ENHANCED RFID-BASED EQUIPMENT BORROWING AND INVENTORY SYSTEM FOCUSED ON SCALABILITY, AUTOMATION, AND MONITORING

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ABSTRACT

The improved RFID-based equipment borrowing and inventory system shown in this project was intended to increase engineering lab productivity, security, and scalability. The system streamlined equipment administration for lab assistants' automated transaction recording. It allowed real-time monitoring by moving from a manual to a web-based solution. It used RFID technology for precise user and object identification, incorporated automatic report production that complies with ISO requirements and built using JavaScript and MySQL to allow both online and offline operations. To ensure long-term maintainability and flexibility across academic institutions, the system placed strong emphasis on data protection, intuitive user interfaces, and modular development. In addition to enhancing daily lab operations, the system laid the groundwork for upcoming integrations, which include analytics, IoT compatibility, and institution-wide implementation.

Keywords: Web-Based application, MySQL database, inventory management, automation, data security.

INTRODUCTION

In higher education, laboratory facilities are essential components of learning and research across disciplines, including engineering, health, and the natural sciences. As laboratories increasingly adopt automation to enhance efficiency and accuracy in record-keeping, it becomes imperative for other laboratories to integrate similar technologies to maintain competitiveness and operational effectiveness. One such innovation is Radio Frequency Identification (RFID) technology, which has proven effective in improving equipment monitoring and scalability in borrowing systems, particularly within engineering laboratories.

At present, the borrowing system utilized in the Computer Engineering, Electrical Engineering, and Electronics Engineering laboratories of the university operates through manual procedures. While these traditional methods are familiar, they are also time-consuming, prone to human error, and lack real-time tracking capabilities. Consequently, this results in outdated records, reduced accountability, and inefficiencies in asset monitoring. The study “Design and Development of Equipment Borrowing System for ECE, EE, and CpE Laboratories” by Vyron et al. (2023) addressed these challenges by introducing an RFID-based automated system designed to streamline equipment borrowing and returning processes. Using MS Access, the researchers developed a database containing equipment information, RFID numbers, transaction histories, and user profiles. Their implementation demonstrated successful RFID scanning and transaction recording, thereby enhancing accuracy and efficiency in laboratory operations.

This paper built upon existing literature and technological frameworks relevant to laboratory inventory management, incorporating web development and database management concepts. Web development involves the creation and maintenance of interactive web platforms and applications through both front-end technologies—such as HTML, CSS, and JavaScript—and back-end programming languages, including Python, PHP, and Ruby. Complementing these technologies is the use of a Database Management System (DBMS), which is essential for the organization, retrieval, and maintenance of structured data. Among modern DBMS platforms, MySQL stands out as a reliable open-source relational database management system that supports data definition, manipulation, and querying. It provides robust performance, scalability, and maintainability, making it well-suited for developing efficient, web-based equipment borrowing systems.

Objectives of the Study

The main objective of this study was to enhance the existing borrowing system in the EE, ECE, and CpE laboratories without sacrificing the accuracy, efficiency, and security of the current database. Specifically, it sought to answer the following:

1. Increase the system's reach by making it available in all of the School of Engineering's labs, including physics and other courses that need lab-based borrowing. This may be done by using both an offline and an online database backup system. This allows many departments and courses to use the system, regardless of their web reliability or technological setup.

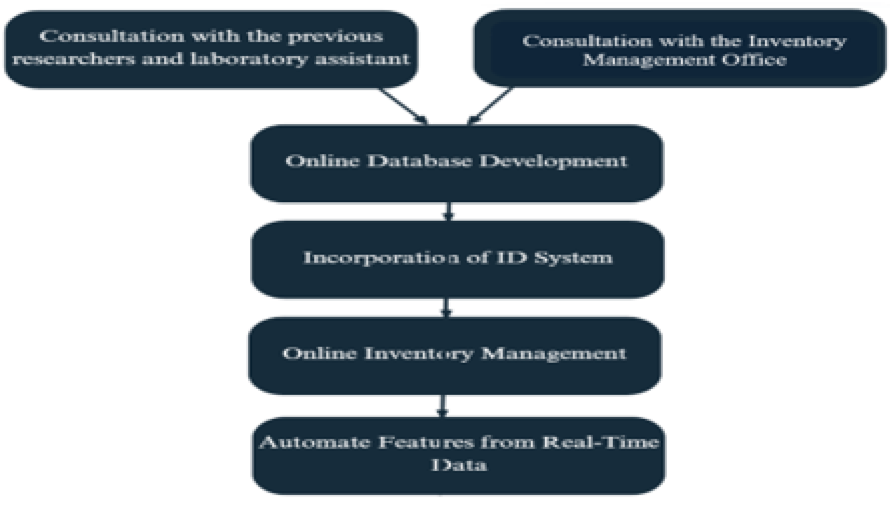
2. Enable the automatic creation of required laboratory forms and integrate system-driven verification of borrowed items to automate the equipment checking and documentation procedures. To help lab workers effectively manage and document equipment transactions, the system included incident report forms, damage reports, and borrowing slips, all of which can be reviewed and printed directly from the system.

Theoretical Framework

This study was a continuation of the thesis project, Design and Development of Equipment Borrowing System for ECE, EE, and CpE Laboratories, by Buen et al. (2023), to identify underlying concerns in the current system and ensure its availability to other departmental laboratories.

Conceptual Framework

Figure 1
Enhancement Process for Scalability and Automating



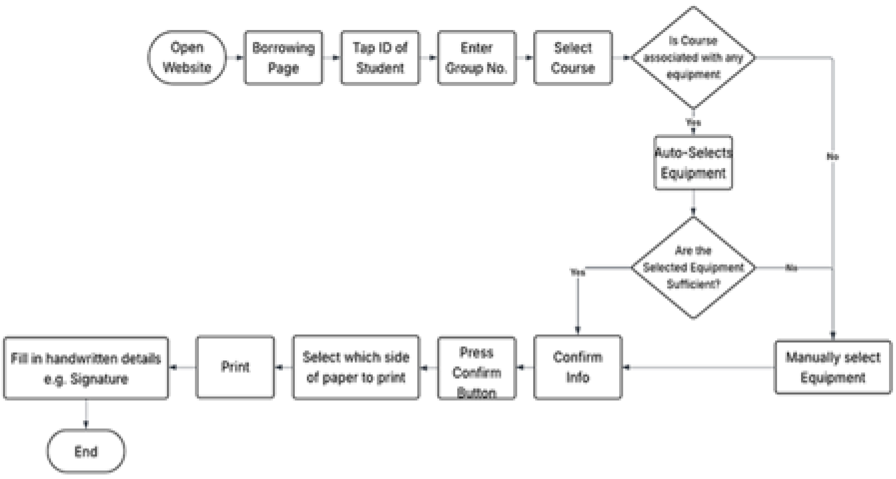
Before proceeding with systemic development, some underlying concerns and processes had to be addressed with the laboratory assistant, previous researchers, and the accounting office to ensure full immersion in the entire framework. Other areas of consultation included its security, scalability, and accessibility.

After that, the researchers developed a prototype of a front and back-end online database for scalability purposes. This was where the researchers utilized MySQL, an online database platform for storing data and real-time status. Additionally, the system retained the features from the previous research paper, which involved a unique identification system for professors, laboratory assistants, students, and equipment. This helped demonstrate how other laboratories and assistants could benefit from the system even without RFID, thereby making it more scalable. Lastly, the researchers prototyped automated features, such as data analytics and report generation, without sacrificing authenticity or accuracy. The automated system was also based on the consulted information from the previous paper, the inventory management office, and the laboratory assistant.

Architectural Framework

Figure 2

Architectural Layer Process for Automation



METHODOLOGY

Research Design

Figure 3

Architectural Layer Process for Monitoring and Scalability

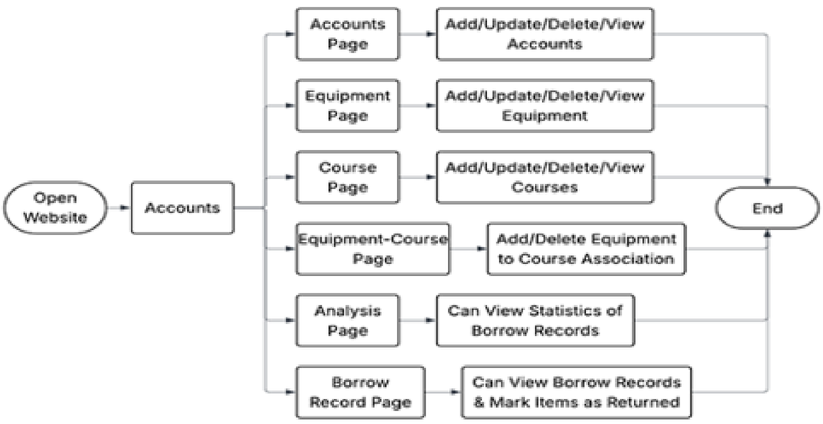
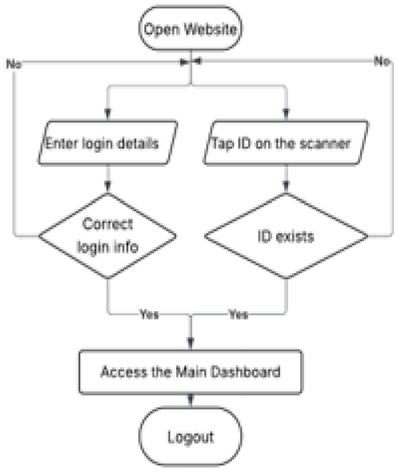


Figure 4
Website Login System



Lab assistants can access the website by either entering their login details or by tapping their recorded ID. The system will verify whether those accounts exist using the username and password, or by their ID. Once their accounts are verified, the system will open the main dashboard for them to use. On the accounts page, lab assistants can add other lab assistants who may use the system. It requires their username, password, ID, and lab room no. To record their ID, they would need to tap their ID into the scanner. The new lab assistant would need to remember their username and password to access the system.

Figure 5
Flowchart of Creating an Account for Lab Assistant

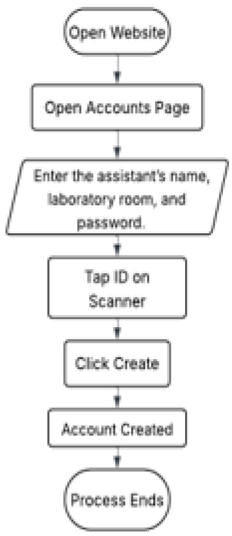
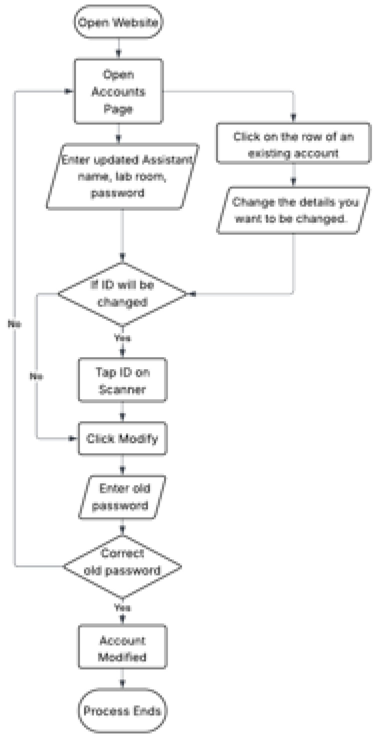
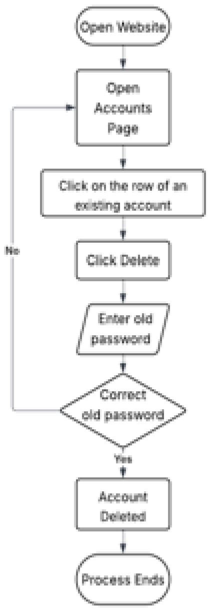


Figure 6
Flowchart of updating the details of an existing account



To update account details, they have to click the row of their account and change the inputs to the correct ones. They would be asked to enter their old password to verify their identity before changing the account details.

Figure 7
Flowchart of deleting an existing account



A lab assistant will need to click on an existing account in the table. Next, he/she would click the delete button, then type the correct password to confirm it is them. The account will be deleted if the password is correct.

Lab assistants will require students to tap their IDs to enter their information. The lab assistant may add the group number if needed. Then, the lab assistant will select the course, enter the instructor's name, and select from a preset list of equipment. The lab assistant may select equipment beyond the preset list. After adding the required equipment, users can confirm the details. The lab assistant will choose which side of the paper they will print the slip on, which will be signed with a pen.

Figure 8
Flowchart for borrowing equipment

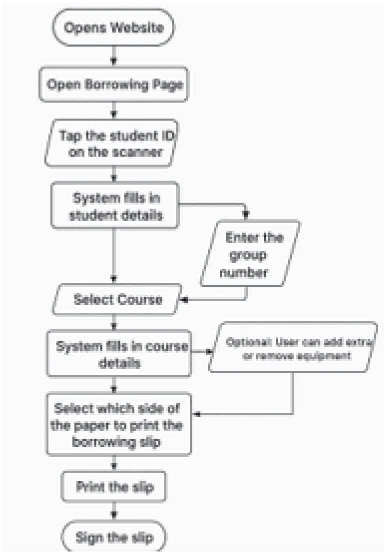
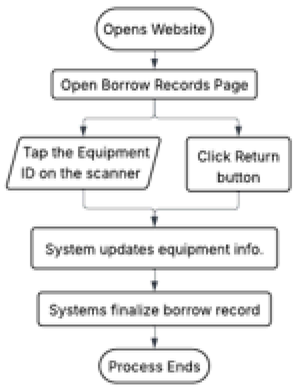


Figure 9
Flowchart of Returning Equipment



The lab assistant will go to the borrow records page (Figure 9). They would need to find the borrowed items and tap the return button or tap the item's RFID to have the system detect it. The system will record the borrowing transaction.

On the courses page (Figure 10), lab assistants can add courses that may use the laboratory assigned to them. It requires the course code, course name, lab room, and instructor name.

To update course details, they would need to click the course row and update the inputs to the correct values. Then, they would need to click the update button to change the records.

A lab assistant will need to click on an existing course on the table. Next, they would click the delete button to delete the course from the list.

Figure 10
Flowchart of Adding Courses

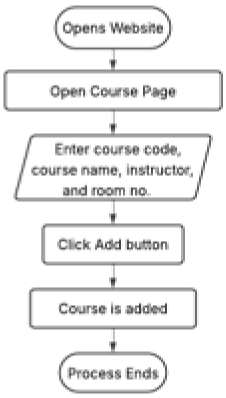


Figure 11
Flowchart of updating the details of an existing course

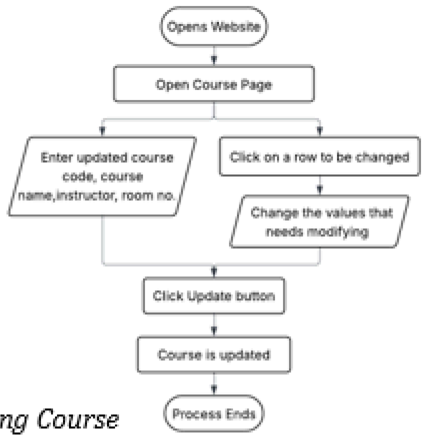


Figure 12
Flowchart of Deleting an Existing Course

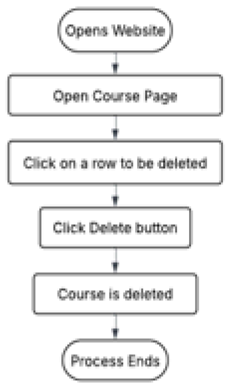
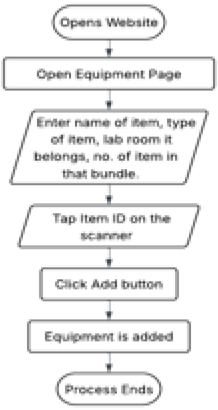
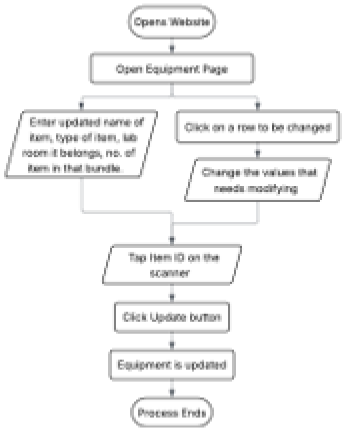


Figure 13
Flowchart of Adding Equipment



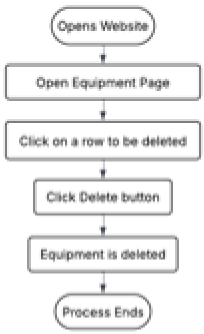
On the courses page, lab assistants can add equipment that will be used from the laboratory assigned to them. It requires the specific name of the item, the item type, the lab room where it will be stored, and the number of stocks in that bundle.

Figure 14
Flowchart of Updating the Details of Existing Equipment



To update equipment details, they would need to click the row of the equipment and change the inputs to the correct ones. Then, they would need to click the update button to change the records.

Figure 15
Flowchart of Deleting Existing Equipment



A lab assistant will need to click the row for the existing equipment in the table. Next, they click the delete button to delete the equipment from the list.

On the equipment courses page, lab assistants can associate equipment with courses that may use the laboratory assigned to them. It requires the course code and the equipment ID.

Figure 16
Flowchart of deleting a course to equipment association

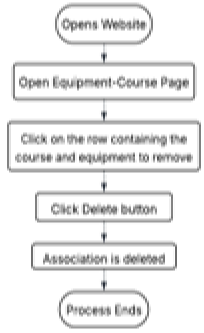
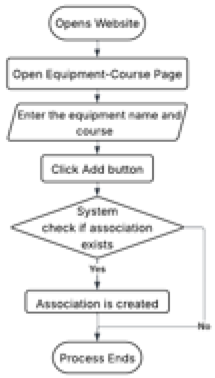


Figure 17
Flowchart of Associating Equipment to a Course



A lab assistant will need to click a row in the table to select the existing equipment's course association. Next, they would click the delete button to remove the equipment-to-course association from the list.

Database Schema

Table 1
Database for Laboratory Room

LABORATORY ROOM DATABASE	
COLUMN NAME	**CONTENT**
room_id	Id no. of lab assistant
lab_room	Room no. for Lab
asst_name	Name of lab assistant
asst_rfid	ID code of lab assistant
password	Password for logging-in

Table 2
Database for Equipment in Laboratory

EQUIPMENT PER LABORATORY ROOM DATABASE	
COLUMN NAME	**CONTENT**
item_id	Primary Key for the Equipment
Item_name	Unique Equipment Name (Arduino A, Arduino B, Arduino C)
RFID	RFID Linked to the Equipment
stock	Number of Items in one clamp.
availability	May be set as available, in-use, or broken
last_used	Date and time for latest usage
lab room	Room no. for Lab.

Table 3
Database for the History of Transactions for Equipment

BORROW HISTORY DATABASE	
COLUMN NAME	**CONTENT**
borrow_id	Code made by the system to record
Item_id	Primary key for the transaction
Student_id	ID of student
date_borrow	Date/Time when an item is taken
date_due	Date/Time expected to return
returned	Yes || No
notes	Remarks on the condition of an item

Table 4
Database for Association of Equipment to a Course

COURSE EQUIPMENT ASSOCIATION DATABASE	
COLUMN NAME	**CONTENT**
equipment_course_id	Primary key for the association
item_id	ID of the Equipment
course_code_id	ID code for the course

Table 5
Database for Students' Information

STUDENT INFORMATION DATABASE	
COLUMN NAME	**CONTENT**
student_id	ID no. of the student
Item_id	ID of the equipment
course_code_id	ID code of the course

Table 6
Database for Course Code

STUDENT INFORMATION DATABASE	
COLUMN NAME	**CONTENT**
course_code_id	Code for the course
course_name	Name of course
instructor	Name of instructor assigned to the course
lab_room	Room no. where the laboratory activity of the course takes place

Note: Tables 1-6 used dummy accounts for pilot and accuracy testing before deployment.

Research Locale

All laboratories in the E-building at Saint Mary's University's School of Engineering, Architecture, and Information Technology were included in the study. To ensure coverage of all specialized areas, including the Electronics, Electrical, and Civil Engineering labs, as well as the Physics and Surveying laboratories, this project shall include the installation and integration of innovative systems with a new interface to the borrowing software system, using a website. With advanced tools to support collaboration across fields, the E-building acts as a center for engineering research and instruction. By improving functionality and resource sharing across the labs, the project sought to develop an integrated, effective research environment within the E-building.

Research Participants

Laboratory assistants and Saint Mary's University teachers and professors, specifically those who use and manage the laboratories in the E-building, were the study's participants. As key technicians responsible for maintaining and operating the lab equipment, laboratory assistants offered valuable perspectives on the operational and technical aspects of the research. As the main users of the laboratories for learning and research, engineering students offered their thoughts on the project's overall performance, user experience, and accessibility. The researchers conducted ten pilot tests to assess accuracy and encryption details, ensuring data correctness.

Research Instrument

The instruments used in this research were computers or laptops for developing website code, including testing for borrowing transactions, generating maintenance reports, and developing databases. RFID scanners and tags for student IDs and equipment in the laboratories were used.

Data Gathering Procedures

During data collection, research participants manually entered information, which was securely stored in an online database. To create different user profiles, students and lab assistants entered their login information into the system, including their names, passwords, and ID numbers. The time and date of each check-out and return, along with the associated user credentials and equipment details, were recorded by lab assistants during equipment transactions. Additionally, lab assistants checked the equipment for problems upon return. If issues were discovered, a maintenance report detailing the specific issues or damages was manually recorded and stored in the database.

These tables stored all sensitive and non-sensitive data input entered by the user/s of the website. With this, a separate database for backing up the system was necessary to protect it from unwanted deletion.

Specifically, this study addressed the following:

To discuss with the laboratory assistant of the EE, ECE, and CpE laboratories the specifics of the currently existing borrowing system, but not restricted to the following areas of concern:

a. Current process of the present borrowing system
b. Monitoring of the laboratory equipment
c. Procedures for the scalability process of the inventory system
d. Offline security of the current database
e. Accessibility of the current database

Incorporate an online database that stores a wider range of laboratory information without sacrificing offline usability, storing the following:

a. Name of the equipment
b. The count of the equipment
c. Transaction records of the equipment
d. Student and instructor profile and their transaction history
e. Laboratory assistant profile
f. Real-time data on the status of the laboratory equipment
g. Automated report for the laboratory assistant

Incorporate dummy students' ID and professor ID as an identifier when borrowing

Create and design an online inventory management backup system that can be accessed by the laboratory assistant:

h. to record the borrowing data: Student ID, instructor ID, and laboratory assistant ID for the borrowing process
i. to automatically fill out the report provided by the International Organization for Standardization (ISO)
j. to reflect data analytics on the most borrowed equipment, tools, and consumables to indicate that those three are in need of new sets and stockings.

Consult the inventory office regarding the accountability process involved in the equipment of the laboratory:

k. Lost equipment
l. Broken equipment
m. Stolen equipment

RESULTS AND DISCUSSION

The results demonstrate the successful interaction among the RFID reader, the MIFARE Classic 13.56 MHz card, and the MySQL database, showcasing the system's ability to capture, process, and store RFID data efficiently and in an expendable manner. Key findings include the accuracy of the RFID data retrieval, the seamless integration of hardware and software components, and the effectiveness of the database in managing the collected information.

Software Development

To ensure scalability, online capabilities, and seamless monitoring, the project was developed in JavaScript, an iterative and flexible language that emphasizes collaboration for small, rapid software development. The process was divided into distinct stages, each contributing to the successful development and deployment of the system. A breakdown of the project's stages and implementation was provided before focusing on the enhancement phase.

In this initial stage, the project requirements were clearly defined, and the scope was established through ongoing communication with stakeholders. Key objectives were outlined to be the foundation of the system:

- Maintaining a local host for the lab assistant to manage operations. This will enable students to borrow equipment from the laboratories.
- Capturing RFID data and storing it in a MySQL database.
- Ensuring the system records all transactions, such as borrowing laboratory equipment and equipment data

Figure 18

Recorded transactions and returned Equipment between student and laboratory assistant

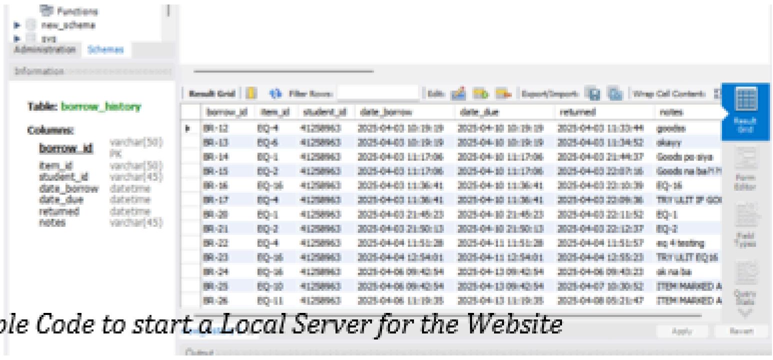


Figure 19

A Back-End Sample Code to start a Local Server for the Website

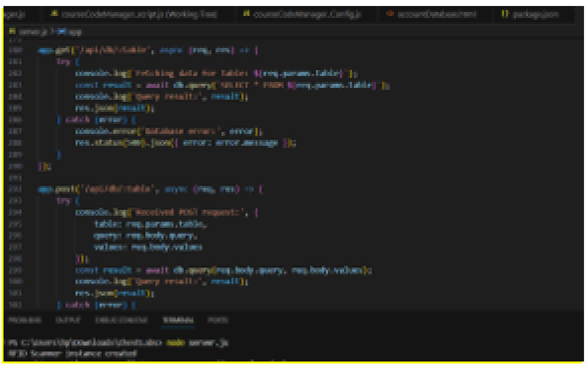
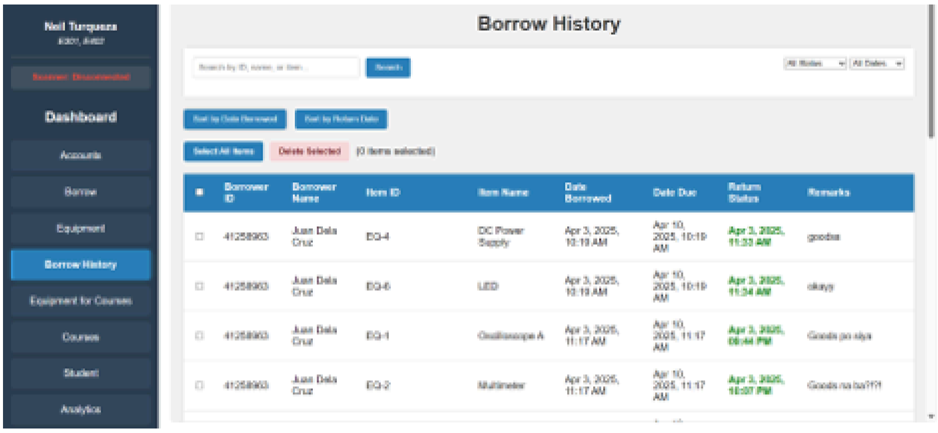


Figure 20
Dashboard that Shows the Records of Equipment

Figure 21
Dashboard that Shows the Records of Borrows History



In this phase, the system architecture was designed to integrate the ACR122U RFID reader, back-end scripts for data capture, and a MySQL database. The laboratory borrowing system was modified to ensure efficient data management, security, and a user-friendly interface. The design also enabled the lab assistant to monitor and manage equipment, ensuring smooth borrowing processes. Regular feedback ensured alignment with project goals and user needs.

The new methodology proposed enabled the researchers to address challenges effectively and incorporate pilot testing at every stage. For instance, during the testing phase, issues such as RFID reader connectivity and database optimization were identified and resolved through iterative cycles of development and testing. This also facilitated collaboration among team members, ensuring that the system components—hardware (ACR122U RFID reader), software (JavaScript), and database (MySQL)—were seamlessly integrated. These results demonstrate the system's ability to accurately capture, process, and store RFID data, validating the approach's effectiveness. Furthermore, the researchers did improvements in the system, such as access control and inventory management, while outlining recommendations for future enhancements.

Alpha Testing

Table 7
Integrity Test for RFID Scanner (Student ID)

Trial	RFID Tags for Student ID	Code Scan	Remarks
	(Student ID is scanned for its RFID Code)		
1	**39284756**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
2	**34728610**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
3	**41827362**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
4	**32579184**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
5	**31846523**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
6	**41258963**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
7	**41827364**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
8	**39034725**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
9	**39586724**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.
10	**38357291**	Yes	The scanner was able to fill up all the first 4 inputs in the borrow dashboard after the RFID was scanned.

Note: (If *Yes,* the RFID scanner was able to scan the tag.)

Table 8 presents the results of alpha testing evaluating the RFID scanner's accuracy in reading student IDs. All ten trials were successful, with each student ID accurately scanned, confirming the scanner's dependable performance in recognizing RFID tags during testing.

Moreover, the system streamlines data entry by auto-populating empty fields on the dashboard with each ID tap, improving efficiency and reducing manual input.

Table 8
Integrity Test for RFID Scanner (Equipment Tag)

Trial	RFID Code of the Equipment	Code Scan	Remarks
	Equipment is scanned for its RFID Code	*The RFID scanner was able to scan the code*	
1	**33134a2d**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.
2	**8342572d**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.
3	**53a6062d**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.
4	**a39d3816**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.
5	**c34a522d**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.
6	**948b7bdf**	Yes	The scanner scanned the equipment's RFID & key tag and showed its equipment details.
7	**343c3bf9**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.
8	**c4fe1cdb**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.
9	**344f82df**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.
10	**f4c566df**	Yes	Equipment RFID & key tags were able to be scanned by the scanner and showed its equipment details.

Note: (If *Yes*, the RFID scanner was able to scan the tag.)

Table 9
Accuracy Test for the Database (Student)

Trial	Student Profile	Insert	Update	Delete	Remarks
1	Yes	Yes	Yes	Yes	CRUD was successful

2	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful
3	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful
4	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful
5	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful
6	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful
7	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful
8	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful
9	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful
10	**Yes**	**Yes**	**Yes**	**Yes**	CRUD was successful

Note: CRUD means Create, Read, Update, and Delete

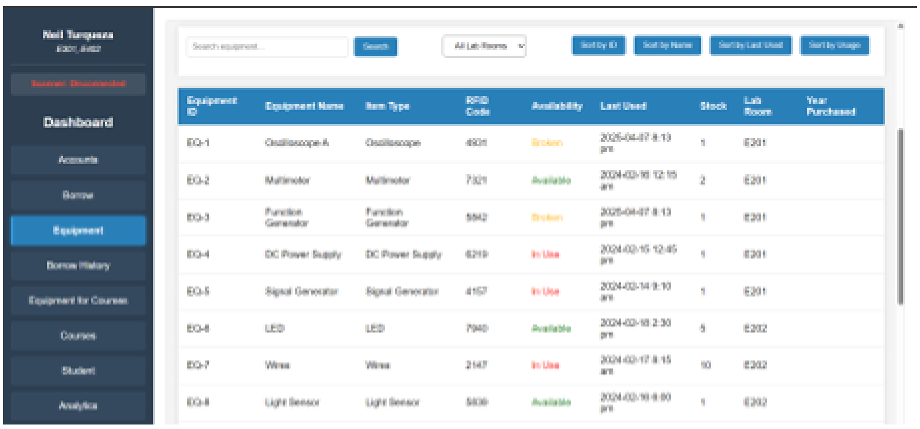
Table 10
Cost of Materials

Components	Quantity	Unit Price	Total Price
RFID Scanner (ACR122U NFC Reader)	1	₱1,799	₱1,799
RFID Tags (13.56MHz RFID IC key tag)	5	₱15	₱75
NFC/RFID Card (13.56MHz MIFARE Classic)	1	₱135	₱135
		Total	₱2,009

Integration of the Previous Research Recommendations

Focusing then on the previous paper's recommendations, the system was continuously optimized to cater to multiple laboratories, monitor accounts, generate PDF forms, and ensure online accessibility. The following are the previous research recommendations, together with the respective actions by the current researchers. The notes written below the previous recommendation are excerpts from the previous paper.

Figure 22
Equipment Dashboard for tool management.



A separate bar option for an equipment management system has been added to the laboratory assistant's default dashboard. This new feature allows the laboratory assistant to directly monitor, edit, update, and delete equipment for their respective laboratories or for those selected from a drop-down menu. This dashboard displays the following data: equipment ID, equipment name, item type, RFID Code, availability, last used, lab room, and stock. All datasets provided are samples based on the CpE, EE, and ECE laboratory, with no major changes to their rows nor any limit on which department would use them. No confidential data has been used in the pilot testing phases of this dashboard. The ID, name, and item type were manually entered while the RFID Code was filled by tapping the equipment's RFID into the option. However, when an item with that specific ID was in a borrowed state, the system automatically labeled it as unavailable – broken or in use; hence, it cannot be borrowed. Additionally, the equipment can be searched by tapping the RFID while the dashboard was active.

Figure 23
Available, In Use, and Broken Status for Each Equipment with a toolbar option.

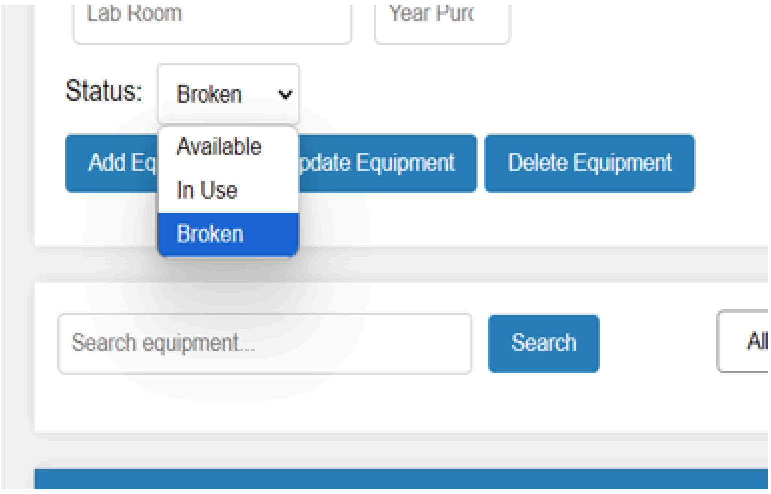
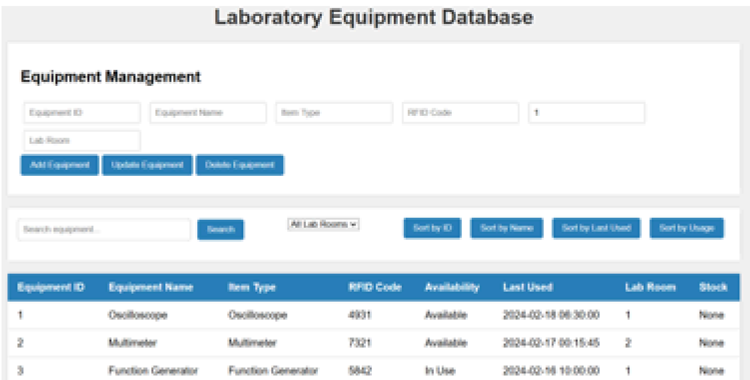


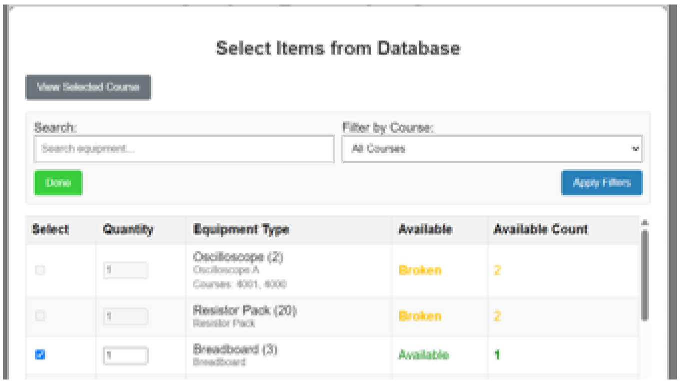
Figure 24
Header Interface for Equipment Dashboard



An additional option in the borrowing interface was for inputting the number of small equipment to be borrowed.

Figure 25

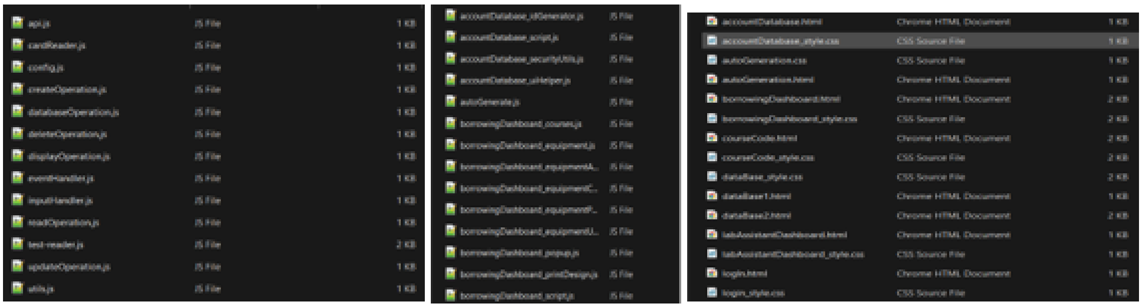
Interface for Inputting the Number of Equipment to be Borrowed.



In the borrowing dashboard, the laboratory assistant can manually enter the number of small items and consumables to be borrowed after the student ID has been tapped. This interface will retrieve data depending on the student's course code and display it accordingly. The laboratory assistant is free to adjust the number of items as needed before the borrow confirmation interface.

Figure 26

Program Structure of the System



Use of modular programming techniques such as encapsulation, abstraction, and method calling to divide the code into smaller, reusable modules.

During the implementation phase, modularity has been achieved through JavaScript's default file structure and server-side organization. Concerns have been split into smaller, more compact files to leverage built-in module systems for NodeJS, MySQL, and ElectronJS. NodeJS has been used to run JavaScript without a browser, enabling it for front-end and back-end development. The researchers took advantage of this by following its modular design principles through file organization and structuring. When encapsulating, NodeJS separated features into different modules, including card reading, data creation, configuration, deletion, display, test reading, and update. This approach ensured code reusability and efficient maintainability without requiring the application of all traditional modular programming techniques, though they were used when needed. To compile these file structures into a single piece of software, the researchers used ElectronJS, which rendered using the Chromium browser engine. Nonetheless, the code structures contained comments and related files to make it easier for future developers to modify and upgrade the system.

Utilization of MySQL for its scalability options and online capabilities.

This project's foundation was MySQL, which was used to store and manage all its databases, making it necessary to reprogram the previously developed software from the ground up. The databases utilized were as follows:

1. Laboratory Assistants' Accounts database
2. Borrow History Database
3. Equipment Database
4. Course Code Database
5. Course Code - Equipment Database
6. Laboratory Rooms Database

The databases containing the laboratory assistants' data were encrypted using MySQL's built-in encryption. This ensured that not even the developers could see the sensitive data. The types of data that have been encrypted were further discussed in the applied ethics section of this paper.

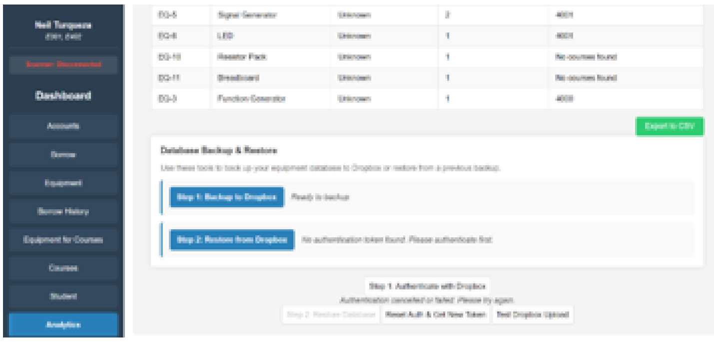
Software Enhancements – Online Scalability

MySQL's online capabilities as a database management system (DBMS) integrated a scalable feature into the system. It enabled online storage, allowing the system to handle large volumes of student data, course information, and borrowing histories. Scalability was now possible thanks to web-based JavaScript, HTML, and CSS, which were packaged into a desktop application with ElectronJS. This web application used Chromium technology, which enabled this system's scalability, albeit it consumes a large portion of the computer's Random Access Memory (RAM). These databases, together with the back-end infrastructure, had been optimized to ensure that data inputs can be scaled to large volumes as needed. To counter this instability, the researchers conducted alpha testing before compiling them into a singular web application.

The reliability of the scalable feature, however, remained highly dependent on how institutions handle large amounts of confidential data across university websites and network systems, making it impossible for the researchers to conduct appropriate and ethical alpha testing of this feature. This was because the data retention policy in this paper limited developers' access to real, confidential data. The implementation of this policy was discussed in the applied ethics section of the paper.

The researchers used Dropbox's Application Programming Interface for the prototype, as it not only aligned with the paper's data retention policy but was also fast and reliable enough to handle laboratory data. The laboratory assistant can then upload the database to their Dropbox accounts and restore any previously uploaded data. This feature was achieved using Dropbox's pre-built components, which support no more than 50 accounts. The number of accounts can be expanded as needed by the institution. The researchers will still have to apply for Dropbox production if needed.

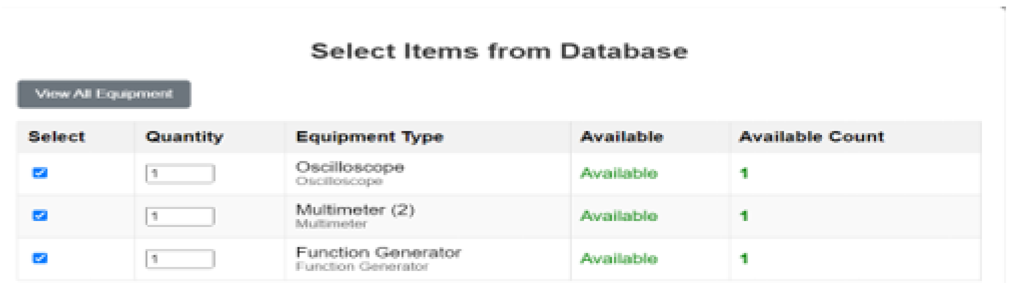
Figure 27
Backup and Restore Feature through Dropbox's built-in Developers Console



Software Enhancements – Automation

A major enhancement to the system was the automated prediction of the student's equipment requirements based on the course code entered.

Figure 28
Automatically Check the Equipment based on Student Course Code



In the figure above, *"Thompson Mascot"* is a student enrolled in code *4000* corresponding to the subject' *Feedback and Control Systems'*. After tapping his/her ID and clicking the 'select equipment' button, the system has already checked all the equipment needed for that specific code. In Figure X, the code *4000* has been pre-programmed to require one oscilloscope, one multimeter, and one Function Generator. This data was then submitted to the database and retrieved using the JavaScript file method, enabling the subsequent automation of inventory report forms.

Another key enhancement was the automation of the International Standardization Organization (ISO) reports, a form used for laboratory assistants' inventory reports. The laboratory assistant will click an auto-generate form button, confirm all the details, and then print them into a single form. This was achieved through a lookup system that retrieved the value from the MySQL table. This feature was the main upgrade, as the system has integrated a form required by the institution itself.

With this, the laboratory assistant does not have to manually fill out the forms while complying with the ISO policy, which requires the laboratory assistant and subject instructor to manually sign the forms.

Figure 29
Verification Details for the Laboratory Assistant to Check before Printing

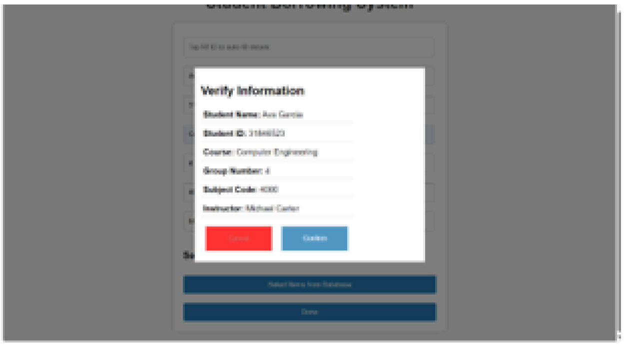


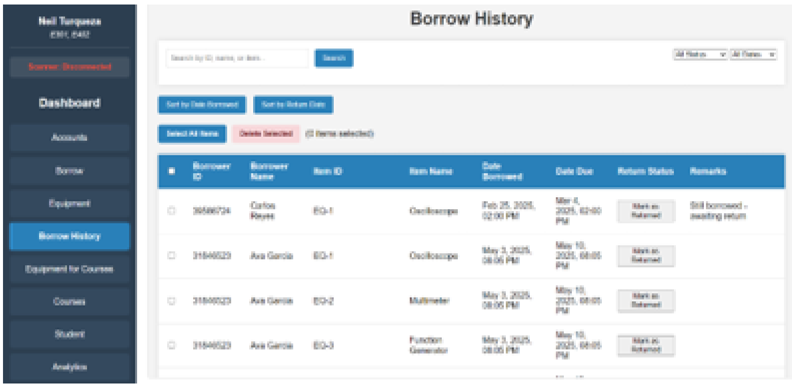
Figure 30
Laboratory Assistants can Manually Select the Print Position for the Document Layout

Figure 31
Generated Documents can be Saved as PDF or Printed to be Signed by the Laboratory Assistant

Software Enhancements – Monitoring

Sorting options have been integrated into the database to monitor each piece of equipment carefully. With the equipment dashboard added to the system, sorting was implemented using MySQL's built-in sorting commands, which were used in the borrow history dashboard and equipment databases. This allowed the laboratory assistant to monitor each piece of equipment's status based on its usage frequency, the date and time of its last use, and the number of stocks remaining. Sortation was also part of the previous researchers'

Figure 32
Borrow History Sorted by Date When the Equipment was Returned



recommendation for developing a separate equipment database with sorting options.

Additionally, laboratory assistants can set the Equipment-Course Code to the usual item borrowed for each course subject. In this instance, the subject *Circuits1* with code *4001* can be pre-programmed to check the Oscilloscope A, Multimeter B, and five LEDs. This can be actively updated and deleted as needed.

Data Security

Hashing and encryption are two mitigation methods that have been widely adopted and successfully implemented to fully secure user passwords and data. In Figure 31, a laboratory assistant named Michael Carter has his ID stored as e4004df9. This ensured that not even the developers could see their password or ID data. The only way to change passwords and access user's data is through the RFID technology developed within the system itself. Instructions on how to change passwords using the laboratory assistant's ID were provided for more detailed guidance.

Figure 33
The Oscilloscope Equipment Syncs into Circuits 1 Subject with Code 4001

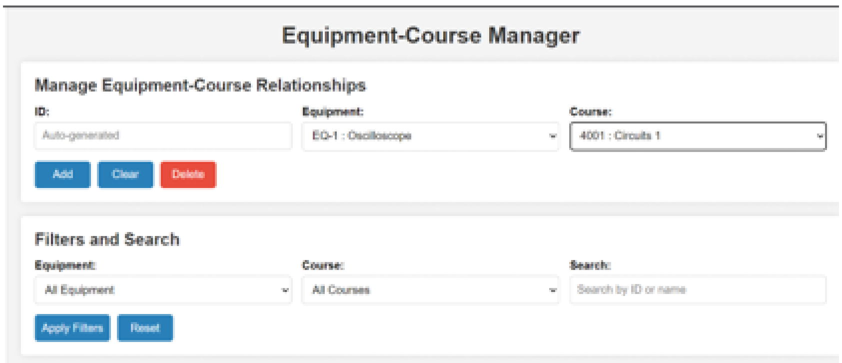


Figure 34
Accounts Dashboards where Laboratory Assistants can be Added and Modified.

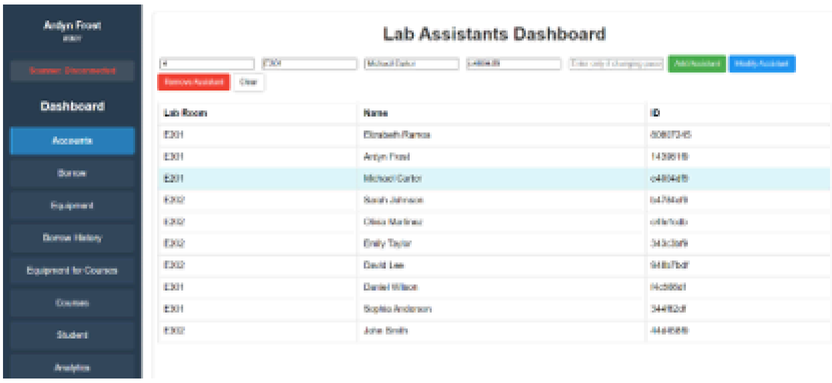
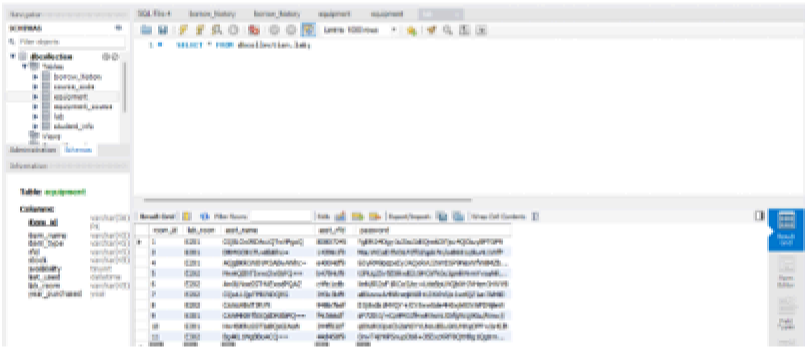
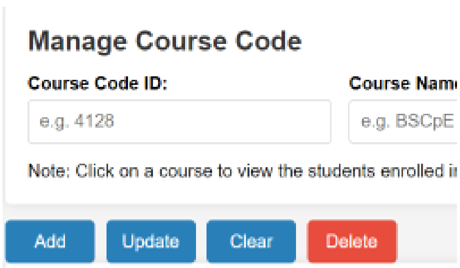


Figure 35
Laboratory Assistants' MySQL Database Encryption



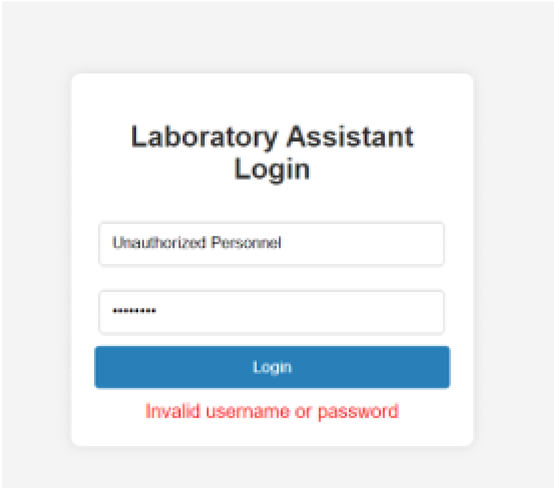
The figure above shows how the names, RFID numbers, and passwords of all laboratory assistants are encrypted. Developers and other programmers will not be able to see this data as the table utilized the built-in encryption syntax of MySQL.

Figure 36
Laboratory Assistants' Data Retention and Access to Deletion



In one of the data retention policies in this paper, the laboratory assistant shall have the option to delete unused data or retain it as needed. This will prevent data overload and cybersecurity risks.

Figure 37
Data Only to be Accessed by an Authorized Laboratory Assistant



All data displayed by the system is protected by the effective login system shown above. The researchers used backend authorization methods to achieve this level of privacy for the institution and ensure that only authorized personnel with their RFIDs can log in to the system and manage data within it.

Implementation of Findings for the Specific Objectives

The main objective of this study was to enhance the existing borrowing system in the EE, ECE, and CpE laboratories without sacrificing the accuracy, efficiency, and security of the current database. Specifically, they are the following:

1. Increase the system's reach by making it available in all of the School of Engineering's labs, including Physics and other courses that need lab-based borrowing. This was done by using both an offline and an online database backup system. This allows many departments and courses to use the system, regardless of their web reliability or technological setup.

Figure 38
Online Database Backup System

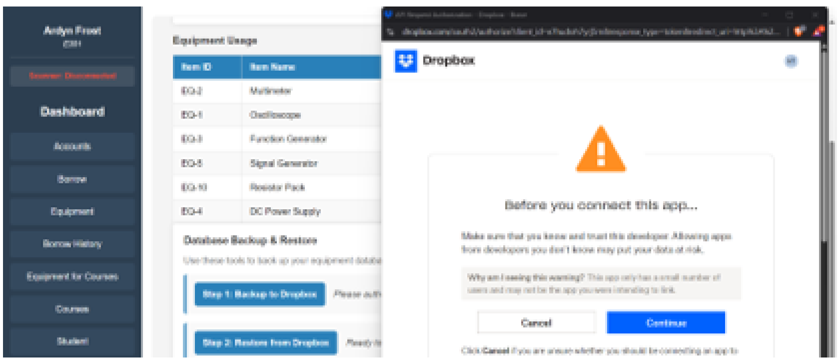


Figure 39
Offline Database by Default

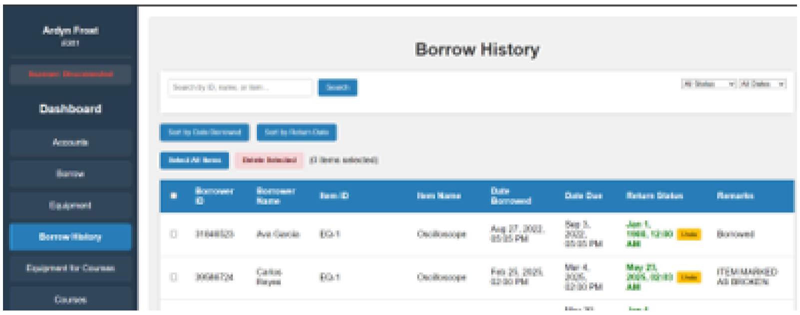
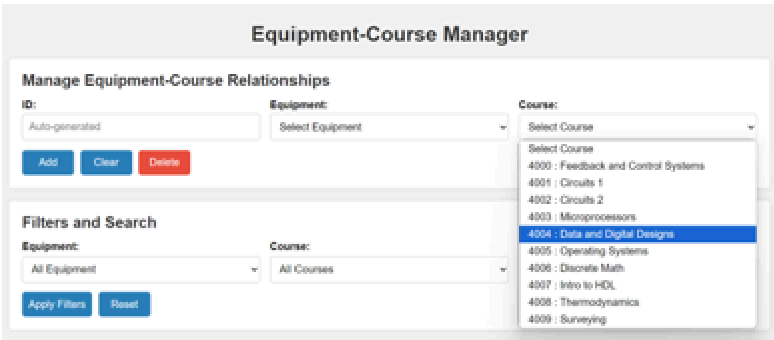


Figure 40
Versatility to Other Laboratories from Other Departments

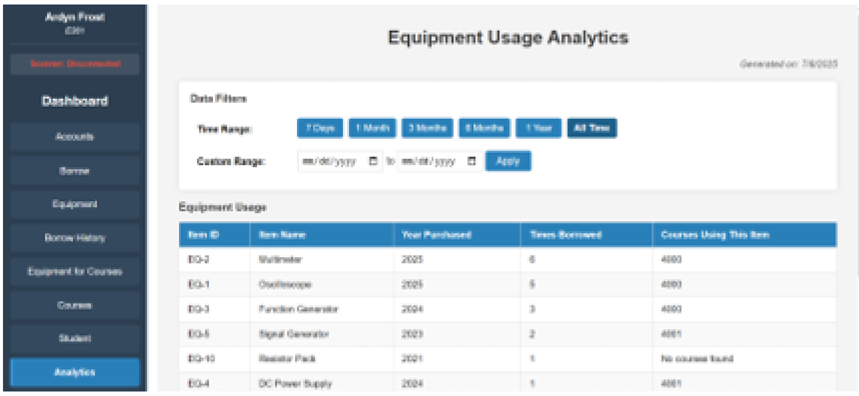


2. Enable the automatic creation of required laboratory forms and integrate system-driven verification of borrowed items to automate the equipment checking and documentation procedures. To help lab workers effectively manage and document equipment transactions, the system included incident report forms, damage reports, and borrowing slips, all of which can be reviewed and printed directly from the system.

Figure 41
Automated Creation of the Different Forms

3. Add monitoring features on frequently used equipment and their status.

Figure 42
Analytics on Frequency of Usage and Equipment Status



CONCLUSION AND RECOMMENDATIONS

Conclusion

The researchers conducted ten alpha tests of the equipment dashboard, borrowing dashboard, and course code databases by tapping the RFID as part of the laboratory operations. Using dummy data, the tests successfully recorded all student details for the borrowing history, equipment dashboard, and course integration. The researchers focused on the recommendation from the previous paper and were on track to implement it.

The researchers have notably integrated an additional equipment database, linking each piece of equipment to different course codes. This enabled the researchers to successfully implement the system automation feature. This dashboard gives laboratory assistants control over pre-programming equipment for their respective course codes. The online backup and restore feature was also successful, while maintaining the paper's privacy and retention policies.

Recommendations

To further enhance the system, the following recommendations are:

1. Add another dashboard for printing different Education Organizations Management Systems (EOMS) forms for calibration requests and other forms. This dashboard should allow the laboratory assistant to update each form accordingly.
2. Incorporate other institutional identification systems on the login page, like the corporate email, in order to utilize institution-wide benefits like Google Cloud for backing up the laboratory data.
3. Use more advanced RFID Hardware like ACS ACR1281U-C1 DualBoost II USB Dual Interface Reader for faster scanning and transactions.
4. Develop a mobile interface for the laboratory assistants whose phones are capable of scanning RFID tags and utilizing the system autonomously.

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