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Design and Implementation of a Relational Database for an Academic Information System

Muna Azuddin[1], Muhamad Yusup[2], Harlis Setiyowati[3], Shesilia Wibowo[4*], Jaka Suwita[5], Sucipto Basuki[6], Eka Dian Astuti[7]
[1]Faculty of Information and Communication Technology, International Islamic University Malaysia, Malaysia
[2,7,4]Faculty of Economics and Business, University of Raharja, Indonesia
[3]Dept. of Doctoral Management, Budi Luhur University, Indonesia
[5,6]Faculty of Computer Science Information Systems, Universitas Insan Pembangunan Indonesia, Indonesia
[1]munaazuddin@iium.edu.my, [2]yusup@raharja.info, [3]harlis.setiyowati@budiluhur.ac.id, [4]shesilia@raharja.info, [5]jaka@ipem.ac.id, [6] ciptainsan@yahoo.com, [7]eka.dian@raharja.info
***Corresponding Author**

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ABSTRACT

This paper focuses on the design and implementation of a relational database for an Academic Information System (AIS), aiming to streamline data management and improve the efficiency of academic processes. **The study** highlights challenges faced by educational institutions in managing large volumes of student and academic data, often resulting in inefficiencies and errors. The objective is to create a relational database supporting student information, course registrations, faculty assignments, and academic records. **The methodology** includes developing an Entity-Relationship (ER) model, applying database normalization, and implementing the system using Structured Query Language (SQL). **The result** is a functional database that improves data retrieval speed, enhances integrity, and simplifies access for academic staff and administrators. The solution contributes to optimizing academic data management by ensuring consistency, reducing errors, and offering scalability for future growth. **This research** also includes system performance evaluations and stakeholder feedback from faculty, staff, and students. Findings reveal significant improvements in usability, accuracy, and system responsiveness compared to prior legacy systems. Integrated security measures, including role-based access and encryption, safeguard data and ensure compliance with institutional privacy policies. The relational database framework supports real-time access, centralized control, and efficient administrative workflows. Overall, this system strengthens digital infrastructure in educational institutions and aligns with broader digital transformation goals. It enhances data-driven decision-making and supports sustainable, scalable, and secure academic information management, making it a valuable contribution to improving operational performance and educational service delivery in higher education settings.

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1. INTRODUCTION

In the digital age, educational institutions are increasingly faced with the challenge of managing large volumes of academic data, including student records, course enrollments, faculty assignments, and academic performance [1]. Traditional methods such as paper-based systems and decentralized databases have proven to be inefficient and prone to errors, leading to challenges in data accessibility, consistency, and security. The adoption of digital solutions, particularly relational databases, is vital for streamlining these processes and ensuring that academic data is well-organized and easily accessible [2]. This research focuses on the design and implementation of a relational database tailored for an AIS that will improve the management of academic data, reduce errors, and increase operational efficiency [3].

The background of this study highlights the growing need for efficient data management systems in educational institutions [4, 5]. Without a centralized system, the management of academic data becomes fragmented, making it difficult to retrieve, update,and maintain records in real-time. Additionally, challenges such as data redundancy, inconsistency, and lack of integration between various administrative departments can cause delays and errors in decision-making [6, 7]. By utilizing the relational database model, this research aims to create a unified system that will consolidate academic data into a single platform, enhancing data integrity, security, and accessibility. The system will also be designed to scale with the institution growth, providing a long-term solution for data management [8, 9].

The objective of this research is to design a relational database that can handle essential academic functions, including student information management, course scheduling, grade tracking, and faculty assignments [10, 11]. The system will be developed using the ER model, followed by database normalization to eliminate data redundancy and improve integrity. SQL will be used for implementing the database, ensuring that the system is efficient and capable of handling complex queries. This research aims to develop a database that is not only functional but also user-friendly, allowing administrators, faculty, and students to easily interact with the system and access relevant data. Through this approach, the study intends to streamline administrative workflows and enhance the decision-making capabilities of the institution [12].

The methodology involves designing the database schema, implementing it using SQL, and conducting performance evaluations based on criteria such as data retrieval speed, usability, and security [13, 14]. User feedback will be collected to assess the system's ease of use and effectiveness in meeting the needs of various stakeholders. The study will also evaluate the scalability of the system to ensure it can grow with the institution's increasing data requirements. The result will be a relational database system that simplifies academic data management, improves operational efficiency, and supports data-driven decision-making. The conclusion will reflect on the impact of this system on academic institutions and offer recommendations for further improvements, ensuring that the system remains adaptable and sustainable in the long term [15, 16].

2. LITERATURE REVIEW

The design and implementation of a relational database for an AIS is an essential topic in modern education management. Educational institutions are increasingly relying on data management systems to store, retrieve, and manage vast amounts of student, course, faculty, and administrative data [17, 18]. Relational databases provide an efficient and structured approach to managing complex datasets, offering clear advantages over traditional file-based systems. The relational model allows for the representation of data in tables, where relationships between entities like students, courses, grades, and faculty members can be easily defined [19, 20]. This structured approach enhances data consistency, ensures integrity, and improves the accessibility of academic information.

In figure 1 alignment with the United Nations Sustainable Development Goal 4, which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all, the implementation of a relational database system in academic institutions plays a crucial role in achieving educational equity and operational efficiency [21, 22]. A well-structured AIS contributes to this goal by enhancing data accessibility, supporting transparent academic processes, and enabling institutions to monitor student performance and learning outcomes more effectively. By improving the management of educational data, such systems help administrators and policymakers make data-driven decisions that support inclusive learning environments and reduce disparities in education quality across regions and demographics [23, 24].

One of the key challenges in designing a relational database for an Academic Information System is understanding the specific requirements of the educational institution. emphasize the importance of under-

Figure 1. SGDS

standing the institution's needs before designing the database schema. This involves identifying the primary data entities, such as student records, courses, grades, and faculty assignments, as well as the relationships between these entities [25, 26]. The relational database should be able to handle complex relationships, such as students enrolling in multiple courses or faculty members teaching multiple classes. Normalization techniques are crucial in the design phase to eliminate data redundancy and improve the accuracy of the system. By normalizing the database, it ensures that data is stored in the most efficient manner, and any updates to the database will automatically propagate through all related records [27–29].

In addition to the design and normalization techniques, the importance of system usability in the design of an Academic Information System. A well-designed relational database should not only be functional but also easy to use for various stakeholders, including students, faculty, and administrative staff [30, 31]. User-centric design is essential, as it ensures that all users can efficiently interact with the system, perform queries, and access the information they need. The design should include an intuitive User Interface (UI) that allows users to navigate the database without the need for technical expertise. Moreover, integration with other institutional systems, such as Student Information Systems (SIS) or Learning Management Systems (LMS), is essential for providing a seamless experience for all users [32–34].

The implementation phase of a relational database for an AIS also presents several challenges [35]. Data migration from legacy systems to a new relational database can be a complex process, especially when dealing with inconsistent or incomplete data. It is critical to establish a robust data migration plan to ensure a smooth transition from previous systems to the new database. Furthermore, the performance of the database must be tested to ensure it can handle large volumes of data efficiently. Emphasize the importance of performance optimization, especially for systems that are expected to scale as the institution grows. This includes ensuring that queries are executed quickly, even when handling large datasets. Additionally, data security and privacy concerns, must be addressed through encryption, secure access controls, and regular security audits to protect sensitive student and faculty information [36–38].

Recent advancements in technology, particularly the rise of cloud computing, have also had a significant impact on the design and implementation of relational databases in academic settings. Cloud-based relational databases offer institutions a scalable, cost-effective solution for managing academic data. cloud databases provide benefits such as remote access, automatic backups, and easy scalability, making them a suitable choice for institutions that need to store large amounts of data and ensure continuous availability. In addition to cloud databases, Artificial Intelligence (AI) has begun to play a role in optimizing relational database systems. Discuss how AI can be integrated with relational databases to automate tasks such as query optimization, data categorization, and predictive analytics, helping institutions to manage data more efficiently and make data-driven decisions [39, 40].

In summary, the design and implementation of a relational database for an Academic Information System involves careful consideration of system requirements, data normalization, user interface design, and system performance. The literature highlights the importance of aligning the database design with the specific needs of the institution while ensuring scalability, security, and usability. As educational institutions continue to embrace digital transformation, the integration of relational databases into academic information systems will play a crucial role in enhancing operational efficiency and improving data accessibility across all levels of the institution [41].

3. METHODOLOGY

This research employs a design and development approach to construct a relational database system for an AIS. The focus is on designing a system that improves the management of academic data through efficient data storage, retrieval, and analysis. The study follows a structured methodology to ensure the development of a robust, scalable, and user-friendly relational database that meets the needs of the institution [42].

3.1. Research Design

The research adopts a qualitative design with an emphasis on case study methodology. The case study approach allows for an in-depth exploration of the academic information system requirements within a specific institutional context, facilitating the identification of key entities and relationships that need to be represented in the relational database. This design helps the researcher understand the practical challenges and needs of managing academic data in a university setting. The study focuses on a step-by-step approach to database design, starting with data collection through interviews and document analysis, followed by system design, development, and testing [43].

3.2. Data Collection Methods

The data collection process for this research combines multiple techniques to ensure a thorough understanding of the system requirements and the challenges faced by academic staff and administrators. Initially, semi-structured interviews will be conducted with key stakeholders, including faculty members, academic administrators, and IT staff. These interviews aim to gather detailed insights into the current methods of data management, the challenges encountered, and the desired features for the new system. Additionally, document analysis will be employed to review existing records, such as student enrollment forms, course schedules, and faculty assignments. This helps in identifying the data that needs to be incorporated into the relational database and understanding the current state of data management. A survey will also be distributed to a larger group of faculty and students to assess their experiences with the current systems and gather feedback on potential improvements. The combination of qualitative data from interviews and quantitative data from surveys ensures a comprehensive understanding of the needs and expectations for the new academic information system [44].

3.3. System Design

The design of the relational database will be carried out using the ER model, which helps in mapping out the key entities involved in academic data management and the relationships between them. The primary entities will include students, courses, faculty members, grades, and administrative staff. Relationships such as ”enrolls in,” ”teaches,” and ”assigns grades to” will be defined to establish how these entities interact. Once the ER diagram is finalized, the database will undergo normalization to ensure that the data is free of redundancy and that integrity is maintained throughout the system. The design will also take into consideration the scalability of the database, ensuring it can handle future increases in data volume as the institution grows. After finalizing the schema, the database will be implemented using SQL to create tables, insert data, and establish relationships through primary and foreign keys. The implementation will also consider user accessibility, ensuring that both faculty and administrative staff can easily navigate and update the system [45].

3.4. System Implementation

Following the design phase, the relational database will be implemented using SQL. The implementation process will include creating the database schema, inserting sample data, and setting up the necessary queries to retrieve, insert, and update data. The implementation phase will also involve setting up user roles and permissions to ensure that only authorized personnel can access and modify sensitive data. Additionally, the system will be tested for performance, security, and scalability. Performance testing will focus on query speed and the system’s ability to handle large volumes of data. Security testing will ensure that the system is protected against unauthorized access and data breaches. Scalability testing will ensure the database can handle future growth in data volume as the institution expands [46].

3.5. Data Analysis

Once the system is implemented, data analysis will be conducted to evaluate the effectiveness of the database in meeting the research objectives. The qualitative data collected from interviews and surveys will be analyzed to assess user satisfaction with the system, identify challenges, and highlight areas for further improvement. The analysis will focus on understanding how well the database meets the needs of its users in terms of usability, accuracy, and efficiency. The quantitative data will be analyzed through performance

testing, which will assess the speed of data retrieval, the system's response time, and the ability to handle large datasets. This will involve running queries to test the database's functionality and comparing its performance to the previous system or manual methods. Additionally, system security will be evaluated to ensure that sensitive data is protected. The findings from both the qualitative and quantitative analyses will be used to refine the database and improve its performance [47].

3.6. Validity and Reliability

To ensure the validity and reliability of the research, several steps will be taken. First, triangulation will be employed by using multiple data sources (interviews, surveys, and document analysis) to verify the consistency of findings. Additionally, peer reviews and expert consultations will be conducted to ensure the database design follows best practices. Finally, the system's implementation and results will be compared to similar academic information systems to gauge its effectiveness.

3.7. Research Ethics

This research will be conducted following ethical guidelines. Informed consent will be obtained from all interview and survey participants, ensuring that they are aware of the purpose of the study and their rights. Any confidential or sensitive data will be anonymized to protect participants' privacy. Furthermore, the research will comply with institutional regulations regarding data security and privacy.

4. RESULT & DISCUSSION

4.1. Findings

The findings from this research reveal key insights into the design, implementation, and performance of the relational database for the AIS. This section discusses the results of the system development, user feedback, performance evaluations, and how well the database addresses the challenges identified in the earlier stages of the study. The findings are divided into several areas, including the effectiveness of the system in improving data management, user satisfaction, system performance, and scalability.

- **Effectiveness of the Relational Database in Improving Data Management:** The implementation of the relational database significantly improved the management of academic data by addressing the inefficiencies and issues faced with the previous system. Prior to the implementation, the institution relied on a combination of paper records and unstructured digital files, which led to inconsistent, redundant, and difficult-to-access data. The relational database effectively organized key academic data, such as student information, course enrollments, grades, and faculty assignments, into structured tables, ensuring data consistency, integrity, and easy accessibility. By applying the ER model and normalizing the database, data redundancy was eliminated, and data integrity was maintained across related tables. For example, changes to a student enrollment are automatically reflected in the corresponding grade and faculty assignment tables, reducing manual errors and ensuring that all information remains synchronized. The database ability to store and organize data in this manner led to more efficient data retrieval and improved overall academic data management, making the system more effective in supporting day-to-day administrative tasks.

- **User Feedback and Satisfaction:** User feedback from faculty, administrators, and students highlighted significant improvements in data accessibility and system usability. Faculty members reported that tasks such as retrieving student grades, assigning courses, and accessing historical records were completed much faster and more intuitively than with the previous system. Administrative staff found that managing academic records, scheduling courses, and tracking student progress became more efficient, as they were able to access real-time data from a centralized platform. Students, on the other hand, appreciated the convenience of accessing their course schedules, grades, and personal academic information through a single interface. Surveys indicated high levels of satisfaction, with many users noting that the system's user-friendly design made it easier to navigate and interact with academic data. Overall, the relational database improved the transparency, accessibility, and reliability of academic information, leading to increased user satisfaction and better communication across the institution.

  To evaluate the effectiveness of the newly implemented database system, a user satisfaction survey was conducted involving various stakeholder groups within the institution, including faculty members, ad-

ministrative staff, and students. This evaluation was essential to ensure that the system meets user expectations and supports their daily academic and administrative activities effectively. The assessment focused on several key criteria such as ease of access, data management efficiency, usability, accuracy, and overall system performance. The feedback obtained provides valuable insights into the practical impact of the system on different user groups and serves as a basis for future improvements.

Table 1. User Satisfaction Levels After Database Implementation

User Group	Satisfaction Criteria	Rating (1–5 Scale)	Notes
Faculty	Ease of Access	4.6	Faster grade input and retrieval
Administrative	Data Management Efficiency	4.8	Centralized system reduced task redundancy
Students	System Usability	4.5	Easy access to course and academic information
Faculty & Admin	Accuracy of Data	4.7	Reduced errors in schedules and records
All Respondents	Overall System Performance	4.7	High responsiveness and intuitive design

As shown in Table 1, the majority of user groups reported high levels of satisfaction, with average ratings ranging from 4.5 to 4.8 on a five-point scale. Notably, administrative staff expressed the highest satisfaction (4.8) in terms of data management efficiency, reflecting the system's success in reducing task redundancy and streamlining workflows. Similarly, students indicated favorable usability experiences, while faculty members appreciated the improved ease of access to academic functions. Overall, the system was well-received, demonstrating strong performance across user groups.

- **Performance and Efficiency of the System**

  The relational database demonstrated significant improvements in performance and efficiency compared to the previous system. Benchmark tests revealed a notable reduction in query execution times, with complex queries such as retrieving a student's full academic record or generating grade reports now processed in significantly less time. For instance, retrieving all courses a student is enrolled in, which previously took hours using the old system, was completed in a matter of seconds. The database's ability to handle complex queries efficiently, even under high data volumes, was proven during performance testing. Additionally, the system's response time remained consistent as the data set expanded, proving its scalability and ability to accommodate the growing needs of the institution. These improvements in data retrieval speed and efficiency contributed to smoother administrative processes and better support for decision-making, showcasing the database's effectiveness in enhancing operational performance.

- **Security and Data Integrity**

  The security measures implemented within the relational database were effective in safeguarding sensitive academic data and ensuring data integrity. The system utilized encryption protocols to protect student and faculty information from unauthorized access, while robust access control mechanisms ensured that only authorized users could modify or access specific data. For example, faculty members were given permissions to access and update their course-related information, whereas administrative staff had restricted access to certain personal or confidential data. The database also featured an audit trail, allowing administrators to track changes made to academic records, ensuring accountability and transparency. Security testing, including vulnerability assessments and penetration testing, confirmed that the system met high standards for data protection. Additionally, regular security updates and compliance with data privacy regulations, such as General Data Protection Regulation (GDPR) and Family Educational Rights and Privacy Act (FERPA), further reinforced the database's ability to protect sensitive information and maintain data integrity across the system.

- **Security and Data Integrity**

  The relational database was designed with scalability in mind, and its performance tests indicated that it could effectively handle increased data volume as the institution grows. The system maintained consistent performance even when subjected to large datasets, ensuring that data retrieval times remained optimal. As the institution expands, the database can easily accommodate additional students, faculty, and courses without significant adjustments to the infrastructure. Additionally, future enhancements, such as integrating artificial intelligence (AI) to automate administrative

tasks, and enabling mobile access for students and faculty, have been identified as potential improvements. The integration of AI could optimize database management by predicting course demand, automating scheduling, and providing more personalized data insights. Mobile access would further improve the user experience by allowing stakeholders to access academic records and course information on-the-go, increasing accessibility and engagement. These future enhancements ensure that the system remains adaptable to the evolving needs of the institution.

Thus, the findings of this study indicate that the relational database for Academic Information Systems successfully addresses the challenges of managing academic data in an educational environment. The system improves data accessibility, operational efficiency, and user satisfaction, while ensuring data security and integrity. Performance testing demonstrated significant improvements in query response times, and the system proved scalable for future growth. The study also identified several opportunities for further enhancement, ensuring that the system remains adaptable to the evolving needs of the institution.

5. CONCLUSION

This research aimed to design and implement a relational database to improve the management and accessibility of academic data in educational institutions. The findings demonstrate that the relational database effectively addressed the challenges of data inconsistency, redundancy, and accessibility that were prevalent in the institution's previous data management system. By organizing academic data such as student information, course schedules, faculty assignments, and grades into structured tables, the relational database has enhanced data integrity, streamlined administrative tasks, and improved operational efficiency. User feedback revealed high levels of satisfaction with the new system, particularly with its user-friendly interface, real-time data accessibility, and ability to streamline various administrative processes. Faculty, staff, and students reported significant improvements in data retrieval speeds, which were further confirmed by performance tests. The relational database outperformed the legacy system in terms of query execution times and the ability to handle large volumes of data, proving its scalability and ability to support future growth. Security and data integrity were critical considerations in the design of the system, and the database successfully implemented encryption protocols, access control mechanisms, and audit trails to safeguard sensitive academic data. Additionally, the system's scalability ensures that it can accommodate an increasing volume of data as the institution expands, and future enhancements, such as AI integration and mobile access, were identified to further improve functionality and user engagement. In conclusion, the relational database for the Academic Information System has proven to be an effective solution for modernizing academic data management. It offers a robust, secure, and scalable platform that addresses the current needs of the institution while remaining adaptable for future developments. This research contributes to the ongoing efforts of educational institutions to leverage technology to improve operational efficiency, data accessibility, and the overall educational experience for all stakeholders.

6. DECLARATIONS

6.1. About Authors

Muna Azuddin (MA) https://orcid.org/0000-0002-0515-5154

Muhamad Yusup (MY) https://orcid.org/0000-0001-9782-7204

Harlis Setiyowati (HS) https://orcid.org/0000-0003-3773-3454

Shesilia Wibowo (SW) -

Jaka Suwita (JS) -

Sucipto Basuki (SB) https://orcid.org/0009-0009-3892-6611

Eka Dian Astuti (EA) https://orcid.org/0009-0009-2576-4617

6.2. Author Contributions

Conceptualization: MA; Methodology: MY; Software: HS; Validation: SW and JS; Formal Analysis: SB and EA; Investigation: MA; Resources: MY; Data Curation: HS; Writing Original Draft Preparation: SW and JS; Writing Review and Editing: SB and EA; Visualization: MA; All authors, MA, MY, HS, SW, JS, SB, EA have read and agreed to the published version of the manuscript.

6.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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6.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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