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SLMS: Development of a Science Laboratory Management System with Analytics Using the Apriori Algorithm

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ABSTRACT

This study developed a Science Laboratory Management System (SLMS) with analytics using the Apriori Algorithm to improve science laboratory resource management and support data-driven decision-making. The study used Agile Software Development methodology to guide the system's design, development, testing, and evaluation. The system developed modules for user management, equipment and chemical inventory, borrowing and return transactions, report generation, and an analytics dashboard. Historical laboratory transaction data were processed using the Apriori Algorithm to identify frequent itemsets and association rules among laboratory equipment, materials, chemicals, and activities. The developed system was evaluated using the ISO/IEC 25010 Software Quality Model in terms of functional suitability, performance efficiency, usability, reliability, security, maintainability, and portability. Results demonstrated that the system effectively automated key laboratory management processes and generated meaningful usage patterns that could support inventory monitoring, procurement planning, and resource allocation. The system received an overall evaluation interpreted as excellent, indicating its acceptability and suitability for laboratory operations. The findings suggest that integrating association rule mining into science laboratory management can enhance operational efficiency and provide actionable insights for administrators. Future enhancements may include predictive analytics, barcode or RFID integration, mobile and cloud deployment, and interoperability with institutional information systems.

Keywords: Science Laboratory Management System; Apriori Algorithm; Data Analytics; Laboratory Resource Management; Association Rule Mining

INTRODUCTION

Inventory refers to the finished goods or raw materials used which are available for sale (Kenton, 2024). It can be categorized into three different ways, which are raw materials, work in progress and finished products. Inventory management refers to managing various inventories. It is where inventory is stored until it is needed and tracks, controls, and optimizes different materials from different facilities.

Managing inventory has different approaches: digital and traditional pen-and-paper approach. The traditional pen-and-paper approach heavily relies on manually updating stocks and inventory whereabouts. However, there are drawbacks to using this kind of approach. Despite having simplicity and being inexpensive, pen-and-paper is prone to human-errors. Paper documents are hard to manage, especially when they are piled up.

Many laboratories use paper-based inventory and management systems, which are frequently inefficient, risky for data security, cause information to be misinterpreted, and increase operating expenses as compared to automated solutions (Seo, 2023). Comparably, relying too much on paper-based laboratory data raises the risk of data loss, compliance problems, and mistakes brought on by unreadable or lost records, which eventually affects accuracy, traceability, and overall productivity (LabWare, 2025).

Implementing a digital inventory could significantly improve efficiency institutions like Centro Escolar University, which currently relies on manual pen-and-paper methods for tracking chemicals and equipment. A digital solution would not only enhance inventory accuracy and traceability but also enable better planning,

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improved compliance, and optimized use of laboratory resources.

The proposed Science Laboratory Management System (SLMS) can automate laboratory operations by maintaining records of equipment, chemicals, and user transactions. However, beyond automation, institutions can benefit from analytics that uncover patterns in laboratory resource usage.

The Apriori Algorithm, a well-known association rule mining technique, can identify frequently occurring combinations of laboratory materials, equipment, and activities. The generated insights can assist laboratory administrators in forecasting demand, optimizing inventory levels, planning laboratory activities, and improving resource allocation.

In the study of Aprilia, Mesran, and Waruwu, they applied the Apriori method to a chemical inventory system at the Medan Forensic Laboratory. Their study demonstrated the application of data mining to laboratory inventory data, particularly in identifying relationships among chemical items. The study provides a relevant basis for applying association-rule mining to laboratory resource management. Similarly, the present study applies the Apriori Algorithm in a Science Laboratory Management System to identify patterns among laboratory equipment, materials, chemicals, and experimental activities. However, unlike the previous study, the proposed SLMS integrates the Apriori-based analytics into a broader laboratory management system encompassing inventory, equipment, transactions, reporting, and analytics.

Objectives of the study

General Objective

To develop and evaluate a Science Laboratory Management System with analytics capabilities using the Apriori Algorithm to improve laboratory resource management and decision-making.

Specific Objectives

1. To design and develop a Science Laboratory Management System for managing:

- Laboratory inventory
- Equipment monitoring
- Chemical management
- User and transaction records

2. To implement the Apriori Algorithm for analyzing laboratory transaction and usage data.
3. To identify frequently used combinations of:

- Laboratory equipment
- Chemicals
- Laboratory activities
- Science experiments

4. To generate analytical reports and recommendations for laboratory administrators.
5. To evaluate the system in terms of:

- Functional suitability

- Performance efficiency
- Usability
- Reliability
- Security
- Maintainability

Conceptual Framework

The conceptual framework of the study adopts the Input–Process–Output (IPO) model to illustrate the development and operation of the proposed Science Laboratory Management System (SLMS). The input consists of laboratory inventory records, equipment usage logs, and user transaction data. These data undergo systematic collection and storage, inventory monitoring, transaction processing, and analysis using the Apriori Algorithm. The algorithm identifies frequent itemsets and association rules from laboratory transactions, which are subsequently presented through an analytics dashboard. The resulting outputs include the Science Laboratory Management System, inventory reports, equipment utilization reports, inventory usage insights, and association rules with corresponding recommendations. A feedback mechanism is incorporated to represent the continuous generation of new laboratory transaction data, which can be used for subsequent analysis and system improvement. The framework demonstrates how raw laboratory data can be transformed into actionable information to support efficient laboratory resource management and data-informed decision-making.

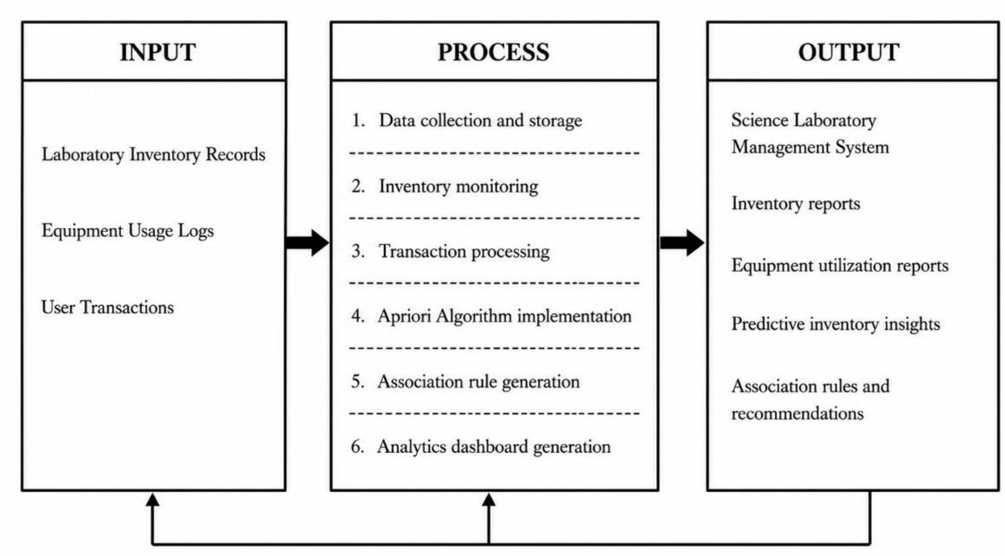

Figure 1. Conceptual Framework

REVIEW OF RELATED LITERATURE

Laboratory Inventory Management Systems

Inventory management is an important part of supply chain and logistics systems in different industries, including laboratories. It helps keep operations efficient by making sure there is a good balance between the amount of stock and the actual demand. To manage inventory well, it's important to consider whether demand is predictable (deterministic) or uncertain (stochastic), and whether items are independent or rely on other items in the system (Munyaka & Yadavalli, 2022). In laboratories, inventory management goes beyond just counting items. Modern systems can automate monitoring, store important Safety Data Sheets (SDS), and give real-time updates on the availability of reagents and equipment. These features help reduce waste, avoid running out of materials, and make work more efficient while also ensuring safety compliance (Gummaru et al., 2025).

Web-based Equipment and Chemical Systems

Web-based laboratory management systems make it easier to keep track of equipment and chemical inventories by giving centralized, real-time access. This makes them more efficient and scalable compared to traditional paper-based or desktop-only systems. Adekunle et al. (2024) created a Web-Based Laboratory Management System (WBLMS) that automated reservations, allowed real-time monitoring, and reduced manual errors. Other studies also show that using QR codes and RFID-based web applications can make inventory tracking faster and more accurate because updates happen instantly.

Partosa et al. (2024) found that using digital inventory systems in academic laboratories improves data accuracy and workflow while reducing the need for manual record-keeping. Similarly, Krutskikh et al. (2024) introduced a Smart Cloud Equipment Tracking and Control System that uses QR codes to connect laboratory instruments to a centralized cloud database for real-time tracking and better asset management. Rabiah et al. (2022) also pointed out that web-based systems are more scalable, can be accessed remotely, and are easier to maintain than desktop-based solutions. These benefits—such as less downtime, better collaboration, and more accurate management—are in line with the goals of our proposed research, which aims to use automated and cloud-enabled laboratory management.

AI Integration in Inventory and Scheduling

Recent developments in artificial intelligence (AI) have made a big impact on inventory tracking and scheduling in many industries, including laboratory management. According to Taertulakarn et al. (2023), AI-powered systems can automatically monitor inventory by checking stock levels and predicting future supply needs using machine learning and data analysis. This reduces the human errors often seen in manual data entry and allows laboratories to make better decisions by anticipating demand. In our case, MOLECULES uses these same capabilities to keep track of chemicals and equipment, making sure that resources are organized, scheduled, and allocated efficiently.

Akanbi et al. (2024) also show how AI can improve supply chain management by making forecasts more accurate and automating reorders. This helps lower costs, prevent running out of supplies, and make the procurement process faster. Similarly, Ünal et al. (2023) explain that AI's predictive analytics and automation can make inventory control and scheduling more efficient, which in turn improves overall operations.

METHODOLOGY

The system was developed in response to the specific needs of the Science laboratory. This study utilizes both developmental and quantitative research approaches. The developmental approach made it possible for the researchers to design and improve the system based on actual laboratory practices and user requirements. Meanwhile, the quantitative approach was used to collect and analyze feedback through surveys and evaluation instruments in order to measure the system's usability, accuracy, and effectiveness. By combining these two approaches, the development process was guided by real-world functionality and validated through measurable data, allowing the system to meet both technical and administrative expectations.

Respondents of the Study

Respondents of the study consist of a total of forty-three (43) participants, which are: five (5) IT

Practitioners, three (3) Science laboratory technicians, and thirty-five (35) requisitioners consisting of students and faculty of medical courses.

The researchers selected these participants to evaluate the system's functionality, effectiveness and reliability to its users and administrators. Respondents composed of five (5) IT practitioners to assess the overall system, both user and admin roles. Three (3) Science laboratory technicians are needed to evaluate the admin role of the system. Lastly, thirty-five (35) faculty and student requisitioners of medical courses are picked to evaluate the overall functionality and compatibility of the user role of the system.

Respondents	**Number of Respondents**
IT Practitioners	5
Science Laboratory Technician	3
Faculty and Student Requisitioners	35

Likert Scale

The study employed a structured 4-point Likert scale to quantitatively assess system performance and user satisfaction. This scale was specifically designed to measure respondents' assessments with the following responses:

Table 1. Likert Scale

Score Interval (Mean)	**Scale**
Poorly Functional	1
Moderately Functional	2
Functional	3
Very Functional	4

Data Gathering

The research team implemented a systematic data collection process to evaluate and enhance the system's functionality. Utilizing Google Forms as the primary data collection instrument, the researchers distributed structured questionnaires to relevant stakeholders. This digital approach ensured efficient data gathering while maintaining the integrity of responses.

All collected response data remained confidential, in strict compliance with the Data Privacy Act of 2012 (Republic Act No. 10173), with access limited exclusively to the research team members. The researchers employed statistical analysis techniques to process quantitative data, identifying patterns and areas requiring system improvement. These findings directly informed iterative refinements to the system architecture and user interface, addressing minor operational errors and usability concerns.

Data Processing and Statistical Treatment

The research team processed all collected data using Microsoft Excel's statistical tools. For quantitative analysis, the mean was calculated for each survey question to determine average

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response values, providing a standardized measure of central tendency across all responses. This statistical approach enabled systematic evaluation of user perceptions regarding system performance and functionality.

RESULTS AND DISCUSSION

System Development Results

The Science Laboratory Management System (SLMS) was successfully developed to automate laboratory operations and provide analytics-driven insights for laboratory administrators. The system consists of the following modules:

- User Management
- Equipment Inventory Management
- Chemical Inventory Management
- Borrowing and Return Management
- Report Generation
- Analytics Dashboard
- Apriori-Based Association Rule Mining

The system enables laboratory personnel to record transactions electronically, monitor inventory levels in real time, and generate reports related to equipment utilization, chemical consumption, and laboratory activities.

Apriori Algorithm Results

Historical laboratory transaction records consisting of 1,250 laboratory activities conducted during the academic year were analyzed using the Apriori Algorithm.

Table 2. Frequent Itemsets Identified

Item Combination	Support (%)
Microscope, Glass Slides	72.4
Beaker, Graduated Cylinder	68.8
Test Tube, Test Tube Rack	64.5
Microscope, Glass Slides, Staining Solution	58.2
Bunsen Burner, Tripod Stand	55.6

Table 2 presents the most frequently occurring item combinations. The results indicate that several laboratory materials are consistently used together during laboratory exercises. The combination of microscope and glass slides recorded the highest support value of 72.4%, indicating that these items are frequently requested simultaneously.

Association Rules Generated

Table 3 shows selected association rules generated by the Apriori Algorithm.

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Table 3. Association Rules Generated

Association Rule	**Support (%)**	**Confidence (%)**
Microscope → Glass Slides	72.4	95.8
Glass Slides → Staining Solution	58.2	84.6
Test Tube → Test Tube Rack	64.5	92.1
Bunsen Burner → Tripod Stand	55.6	89.4
Beaker → Graduated Cylinder	68.8	93.5

The rule "Microscope → Glass Slides" achieved a confidence level of 95.8%, suggesting that when microscopes are utilized, glass slides are almost always required. This information may assist laboratory administrators in forecasting inventory requirements and ensuring the availability of complementary resources.

Similarly, the rule "Beaker → Graduated Cylinder" obtained a confidence level of 93.5%, indicating a strong relationship between these laboratory materials during experimental activities.

The findings demonstrate that the Apriori Algorithm effectively identifies resource usage patterns that may support procurement planning, inventory optimization, and laboratory preparation.

The tables shown below contain the raw data gathered from the evaluation forms in tabular form. It contains the mean per question, per category, and the overall for each evaluator.

Table 2. Summary of Evaluation Results

Evaluation Criterion	**IT Practitioners**	**Science Laboratory Technicians**	**Student/Faculty Requisitioners**
Functional Suitability	3.67	4.00	3.23
Performance Efficiency	4.00	4.00	3.22
Compatibility	3.75	—	—
Usability	3.92	4.00	3.34
Reliability	4.00	—	—
Security	3.75	—	—
Maintainability	3.80	—	—
Portability	4.00	—	—
Overall Mean	**3.86**	**4.00**	**3.26**
Verbal Interpretation	Excellent	Excellent	Very Good

The results indicate that the developed system received positive evaluations from all three respondent groups. The IT practitioners obtained an overall mean of 3.86, indicating an excellent assessment of the system's technical qualities. In particular, Performance Efficiency, Reliability, and Portability received a mean of 4.00, while Usability obtained 3.92, demonstrating strong technical and operational performance.

The Science Laboratory Technicians gave the highest overall mean of 4.00, indicating an excellent assessment of the system in terms of Functional Suitability, Performance Efficiency, and Usability. This suggests that the system effectively addresses the operational requirements of laboratory personnel.

Meanwhile, student and faculty requisitioners obtained an overall mean of 3.26, indicating a very good assessment. Usability received the highest criterion mean at 3.34, followed by Functional Suitability at 3.23 and Performance Efficiency at 3.22. These results suggest that the system is generally functional, efficient, and user-friendly from the perspective of its end users.

Overall, the findings demonstrate that the system was positively evaluated by its technical evaluators, administrators, and end users, confirming its suitability for science laboratory management and resource-related transactions.

CONCLUSIONS

The data gathered from the evaluation forms completed by IT experts and users of the developed system provided the researchers with a clear understanding that the system’s development goals were successfully achieved. All objectives of the study were fulfilled. The researchers were able to create a functional system that supported the Science Laboratory, as well as the students and faculty, by reducing the difficulties associated with laboratory equipment requisition, inventory management, and data reporting. The system was evaluated by IT industry practitioners and end-users based using the ISO 25010 standard. The identified limitations served as the foundation for recommendations for future improvements.

RECOMMENDATIONS

Based on the findings and conclusions of the study, the following recommendations are proposed:

1. Expand the scope of laboratory data collection. Future implementations should continuously collect transaction and usage data to improve the accuracy and relevance of the Apriori Algorithm results. A larger dataset may generate stronger and more meaningful association rules.

2. Integrate predictive analytics and machine learning techniques. Future researchers may incorporate forecasting models, classification algorithms, or artificial intelligence techniques to predict laboratory supply consumption, equipment maintenance schedules, and laboratory utilization trends.

3. Develop mobile and cloud-based versions of the system. Enhancing the system with mobile accessibility and cloud deployment may improve accessibility, real-time monitoring, and collaboration among laboratory personnel, faculty members, and administrators.

4. Integrate barcode or RFID technology. Future enhancements may include barcode or RFID-based inventory tracking to improve the efficiency and accuracy of equipment borrowing, return transactions, and inventory audits.

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