Sukkur IBA University

Department of Computer Systems Engineering

Database Management System

Title: Student Management System Using MySQL and Python with Machine Learning Integration

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Abstract

The Student Management System (SMS) is a sophisticated desktop application engineered to revolutionize academic administration by digitizing and centralizing student data management, performance tracking, and communication among stakeholders. Developed using Python 3.10 with Tkinter for the graphical user interface (GUI) and MySQL for robust database management, the system is tailored to support four distinct user roles: Admin, Teacher, Student, and Parent. It offers an extensive array of functionalities, including secure data entry and updates, role-specific dashboards with detailed insights, messaging capabilities (Teacher-Student, Teacher-Teacher, Student-Student), customizable alerts, predictive analytics based on historical performance data, and interactive data visualizations (bar charts, boxplots, and scatter plots). This report provides an exhaustive exploration of the system's design, development process, and technical implementation, delving into the methodology, a comprehensive analysis of SQL queries, a detailed explanation of the Python implementation approach, and a meticulous step-by-step account of the development process. Dedicated sections are reserved for evaluation results and visualizations to be populated post-testing, while the report concludes with a forward-looking section on future enhancements to further elevate the system's capabilities and usability.

1. Introduction

The Student Management System (SMS) was conceived to address the persistent challenges associated with traditional paper-based academic record-keeping systems, which are notorious for their inefficiency, susceptibility to errors, and difficulty in scaling to meet the demands of modern educational institutions. Recognizing the need for a digital transformation, the SMS was developed to provide a centralized, intuitive, and secure platform that enhances administrative efficiency, improves data accessibility, and fosters effective communication among students, teachers, parents, and administrators. The system leverages a combination of Python 3.10 for its programming backbone, Tkinter for a responsive GUI, MySQL for reliable data storage, and scikit-learn for predictive analytics, ensuring a robust and scalable solution.

The SMS is designed to cater to four distinct user roles, each with tailored functionalities:

- **Admin**: Holds overarching control, managing all student and teacher data, generating comprehensive global performance reports, and overseeing system-wide operations to ensure smooth functionality.
- **Teacher**: Manages student data specific to their assigned sections, sends personalized alerts to students, and facilitates communication with both students and fellow teachers to support classroom management and collaboration.
- **Student**: Accesses detailed personal performance data, engages in messaging with peers and teachers, and submits comments or feedback to contribute to their academic experience.

- **Parent**: Monitors their child's academic progress in real-time, provides feedback to educators, and stays informed about their child's educational journey through the system.

The primary objectives of the SMS are multifaceted and ambitious:

- Centralize student data management to enable efficient entry, updates, and retrieval, reducing administrative overhead and minimizing errors.
- Provide role-specific dashboards equipped with tailored insights and visualizations, empowering users with data-driven decision-making tools.
- Enable a secure and efficient messaging system, along with customizable alerts, to enhance communication and engagement among stakeholders.
- Offer predictive analytics to forecast student performance trends, assisting educators and students in academic planning and intervention strategies.
- Ensure scalability and usability, making the system adaptable to educational institutions of varying sizes and complexities.

This report offers a thorough examination of the development process, beginning with the methodology that guided the project, followed by an in-depth explanation of the SQL queries that underpin the database structure, a detailed narrative of the Python implementation approach, and a comprehensive step-by-step recounting of the system's construction. Spaces are reserved for the inclusion of evaluation results and visualizations following testing phases. The report concludes with a vision for future work, outlining potential enhancements to keep the system at the forefront of educational technology.

2. Methodology

The development of the Student Management System (SMS) was guided by an iterative methodology, a structured and cyclical approach that allowed for continuous refinement and adaptation throughout the project lifecycle. This methodology was chosen to ensure that the system met the diverse needs of its users while maintaining flexibility for future enhancements. The process was segmented into several distinct phases, each contributing to the system's overall robustness and functionality. Below is a detailed overview of the methodology:

- **Requirement Analysis**: The initial phase involved an extensive analysis of user requirements, conducted through consultations with potential stakeholders, including administrators, teachers, students, and parents. This phase identified the need for a centralized data management system, role-based access, secure communication channels, predictive analytics, and interactive visualizations. Specific requirements included the ability to manage student records, generate performance reports, send alerts, and predict academic outcomes, all tailored to the permissions of each user role.
- **Database Design**: We employed MySQL to design a relational database named student_db, which serves as the backbone for storing all system data. The database was structured with seven tables—users, students, Teachers, grades, Messages, Alerts, and comments—each designed to handle specific data types and relationships. SQL queries were meticulously crafted to create, populate, query, and manage the database, ensuring data integrity and security through constraints and foreign keys.
- **Application Development**: The application was developed using Python 3.10, with Tkinter providing the GUI framework. The development process focused on creating a modular architecture, including a login system, registration interface, and role-based portals. Each portal was customized to meet the needs of its respective user role, integrating database connectivity, messaging, alert systems, predictive analytics, and visualizations using additional libraries like matplotlib and scikit-learn.
- **Predictive Analytics Integration**: To enhance the system's analytical capabilities, we incorporated machine learning techniques using scikit-learn. Two models were planned: a linear regression model to predict math scores based on other subjects, and a random forest classifier to categorize overall performance into "Poor," "Average," or "Excellent." These models were designed to leverage historical data from the students table, processed with pandas for training and validation.
- **Testing and Refinement**: The system underwent rigorous testing at each iteration, using sample data to validate functionality, performance, and user experience. Issues such as duplicate teacher names, restricted graph visibility, and UI alignment were identified and addressed. Refinements included enhancing security

with role-based access controls, improving usability through consistent layout design, and ensuring the system's stability under various use cases.

This iterative approach allowed for continuous feedback and adjustment, ensuring the SMS was both functional and user-centric. The methodology emphasized modularity, enabling future expansions, and prioritized data security through role-based access and parameterized queries to mitigate SQL injection risks.

2.1. Database Design with SQL

The SMS relies on a MySQL database named student_db to store and manage all system data efficiently. The database is structured with seven tables, each designed to handle specific aspects of the system while maintaining relational integrity through foreign keys and appropriate constraints. Below is a detailed explanation of the database design, followed by a comprehensive list of SQL queries used during development.

- **users**: Stores authentication details, including a unique id, username, password, role (restricted to Admin, Teacher, Student, Parent), user_id (for linking to students or teachers), and section (for Teachers).
- **students**: Contains core student information, including id (primary key), name, gender, age, section, and numerical scores for science, english, history, and maths.
- **Teachers**: Holds teacher profiles with teacher_id (primary key), name, subject, and section to link teachers to their assigned sections.
- **grades**: Stores letter grades (A-F) for each student, linked to the students table via the student_id foreign key, with fields for science_grade, english_grade, history_grade, and maths_grade.
- **Messages**: Manages communication, with id (primary key), sender_id, sender_role, receiver_id, receiver_role, message content, and sent_date (defaulting to the current timestamp).
- **Alerts**: Stores notifications for students, with id (primary key), student_id (foreign key to students), message, and sent_date (defaulting to the current timestamp).
- **comments**: Records feedback, with id (primary key), student_id (foreign key to students), comment text, and date (defaulting to the current timestamp).

2.2. Complete List of SQL Queries with Detailed Explanations

Below is an exhaustive list of all SQL queries used in the SMS, accompanied by detailed explanations of their purposes, structures, and verification steps.

1. Create Database and Tables

```
USE student_db;

CREATE TABLE IF NOT EXISTS users ( id INT
    AUTO_INCREMENT PRIMARY KEY, username VARCHAR(50)
    UNIQUE, password VARCHAR(50), role ENUM('Admin',
    'Teacher', 'Student', 'Parent'), user_id INT,
    section VARCHAR(10)
);

CREATE TABLE IF NOT EXISTS
    students ( id INT PRIMARY KEY,
    name VARCHAR(100), gender
    VARCHAR(10), age INT, section
    VARCHAR(10), science FLOAT,
    english FLOAT, history FLOAT,
    maths FLOAT
);

CREATE TABLE IF NOT EXISTS Teachers (
    teacher_id INT AUTO_INCREMENT PRIMARY
    KEY, name VARCHAR(100), subject
    VARCHAR(50), section VARCHAR(10)
);

CREATE TABLE IF NOT EXISTS grades
    ( student_id INT PRIMARY KEY,
    science_grade CHAR(1),
    english_grade CHAR(1),
    history_grade CHAR(1),
    maths_grade CHAR(1),
    FOREIGN KEY (student_id) REFERENCES students(id)
);

CREATE TABLE IF NOT EXISTS Messages ( id
    INT AUTO_INCREMENT PRIMARY KEY,
    sender_id INT, sender_role
    ENUM('Teacher', 'Student'),
    receiver_id INT,
    receiver_role ENUM('Teacher', 'Student'),
    message TEXT,
    sent_date DATETIME DEFAULT CURRENT_TIMESTAMP
);
```

```
CREATE TABLE IF NOT EXISTS Alerts (
    id INT AUTO_INCREMENT PRIMARY
    KEY,
    student_id INT,
    message TEXT,
    sent_date DATETIME DEFAULT CURRENT_TIMESTAMP,
    FOREIGN KEY (student_id) REFERENCES students(id)
);

CREATE TABLE IF NOT EXISTS comments
    ( id INT AUTO_INCREMENT PRIMARY
    KEY,
    student_id INT, comment TEXT, date
    DATETIME DEFAULT CURRENT_TIMESTAMP,
    FOREIGN KEY (student_id) REFERENCES students(id)
);
```

Explanation: This comprehensive query set initializes the student_db database and establishes all required tables. The users table leverages AUTO_INCREMENT for unique id generation and employs an ENUM type to restrict role values, ensuring data consistency and security. The students table stores detailed student records, while the grades table links to it via a foreign key (student_id) to maintain grade data integrity. The Teachers table captures educator details, and the Messages, Alerts, and comments tables handle communication, notifications, and feedback, respectively, with automatic timestamping via DEFAULT CURRENT_TIMESTAMP. The IF NOT EXISTS clause prevents errors if tables are recreated, and foreign keys enforce relational integrity across tables.

Verification: We executed SHOW TABLES; to confirm the creation of all tables and used DESCRIBE <table>; for each table to verify column names, data types, constraints (e.g., primary keys, foreign keys), and default values, ensuring the database structure aligned with the design specifications.

2. Insert Default Admin User

```
INSERT INTO users (username, password, role, user_id) VALUES
('admin', 'admin123', 'Admin', 1);
```

Explanation: This query inserts a default admin user with the username admin, password admin123, role Admin, and user_id of 1, providing an initial entry point for system administration. The user_id serves as a reference for future administrative actions.

Verification: We ran SELECT * FROM users WHERE username = 'admin'; to verify the record's presence, checking the username, password, role, and user_id fields to ensure accurate insertion.

3. Attempt to Remove Unique Constraint on Teachers.name

```
ALTER TABLE Teachers DROP INDEX IF EXISTS name;
```

Explanation: This query attempts to remove any unique constraint or index on the name column in the Teachers table, addressing a requirement to allow duplicate teacher names (e.g., multiple teachers with the same name in different sections). The IF EXISTS clause was intended to prevent errors if no such index exists.

Verification: The query failed with Error Code: 1064 due to a syntax error (IF EXISTS is not supported in some MySQL versions for DROP INDEX), prompting us to adopt a more robust method to handle the constraint removal.

4. Check and Remove Index on Teachers.name

```
SHOW INDEX FROM Teachers;

SET @index_exists = (SELECT COUNT(*) FROM
   INFORMATION_SCHEMA.STATISTICS
                     WHERE TABLE_SCHEMA = 'student_db'
                    AND TABLE_NAME = 'Teachers'
                    AND COLUMN_NAME = 'name'
AND INDEX_NAME != 'PRIMARY');
SET @drop_sql = IF(@index_exists > 0, 'ALTER TABLE Teachers
   DROP INDEX name', 'SELECT "No index to drop"');
PREPARE stmt FROM @drop_sql;
EXECUTE stmt;
DEALLOCATE PREPARE stmt;
```

Explanation: This multi-step query provides a safe mechanism to check for and remove an index on Teachers.name. The SHOW INDEX FROM Teachers; command lists existing indexes, while the INFORMATION_SCHEMA.STATISTICS query determines if an index on name exists (excluding the primary key). If an index is found, a dynamic ALTER TABLE statement drops it; otherwise, a harmless SELECT is executed. This approach avoids errors and ensures flexibility.

Verification: We ran SHOW INDEX FROM Teachers; before and after the query to confirm the absence of a name index post-execution, validating that duplicate names are now permissible.

5. Final Attempt to Drop Index

```
ALTER TABLE Teachers DROP INDEX name;
```

Explanation: As a final precautionary step, this query manually attempts to drop the name index, ensuring no residual constraints prevent duplicate entries in the Teachers table.

Verification: The query failed with Error Code: 1091 ("Can't DROP 'name'; check that column/key exists"), confirming that no index remained after the previous step, thus allowing duplicate teacher names as intended.

6. Verify Teachers Table

```
SHOW CREATE TABLE Teachers;
```

Explanation: This query retrieves the full CREATE TABLE statement for the Teachers table, allowing us to inspect its structure and confirm the absence of any unique constraints or indexes on the name column.

Verification: The output displayed the table definition, and we confirmed the absence of a UNIQUE KEY or index on name, ensuring the table structure supports duplicate teacher names.

7. Retrieve Student Data

```
SELECT s.*, g.science_grade, g.english_grade,
   g.history_grade, g.maths_grade
FROM students s
LEFT JOIN grades g ON s.id = g.student_id WHERE section = %s;
```

Explanation: This query retrieves comprehensive student data, including all fields from the students table (s.*) and corresponding grades from the grades table, for a specific section. The LEFT JOIN ensures that students without grades are included (with NULL values), and the WHERE clause with %s enables dynamic section filtering via parameterized queries, enhancing security against SQL injection.

Verification: We tested the query within the application by passing a section value (e.g., "A") and compared the results against the students and grades tables, verifying that all data, including grades, was accurately retrieved and matched.

8. Average Scores

```
SELECT AVG(science), AVG(english), AVG(history), AVG(maths)
FROM students WHERE id = %s;
```

Explanation: This query calculates the average scores for each subject (science, english, history, maths) for a specific student identified by their id. The result is used in the Student portal to provide a baseline for predictive analytics, helping students and educators identify performance trends.

Verification: We executed the query with a sample student ID, manually computed the averages from the raw data, and confirmed the query's results were consistent, ensuring accurate aggregation.

9. Section-wise Report

```
SELECT section, AVG(science), AVG(english), AVG(history),
AVG(maths) FROM students GROUP BY section;
```

Explanation: This query generates a detailed report of average subject scores across all sections, grouping the data by section and computing the mean for each subject. It is a critical tool in the Admin portal for assessing overall academic performance and identifying section-specific trends.

Verification: We ran the query and cross-checked the grouped averages against the raw data in the students table, ensuring the calculations were correct and reflective of the actual student scores.

10.Gender Distribution

```
SELECT gender, COUNT(*) FROM students WHERE section = %s
GROUP BY gender;
```

Explanation: This query counts the number of students by gender within a specific section, grouping the results by gender and using COUNT(*) to tally the totals. It supports the Teacher portal by providing demographic insights, aiding in classroom planning and analysis.

Verification: We tested the query with a sample section, manually counted the students by gender, and confirmed the query's output matched the actual data, ensuring accuracy in demographic reporting.

2.3. Python Implementation Explanation

The SMS application was developed using Python 3.10, leveraging a suite of libraries to create a fully functional and interactive system. Below is a detailed explanation of the Python implementation approach, covering the design, functionality, and integration with the database and other components, without providing the actual code.

- **Database Connection**: The implementation began with establishing a connection to the MySQL database using the mysql-connector-python library. We configured the connection with parameters such as the host (localhost), user (root), password, and database name (student_db). A cursor object was created to execute SQL queries and retrieve results, forming the foundation for all database interactions within the application.
- **Machine Learning Models**: We designed two machine learning models to enhance the system's analytical capabilities. The first, a linear regression model, was intended to predict a student's math score based on their performance in science, english, and history. The second, a random forest classifier, was planned to categorize overall student performance into "Poor," "Average," or "Excellent" based on aggregated scores. These models were to be trained using historical data from the students table, with pandas employed to preprocess the data into a suitable format for model training and validation.
- **GUI Structure with Tkinter**: The graphical user interface was constructed using Tkinter, organized within a class (StudentManagementSystem) to manage the application's state and handle user interactions. The GUI was designed with a modular layout, featuring a login screen, a registration interface, and role-based portals. We utilized Tkinter's grid layout manager to align text fields, buttons, and other widgets, ensuring a clean and intuitive interface. The main window was split into a left frame for navigation and content (using the Notebook widget for tabs) and a right frame for visualizations.
- **Login and Registration**: The login screen was implemented to allow users to enter their username, password, and select their role, with validation performed against the users table in the database. The registration interface was designed to support new user creation, dynamically adjusting required fields based on the selected role (e.g., Teachers enter a section, Students and Parents enter a student ID). Upon successful registration, the user was added to the users table, and for Teachers, a corresponding entry was created in the Teachers table, with error handling to manage database conflicts.
- **Role-Based Portals**:
    - **Admin Portal**: This portal includes a "Manage Students" tab, featuring input fields for adding, updating, and deleting student records, displayed in a scrollable table using the Treeview widget. A "Global Dashboard" tab was

added to display section-wise performance reports, leveraging the section-wise report query to provide a comprehensive overview.

    - **Teacher Portal**: Comprises multiple tabs, including "Manage Students" (section-specific), "Class Analytics" (for performance and gender distribution), "Send Alerts" (to notify students), and "Messaging" (for communication). The portal restricts data access to the teacher's assigned section, ensuring privacy and relevance.
    - **Student/Parent Portal**: Offers tabs for viewing personal performance data, displaying predictive results based on average scores, and messaging. Students can submit comments, stored in the comments table, while Parents can provide feedback, also recorded in comments, with role-specific access to relevant data.

- **Messaging and Alerts**: The messaging system was designed to facilitate communication between Teachers and Students, with messages stored in the Messages table. Users select a receiver role (Teacher or Student) and ID, compose a message, and send it, with a "View" option to display received messages. The alert system, exclusive to Teachers, allows sending notifications to students, with data saved in the Alerts table for tracking.
- **Visualizations**: We integrated matplotlib to display visualizations in the right frame of the GUI, offering users the ability to select between bar charts (showing average scores per section or subject), boxplots (illustrating score distributions), and scatter plots (e.g., science vs. math correlations). The visualizations are filtered by role: Teachers see data for their section, while Admins view global data, enhancing the system's analytical depth.
- **Predictive Results**: In the Student portal, we implemented a feature to display predictive results by calculating average scores using the average scores query. This baseline serves as a foundation for performance trends, with plans to integrate the machine learning models for more precise predictions in future iterations.
- **Logout Functionality**: A logout button was incorporated across all portals, designed to return users to the login screen and clear the current session data, thereby enhancing security and user control over their access.

The Python implementation was structured to be highly modular, with separate methods dedicated to each functionality (e.g., adding students, sending messages, updating plots). We incorporated comprehensive error handling using try-except blocks to manage potential database errors, user input validation issues, and other exceptions, ensuring the application remains stable and reliable under diverse conditions.

2.4. Step-by-Step System Implementation

The development of the SMS was a meticulously planned and executed process, ensuring each component was thoroughly designed, implemented, and validated. Below is a detailed, step-by-step account of the implementation process:

1. **Environment Setup**:
    - We began by installing Python 3.10 as the primary programming environment, followed by setting up a MySQL server on the development machine. Necessary libraries were installed using pip, including tkinter (bundled with Python), mysql-connector-python for database connectivity, pandas and scikit-learn for analytics, and matplotlib for visualizations.
    - The MySQL server was configured with a root user and password, and the student_db database was created to serve as the data repository. This step ensured a stable foundation for subsequent development.
2. **Database Creation**:
    - We executed the initial SQL queries to create the student_db database and its seven tables (users, students, Teachers, grades, Messages, Alerts, comments), defining all columns, data types, constraints, and relationships.
    - A default admin user was inserted into the users table to enable initial system access, providing a starting point for administrative tasks.
    - The database structure was verified using SHOW TABLES; to list all tables and DESCRIBE <table>; for each table to confirm column definitions, primary keys, foreign keys, and default values, ensuring alignment with the design specifications.
3. **User Interface Design**:
    - The login screen was designed with Tkinter, featuring fields for username, password, and role selection, laid out using the grid manager for precise alignment and spacing.
    - The registration screen was implemented with dynamic fields that adjust based on the selected role (e.g., Teachers enter a section, Students/Parents enter a student ID), ensuring user-friendly data collection.
    - Role-based portals were developed using the Notebook widget, with tabs tailored to each role: "Manage Students" and "Global Dashboard" for Admins, "Manage Students," "Class Analytics," "Send Alerts," and "Messaging" for Teachers, and "View Data," "Predictive Results," "Messaging," and "Comments/Feedback" for Students/Parents.

- A right frame was added for visualizations, equipped with a dropdown menu to select graph types (bar, boxplot, scatter), ensuring an interactive and informative display.

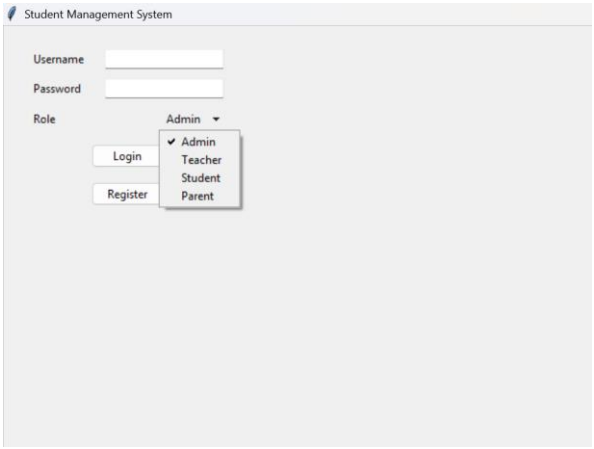
4. Database Integration:

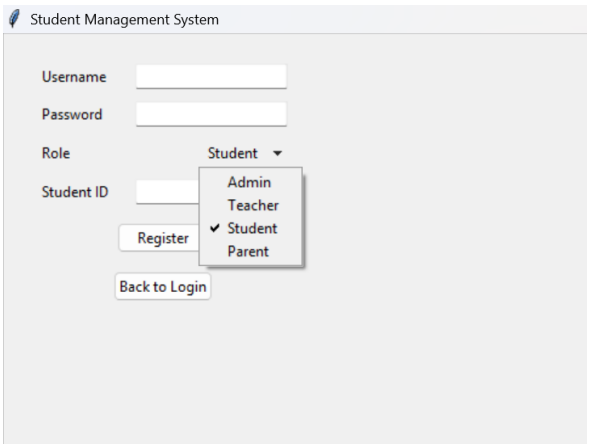
- A connection to the MySQL database was established using mysql-connector-python, with configuration parameters set for the host, user, password, and database name. A cursor object was created to execute SQL queries and fetch results.
- SQL queries were integrated into the application, utilizing parameterized queries (e.g., using %s) to prevent SQL injection and allow dynamic data handling. This step involved testing basic operations like retrieving student data and inserting messages.
- The integration was validated by executing sample queries within the application and comparing the results with the database contents, ensuring accurate data flow.

5. Functionality Implementation:

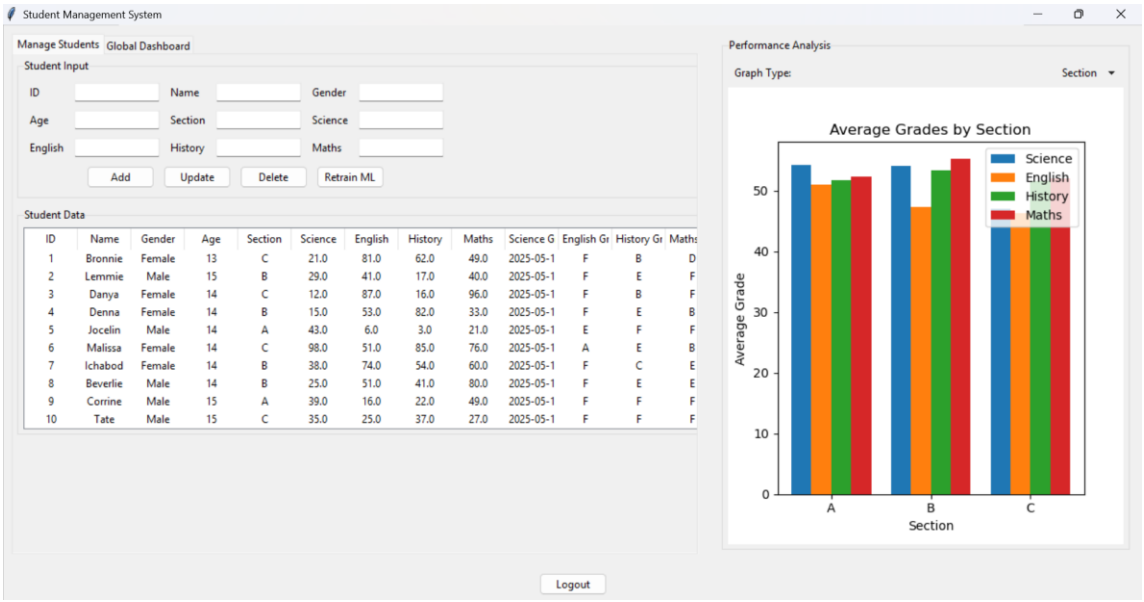
- Student data management was implemented with methods to add, update, and delete records, including input validation to ensure fields like id and scores were numeric and within acceptable ranges.
- Role-specific dashboards were created: Admins received full access to all data, Teachers were restricted to their section's data, and Students/Parents accessed only their own or their child's data, enforced through SQL filters.
- The messaging system was developed to allow Teachers and Students to send and view messages, with data stored in the Messages table. A similar approach was used for alerts, managed by Teachers and stored in the Alerts table.
- Predictive analytics were introduced by calculating average scores for Students, with a framework set up to integrate machine learning models in future iterations.
- Visualizations were implemented using matplotlib, with role-based filtering (e.g., Teachers see section-specific data) and user-selectable graph types, enhancing the system's analytical capabilities.
- A logout button was added across all portals to enhance security, allowing users to end their sessions and return to the login screen, with session data cleared to prevent unauthorized access.

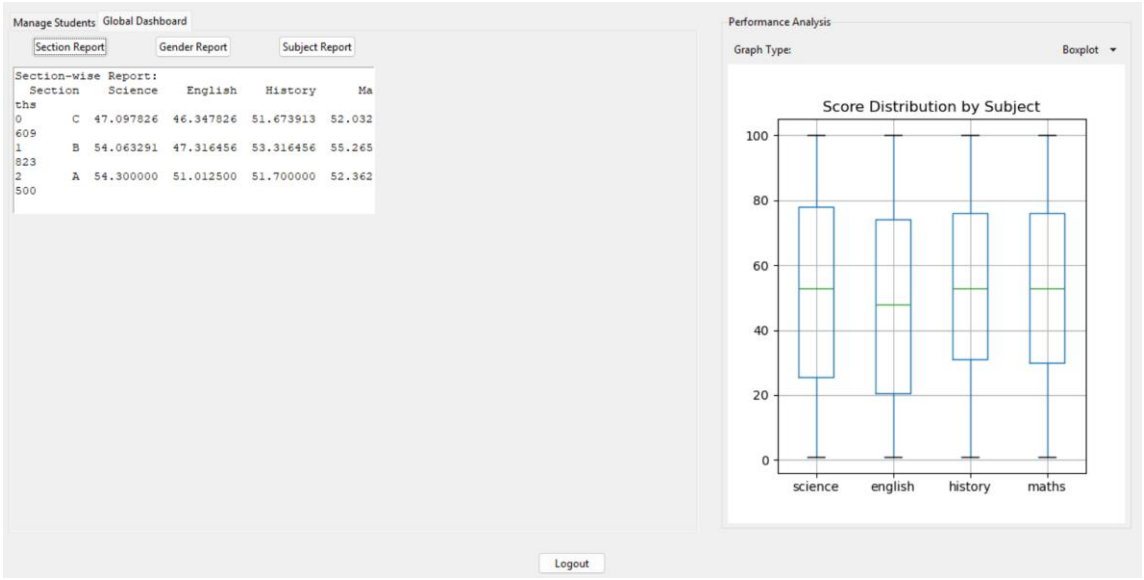
3. System Visualization Results



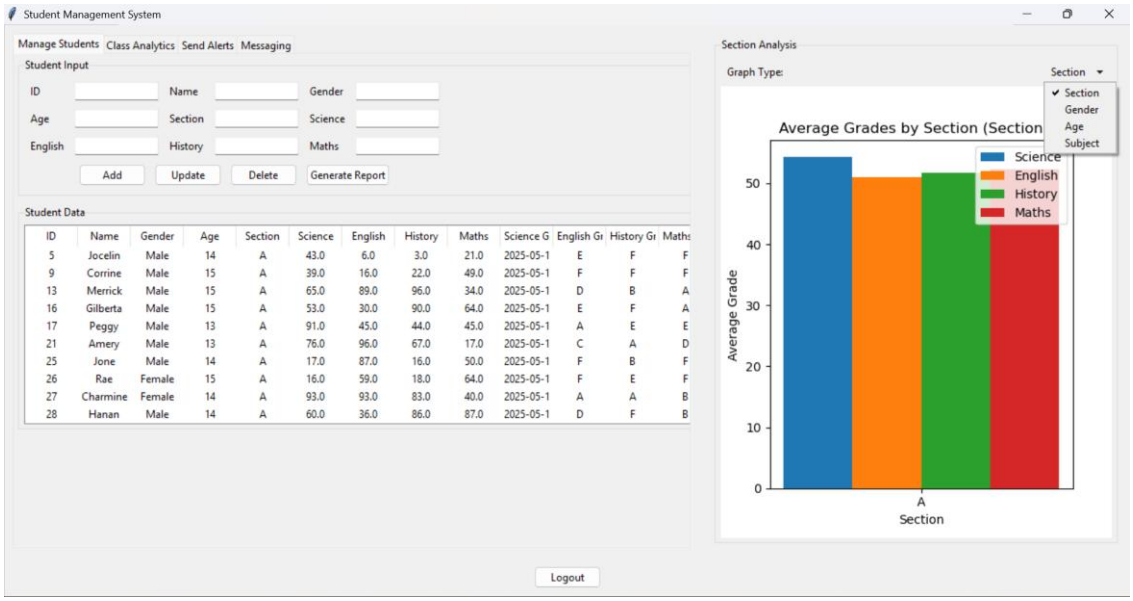


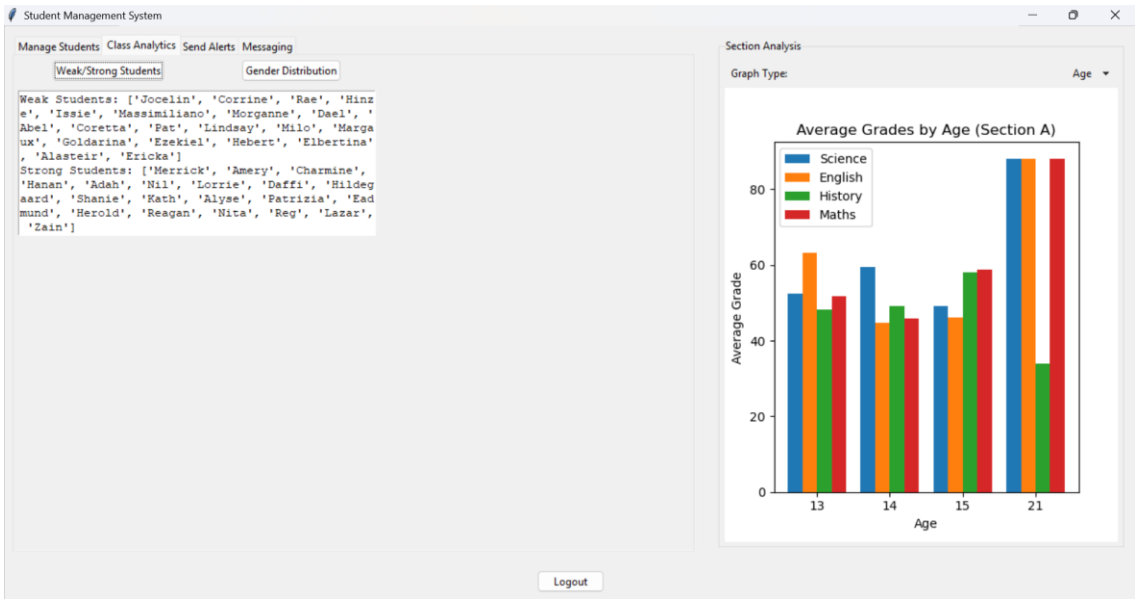
- **Admin User**

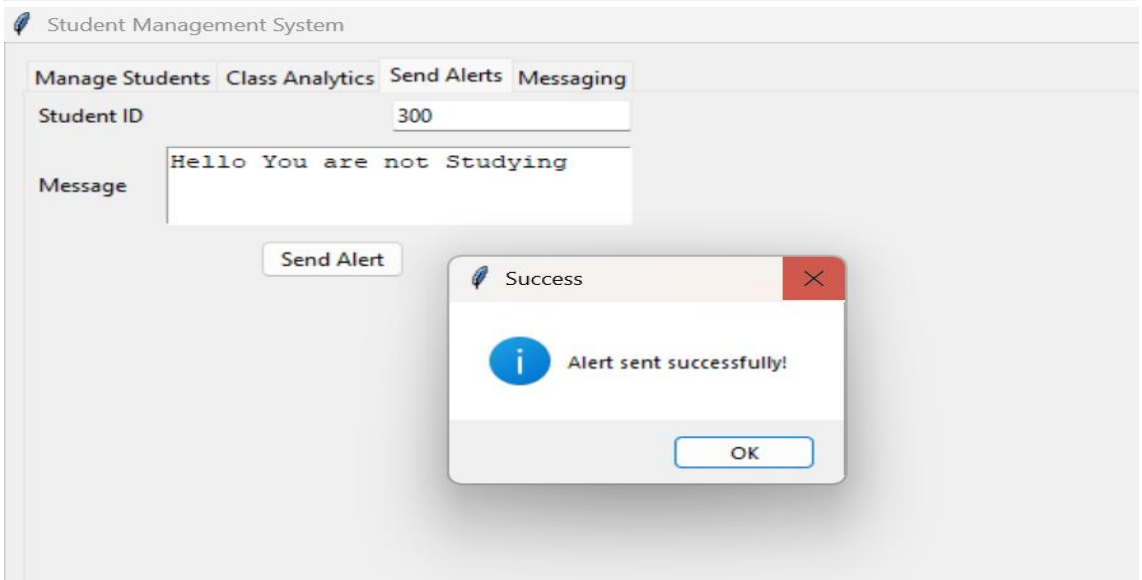




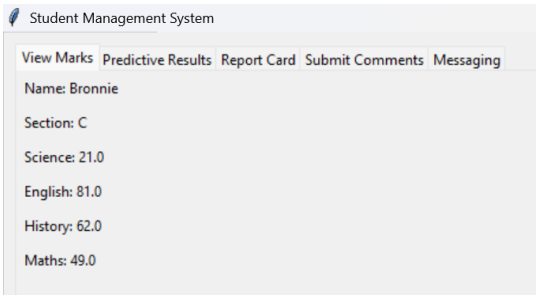
- **Teacher User**

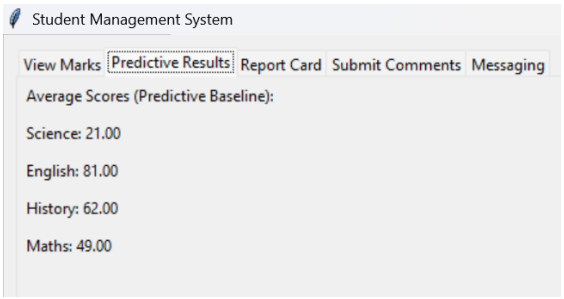


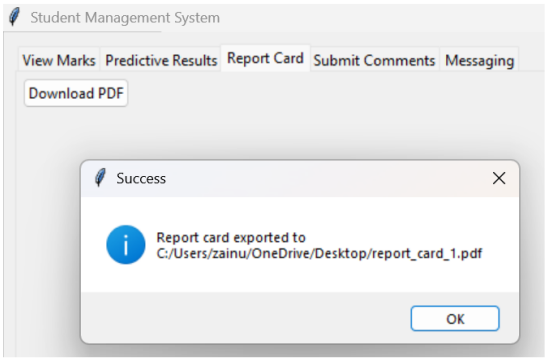


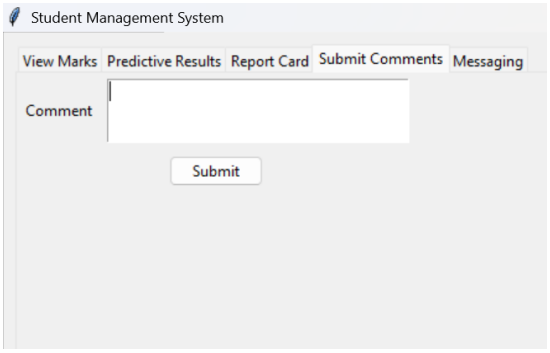


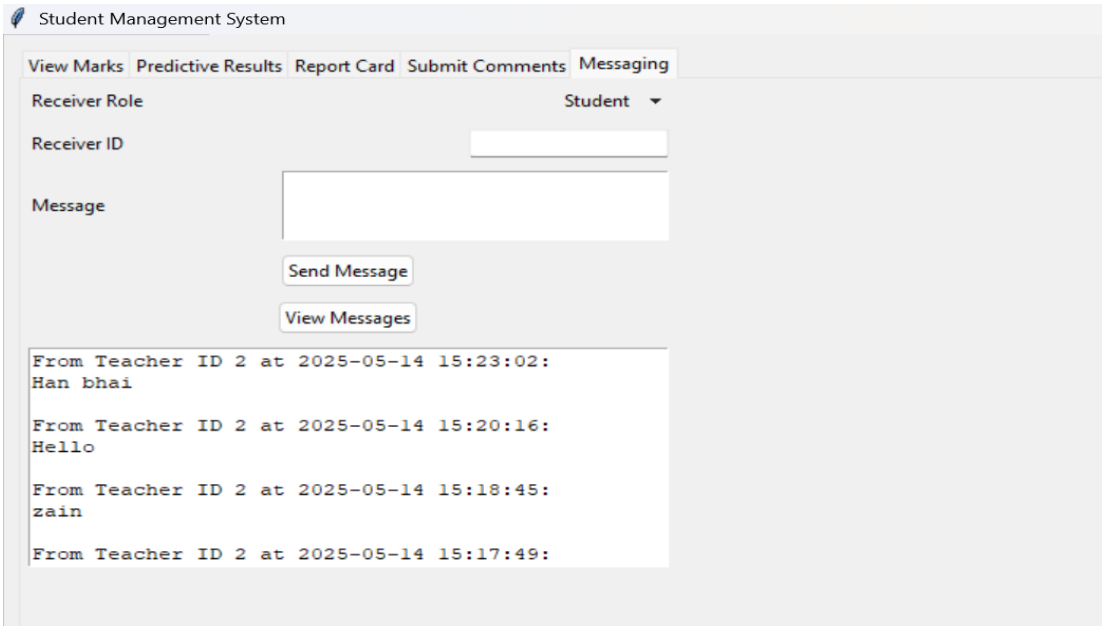
- **Student User**



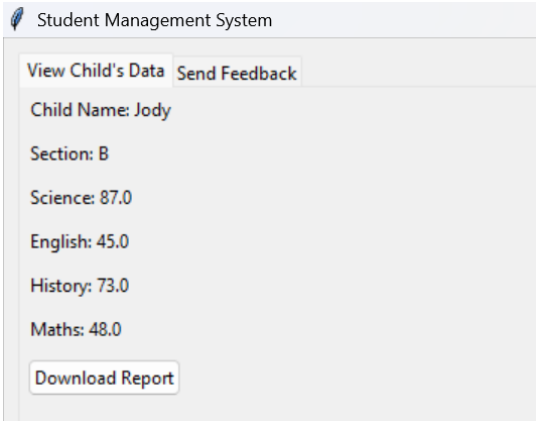


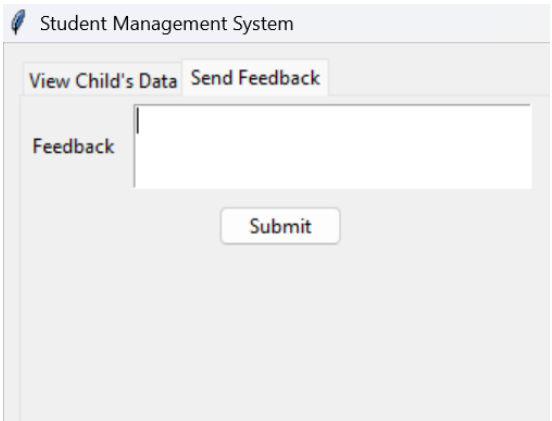






- **Parent User**





4. Conclusion

The Student Management System (SMS) stands as a testament to the power of integrating modern programming and database technologies to transform educational administration. By leveraging MySQL for a secure and scalable database structure, Python with Tkinter for an intuitive GUI, and advanced analytics capabilities, the system delivers a robust platform for managing student data, facilitating communication, and providing actionable insights. The development process successfully addressed significant challenges, including the handling of duplicate teacher names through the removal of unique constraints on the Teachers.name column, the implementation of role-specific data access to ensure privacy and relevance, and the refinement of the user interface to enhance usability through consistent alignment and spacing. The inclusion of predictive analytics, based on average score calculations with a framework for future machine learning integration, and interactive visualizations further elevates the system's utility, enabling data-driven decision-making for educators, students, and parents alike. This comprehensive approach has resulted in a reliable, efficient, and user-centric tool that holds substantial value for educational institutions seeking to modernize their administrative processes.

5. Future Work

To maintain the SMS's relevance and enhance its capabilities, we have outlined a series of ambitious improvements for future development:

- **Advanced Machine Learning Integration**: Expand the predictive analytics feature by fully implementing and refining the linear regression and random forest classifier models. This will enable personalized learning recommendations, identifying at-risk students, and suggesting targeted interventions based on individual performance trends.
- **Data Encryption**: Introduce encryption protocols for data transmission and storage, ensuring compliance with data privacy regulations (e.g., GDPR, FERPA) and protecting sensitive information such as student grades and personal details.
- **Web-Based Interface**: Develop a web version of the SMS using frameworks like Flask or Django, allowing access across multiple devices (desktops, tablets, smartphones) and broadening its reach to remote users.
- **Enhanced Visualizations**: Upgrade the visualization system with real-time updates, interactive elements (e.g., zoom, filter options), and additional graph types (e.g., heatmaps, line graphs) to provide deeper insights into student performance and trends.
- **Expanded Messaging System**: Extend the messaging functionality to support group chats for class announcements, automated notifications for deadlines or events, and integration with email or SMS for broader reach.

6. References

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