the initial dashboard interface of the SIONLAP 2.0 application. The image includes a web information slider, Laboratory Data, view items, members, FAQ, and Sign options. To utilize this application, every user must have a registered account within the application, and each user must log in first according to their access rights before using the application.

Fig. 5. SIONLAP 2.0 Home View Dashboard

Fig. 6 illustrates the dashboard interface with Administrator access. This access level includes the following menus: 1) Master, with submenus including Institution, Category of Items, Items, SIMAK

Category, Unit, Slider, Semester, User Level, Province, and Category of ID Numbers. Fig. 5 showcases the test result of data entry for the institution's users of the SIONLAP 2.0. The aim is for this application to be utilized in all higher education institutions in Indonesia; 2) Manage Menu, with submenus managing Users and Announcements.

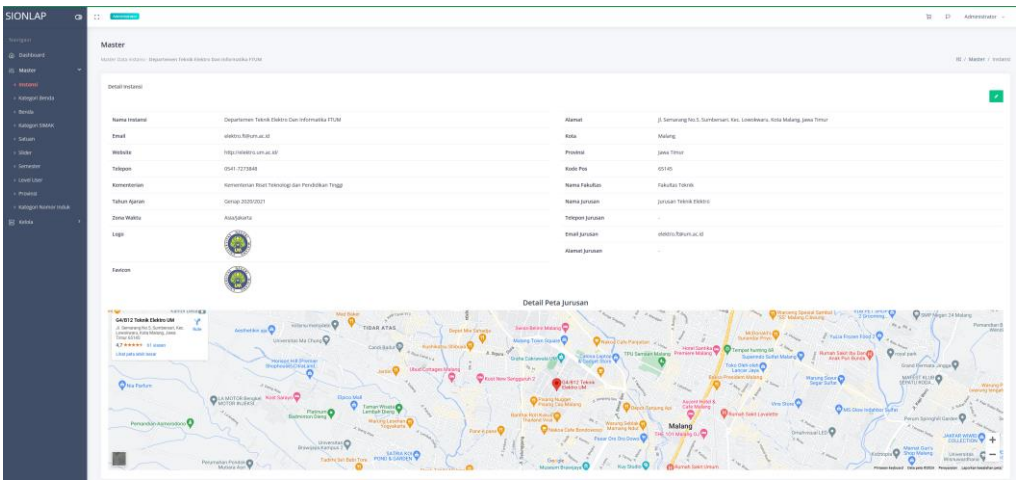

Fig. 6. SIONLAP 2.0 Administrator Dashboard

Fig. 7 demonstrates the capability of SIONLAP 2.0 in providing user-friendly access rights and facilitating users in higher education institutions with multiple roles.

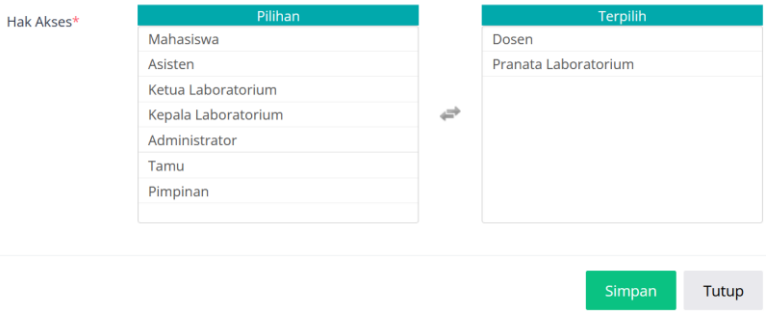

Fig. 7. SIONLAP 2.0 Administrator Dashboard Manage Users

In Fig. 8, SIONLAP 2.0 demonstrates its capability to streamline equipment data and inventory information management flow. When equipment shares the exact specifications, the equipment specification data entered into SIONLAP only needs to be done once, followed by entering the inventory code and equipment placement location.

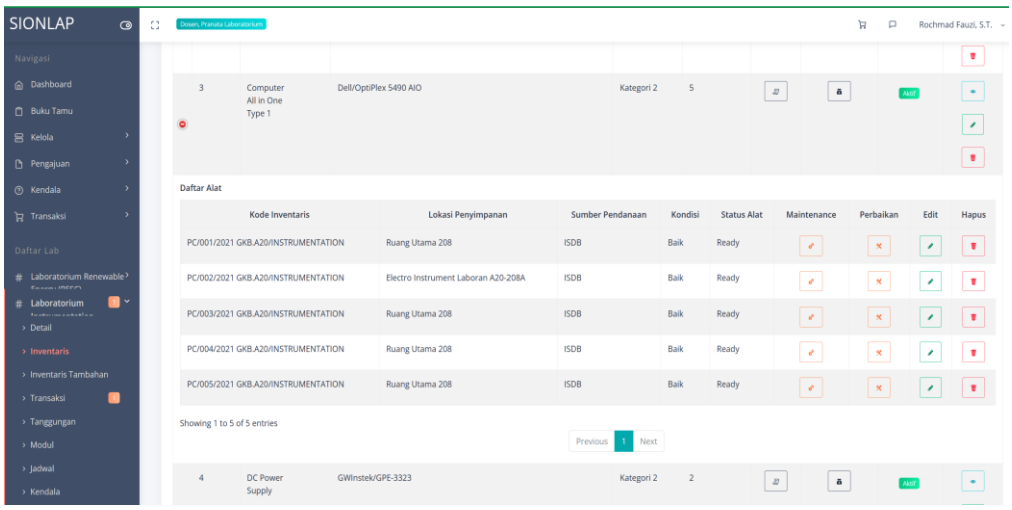

Fig. 8. Dashboard Manage Inventory on Laboratory Staff Access Rights

This application is equipped with Standard Operating Procedures (SOPs) for equipment operation, maintenance, inspection, calibration, and functionality testing, as presented in Fig. 9 equipment rental transactions.

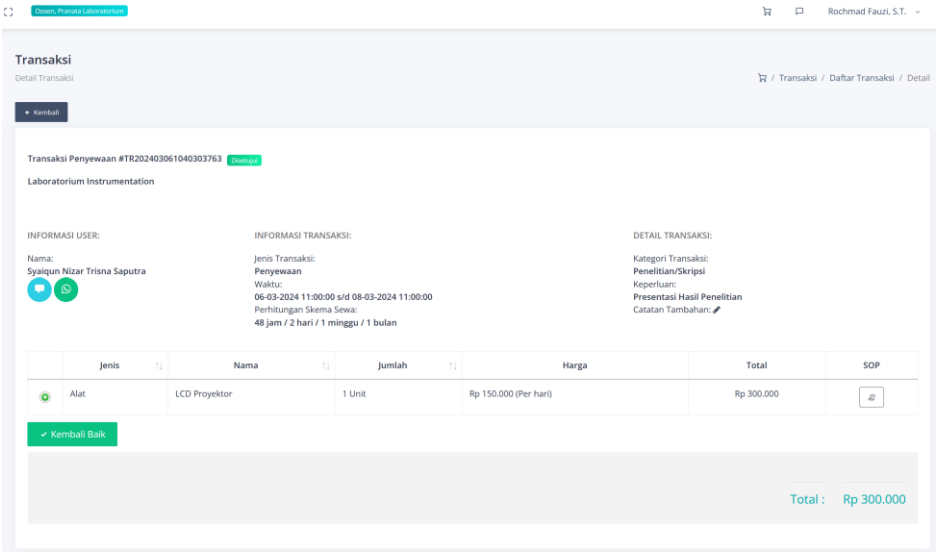

Fig. 9. Laboratory Equipment Rental Transaction Dashboard

At this stage, the SIONLAP 2.0 application has been realized and operationalized by users, and maintenance activities have been conducted.

The implementation of SIONLAP 2.0 has demonstrated its ability to meet various user needs in managing laboratories at higher education institutions. Based on a user needs analysis, SIONLAP 2.0 features have been designed to facilitate user access management for those with multiple roles and enhance laboratory inventory data management efficiency. Laboratory technicians, assistants, and technologists can now manage lab schedules, inventory, and issues more easily through a user-friendly interface and an integrated management system.

Application testing using the black box method has ensured that each program unit operates according to the specified requirements [26]. This is crucial to guarantee the reliability of the application in actual operational environments. Regarding inventory management, SIONLAP 2.0 streamlines the process of recording and monitoring inventory by requiring a single data entry for equipment with the exact specifications, followed by entering the inventory code and equipment placement location. This feature is expected to reduce the workload and minimize human errors in inventory management.

Furthermore, implementing standard operating procedures (SOPs) for equipment operation, maintenance, inspection, calibration, and functionality testing in SIONLAP 2.0 ensures that laboratory equipment is consistently in optimal condition and ready for use. This is crucial for maintaining quality and safety in laboratory practices. Incorporating these features into SIONLAP 2.0 enhances the efficiency and effectiveness of laboratory management and the quality of education and research at higher education institutions in Indonesia.

Implementing SIONLAP 2.0 in higher education environments in Indonesia has the potential to yield significant positive implications. Primarily, this system can markedly enhance the operational efficiency of laboratories. With a centralized management system and features such as user-friendly access management, simplified equipment inventory, and structured SOP implementation, SIONLAP 2.0 can reduce the administrative burden on laboratory staff, thereby enabling them to prioritize more critical tasks such as research and teaching.

The capacity to generate revenue from laboratory assets enables higher education institutions to optimize the utilization of their laboratory facilities [27]. This can facilitate collaboration with industries and other external parties, generating additional funding for the institutions [28]. This additional revenue can be utilized to enhance laboratory facilities, purchase new equipment, or support further research, enhancing the quality of education and research at the institutions.

In a broader sense, implementing SIONLAP 2.0 can facilitate the standardization of laboratory management across higher education institutions in Indonesia. By utilizing a unified system, there is the potential to create best practices that all institutions can adopt. This can enhance transparency, accountability, and the overall quality of laboratory management [29], [30]. Furthermore, the data generated from this system can be utilized for further analysis, providing valuable insights for decision-making at both the managerial level and national education policy. Consequently, the implementation of SIONLAP 2.0 not only affects individual institutions but also has the potential to influence the higher education system in Indonesia.

4. Conclusion

Drawing upon the findings of this research endeavor, it becomes evident that the development of the SIONLAP 2.0 application marks a significant stride forward, effectively resolving challenges encountered in its predecessor. Through meticulous refinement and innovation, SIONLAP 2.0 emerges as a robust and user-centric solution, equipped with an array of features and functionalities tailored to meet the diverse needs of stakeholders within higher education institutions. One of the critical strengths of SIONLAP 2.0 lies in its user-friendly access management capabilities, which empower users with multi-role functions to navigate and engage with the platform seamlessly. This enhancement enhances user satisfaction and fosters greater efficiency and productivity within educational settings, facilitating smoother collaboration and coordination among users with varying roles and responsibilities. Moreover, SIONLAP 2.0 introduces streamlined management workflows for equipment data and inventory information, simplifying processes and enhancing transparency and accountability in laboratory operations. By providing a centralized platform for managing equipment and inventory, SIONLAP 2.0 enables stakeholders to make informed decisions, optimize resource utilization, and streamline administrative tasks, fostering a more conducive learning and research environment. Furthermore, incorporating a feature for renting laboratory assets represents a significant advancement, enabling educational institutions to leverage their laboratory assets to generate additional income. This feature serves as a sustainable revenue stream for institutions and promotes efficient utilization of resources, maximizing the value derived from laboratory facilities. In essence, the development of SIONLAP 2.0 heralds a new era of innovation and excellence in laboratory management within higher education institutions. By addressing critical pain points and introducing transformative features, SIONLAP 2.0 paves the way for enhanced efficiency, productivity, and sustainability, ultimately advancing the mission of educational institutions to foster excellence in teaching, learning, and research.

References

[1] Y. Zhao, M. Zhao, and F. Shi, "Integrating Moral Education and Educational Information Technology: A Strategic Approach to Enhance Rural Teacher Training in Universities," *J. Knowl. Econ.*, vol. 15, no. 3, pp. 15053–15093, Dec. 2023, doi: 10.1007/s13132-023-01693-z.

[2] T. N. Fitria, "Understanding the Educational Psychology and English Language Teaching: Insights for both EFL and Non-EFL Learners," *JETLEE J. English Lang. Teaching, Linguist. Lit.*, vol. 4, no. 1, pp. 37–53, Jan. 2024, doi: 10.47766/jetlee.v4i1.1932.

[3] T. H. J. Marchand, *The pursuit of pleasurable work: Craftwork in twenty-first century England*, vol. 4. Berghahn Books, 2021, doi: 10.3167/9781800732742.

[4] K. K. Inkelas, J. E. Jessup-Anger, M. Benjamin, and M. R. Wawrzynski, *Living-learning communities that work: A research-based model for design, delivery, and assessment*, 1st ed. Taylor & Francis, p. 16, 2023, doi: 10.4324/9781003445777-1 .

[5] B. D. Ruben, R. De Lisi, and R. A. Gigliotti, *A guide for leaders in higher education: Concepts, competencies, and tools*. 2n ed, Taylor & Francis, p. 486, 2023, doi: 10.4324/9781003442769.

[6] A. R. Saravanakumar, K. Krishnamoorthi, A. Saravanakumar, K. Krishnamoorthy, and K. Krishnamoorthy Head, "Empowering Minds: The Evolution of Higher Education in Tamil Nadu towards Innovation and Excellence," pp. 1–8, 2023, doi: 10.32388/LXTI2J.

[7] P. S. Aithal and S. Aithal, "Key Performance Indicators (KPI) for Researchers at Different Levels & Strategies to Achieve it," *Int. J. Manag. Technol. Soc. Sci.*, vol. 8, no. 3, pp. 294–325, 2023, doi: 10.47992/IJMTS.2581.6012.0304.

[8] M. du Plessis, C. D. Jansen van Vuuren, A. Simons, J. Frantz, N. Roman, and M. Andipatin, "South African higher education institutions at the beginning of the Covid-19 pandemic: Sense-making and lessons learnt," in *Frontiers in education*, 2022, vol. 6, doi: 10.3389/feduc.2021.740016.

[9] G. Bugtai, J. Batilaran, and O. K. Kilag, "Enhancing Science Education in Middle Schools: A Systematic Review," *Int. Multidiscip. J. Res. Innov. Sustain. Excell.*, vol. 1, no. 2, pp. 7–13, 2024, [Online]. Available at: https://risejournals.org/index.php/imjrise/article/view/32.

[10] M. Shaikh and F. Birajdar, "Ensuring Purity and Health: A Comprehensive Study of Water Quality Testing Labs in Solapur District for Community Well-being," *Int. J. Innov. Sci. Res. Technol.*, vol. 9, no. 1, pp. 271–281, 2024, [Online]. Available at: https://ijisrt.com/ensuring-purity-and-health-a-comprehensive-study-of-water-quality-testing-labs-in-solapur-district-for-community-wellbeing.

[11] E. Panagiotidou, P. T. Chountalas, A. I. Magoutas, and F. C. Kitsios, "The multifaceted impact of ISO/IEC 17025 accreditation: a sector-specific analysis in civil engineering testing and calibration laboratories," *TQM J.*, 2024, doi: 10.1108/TQM-10-2023-0347.

[12] E. O. Itua, J. T. Bature, and M. A. Eruaga, "Pharmacy practice standards and challenges in Nigeria: a comprehensive analysis," *Int. Med. Sci. Res. J.*, vol. 4, no. 3, pp. 295–304, 2024, doi: 10.51594/imsrj.v4i3.921.

[13] O. J. Akindote, A. O. Adegbite, A. Omotosho, A. Anyanwu, and C. P. Maduka, "Evaluating the effectiveness of it project management in healthcare digitalization: a review," *Int. Med. Sci. Res. J.*, vol. 4, no. 1, pp. 37–50, 2024, doi: 10.51594/imsrj.v4i1.698.

[14] S. H. AL Thagafi, A. A. AL Mutairi, O. K. Qassem, N. E. AL Sbeay, and I. S. AL Sowailim, "Revolutionizing Healthcare: The Technological Transformation of Medical Laboratory Outcomes," *Int. J. Biol. Pharm. Sci.*, vol. 8, no. 1, pp. 1–8, Aug. 2022, doi: 10.53555/EIJBPS.V8I1.41.

[15] E. S. Lee, B. Szkudlarek, D. C. Nguyen, and L. Nardon, "Unveiling the canvas ceiling: A multidisciplinary literature review of refugee employment and workforce integration," *Int. J. Manag. Rev.*, vol. 22, no. 2, pp. 193–216, 2020, doi: 10.1111/ijmr.12222.

[16] C. Creed, M. Al-Kalbani, A. Theil, S. Sarcar, and I. Williams, "Inclusive AR/VR: accessibility barriers for immersive technologies," *Univers. Access Inf. Soc.*, vol. 23, no. 1, pp. 59–73, 2024, doi: 10.1007/s10209-023-00969-0.

[17] J. J. Pittaway and A. R. Montazemi, "Know-how to lead digital transformation: The case of local governments," *Gov. Inf. Q.*, vol. 37, no. 4, p. 101474, 2020, doi: 10.1016/j.giq.2020.101474.

[18] H. Crompton, M. V Jones, and D. Burke, "Affordances and challenges of artificial intelligence in K-12 education: A systematic review," *J. Res. Technol. Educ.*, vol. 56, no. 3, pp. 248–268, 2024, doi: 10.1080/15391523.2022.2121344.

[19] B. V. Thummadi and K. Lyytinen, "How Much Method-in-Use Matters? A Case Study of Agile and Waterfall Software Projects," *J. Assoc. Inf. Syst.*, vol. 21, no. 4, pp. 864–900, Jul. 2020, doi: 10.17705/1jais.00623.

[20] T. Thesing, C. Feldmann, and M. Burchardt, "Agile versus Waterfall Project Management: Decision Model for Selecting the Appropriate Approach to a Project," *Procedia Comput. Sci.*, vol. 181, pp. 746–756, Jan. 2021, doi: 10.1016/j.procs.2021.01.227.

[21] K. Oyibo, "EMVE-DeCK: a theory-based framework for designing and tailoring persuasive technology," in *Adjunct proceedings of the 29th acm conference on user modeling, adaptation and personalization*, 2021, pp. 257–267, doi: 10.1145/3450614.3464617.

[22] Q. Lu, L. Zhu, X. Xu, J. Whittle, and Z. Xing, "Towards a roadmap on software engineering for responsible AI," in *Proceedings of the 1st International Conference on AI Engineering: Software Engineering for AI*, 2022, pp. 101–112, doi: 10.1145/3522664.3528607.

[23] T. Natarajan and S. Pichai, "Transition from Waterfall to Agile Methodology-An Action Research Study," *IEEE Access*, 2024, doi: 10.1109/ACCESS.2024.3384097.

[24] A. E. H. Berjawi, S. L. Walker, C. Patsios, and S. H. R. Hosseini, "An evaluation framework for future integrated energy systems: A whole energy systems approach," *Renew. Sustain. Energy Rev.*, vol. 145, p. 111163, 2021, doi: 10.1016/j.rser.2021.111163.

[25] H. Allioui and Y. Mourdi, "Exploring the full potentials of IoT for better financial growth and stability: A comprehensive survey," *Sensors*, vol. 23, no. 19, p. 8015, 2023, doi: 10.3390/s23198015.

[26] X. Feng *et al.*, "Snipuzz: Black-box fuzzing of iot firmware via message snippet inference," in *Proceedings of the 2021 ACM SIGSAC conference on computer and communications security*, 2021, pp. 337–350, doi: 10.1145/3460120.3484543.

[27] M. Usman and A. Ab Rahman, "Funding higher education through waqf: a lesson from Pakistan," *Int. J. Islam. Middle East. Financ. Manag.*, vol. 14, no. 2, pp. 409–424, 2021, doi: 10.1108/IMEFM-05-2019-0200.

[28] A. Leckel, S. Veilleux, and L. P. Dana, "Local Open Innovation: A means for public policy to increase collaboration for innovation in SMEs," *Technol. Forecast. Soc. Change*, vol. 153, p. 119891, 2020, doi: 10.1016/j.techfore.2019.119891.

[29] A. Alamanos, P. Koundouri, L. Papadaki, T. Pliakou, and E. Toli, "Water for tomorrow: A living lab on the creation of the science-policy-stakeholder interface," *Water*, vol. 14, no. 18, p. 2879, 2022, doi: 10.3390/w14182879.

[30] S. Reddy, "Generative AI in healthcare: an implementation science informed translational path on application, integration and governance," *Implement. Sci.*, vol. 19, no. 1, p. 27, 2024, doi: 10.1186/s13012-024-01357-9.