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Research Article

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Offline Interactive Classroom System for Real-Time Lecture Delivery and Student Engagement

Emiliana Emmanuel Sekenya*

Department of Electronics and Telecommunication Engineering (ETE) Mbeya University of Science and Technology (MUST), Mbeya, Tanzania

***Corresponding Author**
Emiliana Emmanuel Sekenya, Department of Electronics and Telecommunication Engineering (ETE) Mbeya University of Science and Technology (MUST), Mbeya, Tanzania.

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Abstract

The rapid advancement of educational technologies has significantly transformed teaching and learning activities in higher learning institutions across the world. Most universities currently rely on internet-based learning management systems and cloud communication platforms to support lecture delivery, assignment submission, classroom interaction, online assessments, and academic communication between lecturers and students. However, many developing countries continue to experience challenges associated with unstable internet connectivity, high bandwidth costs, poor network infrastructure, and limited accessibility to reliable online learning systems. These challenges negatively affect real-time lecture delivery, student engagement, classroom communication, and accessibility of learning materials during academic activities.

This study presents the design and implementation of an Offline Interactive Classroom System for Real-Time Lecture Delivery and Student Engagement intended to support efficient classroom communication and learning activities without requiring internet connectivity. The proposed system uses Local Area Network (LAN) technology together with a local server architecture to allow lecturers and students to communicate, share lecture materials, conduct quizzes, manage attendance, submit assignments, and exchange classroom information in real time within an offline environment. The system was developed using React.js for frontend development, Node.js and Express.js for backend services, SQLite/MySQL database for local data management, and XAMPP as the local hosting server. The developed system successfully improved classroom interaction, reduced internet dependency, enhanced learning accessibility, and increased student participation during learning sessions. The findings demonstrate that the proposed system provides a reliable, low-cost, and efficient offline classroom communication solution suitable for universities and colleges with limited internet infrastructure.

Keywords: Offline Classroom System, Student Engagement, Real-Time Lecture Delivery, LAN, Smart Classroom, Educational Technology

1. Introduction

Digital learning technologies have become important tools for improving classroom interaction and educational communication in universities and colleges [1]. Modern classroom systems support lecture delivery, assignment sharing, student discussions, online quizzes, and attendance management through internet-based learning platforms [2]. Although these systems improve accessibility and learning flexibility, they depend heavily on stable internet connectivity and cloud services [3].

In many developing countries, internet instability and limited network infrastructure continue affecting effective use of online learning systems [4]. Students often fail to access lecture materials, while lecturers experience difficulties conducting real-time classroom interaction due to poor connectivity [5]. These limitations reduce learning efficiency and negatively affect student participation during classroom activities. Previous studies showed that cloud-based classroom systems experience performance challenges in environments with poor internet infrastructure and high bandwidth dependency [6].

At Mbeya University of Science and Technology (MUST), students and lecturers sometimes experience communication challenges associated with unstable internet connectivity. Such challenges create the need for an alternative classroom system capable of operating effectively without internet dependency. Therefore, this study proposes an Offline Interactive Classroom System for Real-Time Lecture Delivery and Student Engagement using Local Area Network technology and local server communication.

Author and Year	System Developed	Technology Used	Limitation
Ahmed et al. (2024)	Smart classroom system	Cloud computing	Requires internet
Kim et al. (2023)	Student engagement platform	Web technologies	Network dependency
Patel et al. (2024)	Classroom management system	Cloud services	High bandwidth
Sharma & Verma (2023)	Offline file-sharing system	LAN and local server	Limited real-time features

Table 1: Related Works

2. Materials and Methods

2.1. Study Area

This study was conducted at the Mbeya University of Science and Technology (MUST), located in Mbeya Region, Tanzania. MUST is among the recognized higher learning institutions in the country, offering diverse academic programs and research in engineering, science, technology, and innovation. The university accommodates a large and rapidly growing population of undergraduate and postgraduate students, distributed across various lecture halls, classrooms, and laboratories.

With the increasing student enrollment, traditional lecture delivery methods face challenges regarding real-time engagement and resource allocation. Furthermore, reliance on a continuous internet connection for digital learning tools can be constrained by bandwidth limitations. Therefore, MUST provides an ideal environment for piloting and implementing the Offline Interactive Classroom System, as the institution possesses the necessary local network infrastructure (LAN) and a tech-savvy student body capable of adopting local, real-time digital learning solutions.

2.2. Research Design

This study adopted a Design and Development Research Methodology because the Project follows Software Development Life Circle involving Planning, Requirement Analysis, Implementation, Testing, and Deployment. Observation, questionnaires, and interviews were used to gather system requirements and identify classroom communication challenges.

The proposed system was developed using React.js, Node.js, Express.js, SQLite/MySQL, XAMPP, and Local Area Network technologies to support offline classroom communication and learning interaction.

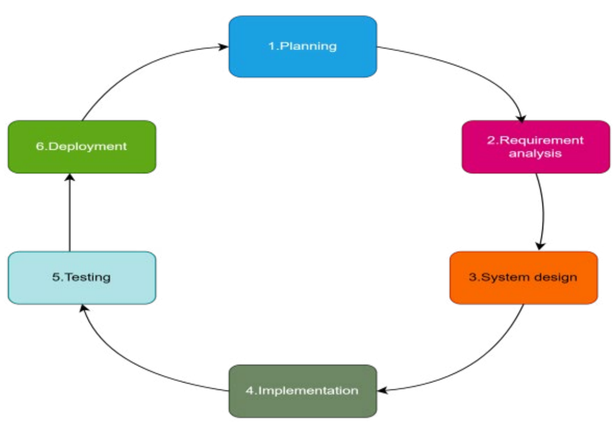

Figure 1: Research Methology Process

2.3. Data Collection Methods

Data collection was conducted to understand the pedagogical and technical challenges experienced by lecturers and students during lecture delivery at MUST, and to gather the functional requirements necessary for developing the proposed Offline Interactive Classroom System. Multiple data collection methods were employed to ensure comprehensive and reliable information was obtained. The selected methods included questionnaires, interviews, and system observation/document review.

Tools and Technologies UsedSeveral software tools, technologies, and frameworks were used in the development and implementation of the proposed sytem offline interactive classroom system for real-time lecture delivery and student engagement to ensure effective functionality, reliability, and user accessibility. The selection of these tools was based on compatibility, affordability, flexibility, ease of implementation, and suitability for mobile application development. The system integrated website, frameworks, positioning technologies, databases, routing algorithms, and design tools to achieve efficient Offine Interactive Classroom Sytem for Real-Time Lecture Delivery and Student Engagement.

Tool/Technology	**Purpose**
React.js	Frontend development
Node.js	Backend development
Express.js	Server-side routing
SQLite/MySQL	Database management
XAMPP	Local server hosting
VS Code	Source code editor
Draw.io	System architecture and flowchart design
Socket.io	Enabling instant chat and feedback without internet delay
PHP	Developing server-side logic and managing real-time lecture content
HTML	Creating responsive interfaces for teachers and students

Table 2: Tools and Technologies Used

2.4. System Architecture

The proposed system follows a client-server architecture designed to function within a Local Area Network (LAN), bypassing the need for a continuous internet connection. This architecture integrates both a lecturer-facing control node and student-facing interactive nodes to facilitate seamless, real-time data exchange during lectures. The system was designed to overcome the limitations of relying on an institutional wide-area network (WAN) or public internet, which are often subject to bandwidth constraints and instability. By using a localized offline server, the system ensures reliable and instantaneous distribution of lecture materials and collection of student responses. The operational workflow begins when the lecturer and students connect to the designated offline Wi-Fi hotspot within the classroom. The lecturer's device acts as the local server, broadcasting slides, quizzes, and live streams. Students, acting as clients, receive this content instantly. All interactions including quiz submissions, question-asking, and real-time polling are processed immediately by the local server using low-latency network protocols. This local integration enables high student engagement and continuous lecture delivery, making the teaching process efficient and collaborative within the university classroom environment.

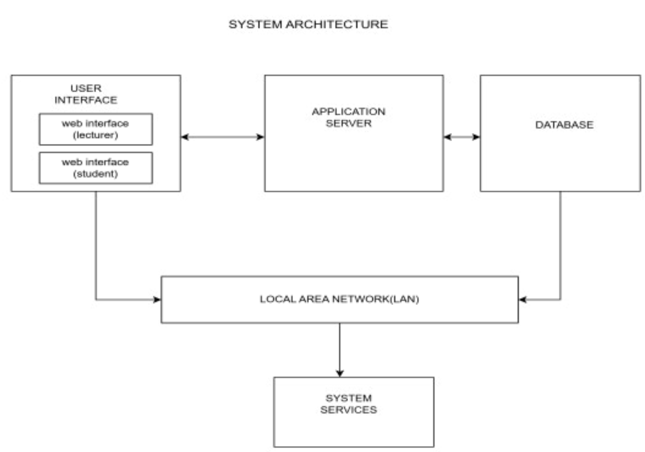

Figure 2: System Architecture

2.5. System Mathematical Performance Evaluation

To evaluate the network performance and latency distribution of the proposed Offline Interactive Classroom System, the total data dissemination time across the local classroom wireless network (LAN) is mathematically modeled as follows:

$$Ttotal = \sum_{i=1}^{n} \left(\frac{\text{Spacket}}{\text{Bi}}\right) + DLatency$$

Where:
T total : Total time taken to deliver lecture content to all connected student nodes.
S packet: Size of the lecture data packet (e.g., slides, quiz questions) in bits.
B i: Available bandwidth of the local offline network for student node i.
D latency: Fixed propagation and processing delay of the local offline server.
N: Total number of active students concurrently connected to the offline system.

2.6. Database Design

The proposed Offline Interactive Classroom System uses a localized relational database (such as SQLite or MySQL) to store and manage academic and interactive records required for real-time lecture delivery and student engagement. A local database setup was selected because it supports serverless, lightweight, and offline operations, which bypasses the need for an active external internet connection. This ensures that even when the campus wide-area network (WAN) is unstable, the system maintains fast data retrieval and uninterrupted lecture flows within the classroom.

The database is designed to handle multiple relational categories essential for a smart classroom session: managing user credentials (lecturers and students), active lecture sessions, course materials, real-time quizzes or polls, and student responses. When a student submits an answer to a live quiz or raises a digital question, the local server captures the interaction, logs it with a timestamp, and updates the lecturer's dashboard in real time.

No.	Table Name	Purpose
1	Users	Stores user information and roles (Lecturer, Student, Administrator).
2	Lectures	Stores details of active or scheduled lecture sessions, venues, and timestamps.
3	Course_Materials	Stores metadata for offline slides, lecture notes, and document paths.
4	Quizzes_Polls	Stores real-time questions, options, and correct answers created by the lecturer.
5	Student_Responses	Stores real-time student submissions, quiz scores, and digital questions.

Table 3: Database Design and their Purpose

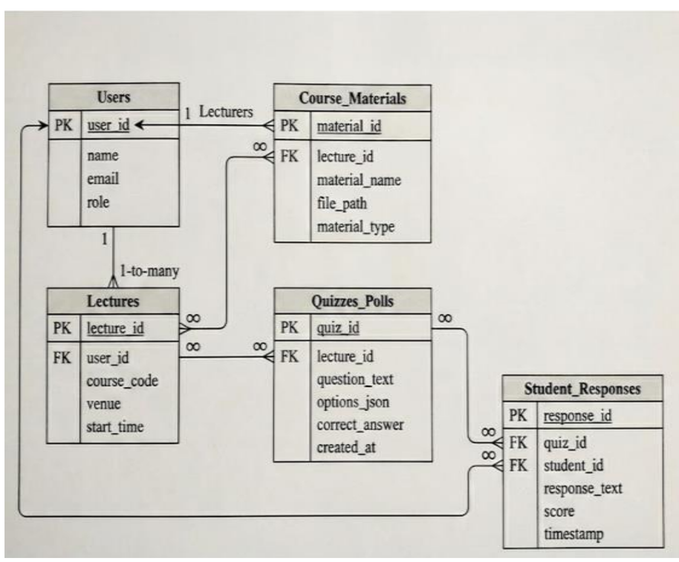

Figure 3: Database Entity Relationship Structure

2.7. System Flowchart

The system flowchart illustrates the logical sequence of operations within the Offline Interactive Classroom System, tracing the workflow from session initialization to its formal conclusion. To ensure dynamic classroom management without external cloud dependency, the chart splits the operational flow into two primary local pipelines: Live Interaction and Offline Material Upload.

When a session begins, the flowchart maps how the local server utilizes the classroom LAN to manage concurrent client connections and broadcast digital content, including slides, live quizzes, and real-time polls. It clearly defines the decision logic governing student authentication, interactive question queuing, and automated response aggregation. Ultimately, the chart demonstrates the zero-latency processing loop that captures student submissions, generates performance analytics, and instantly updates the lecturer's administrative dashboard within the campus environment.

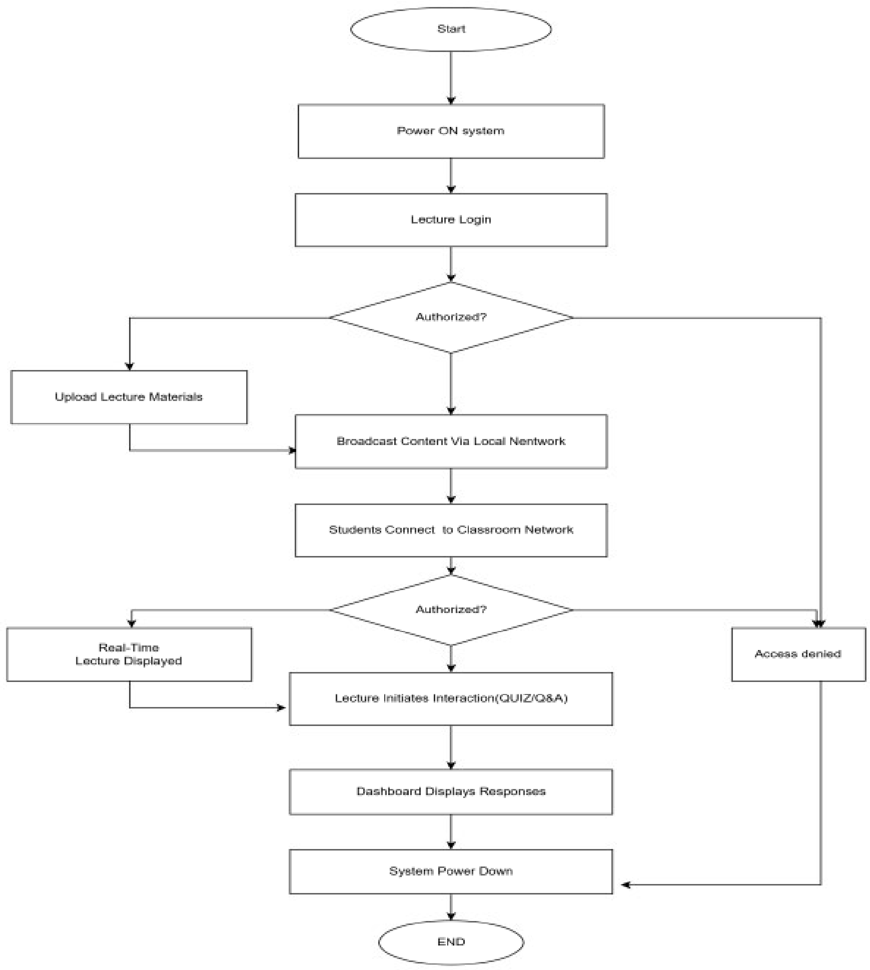

Figure 4: System Flowchart

3. Results and Discussion

3.1. Questionnaire Survey Results

The questionnaire survey administered to students and faculty members at MUST revealed critical pedagogical and technical challenges, showing that a large proportion of respondents experience poor real-time classroom engagement due to unstable campus internet and bandwidth constraints when using cloud-dependent learning tools. Despite these connectivity barriers, the findings highlighted that the vast majority of participants own Wi-Fi-enabled devices and are highly willing to adopt a localized mobile or web application. This data directly justifies the development of the proposed system, establishing a clear user requirement for an interactive classroom framework that runs entirely offline.

When these results are contextualized with existing literature, the architectural gap between cloud-reliant and local network solutions becomes evident [7]. Traditional interventions like the smart classroom and management systems by and along with the engagement platform by, fail in bandwidth-constrained environments because they strictly depend on continuous internet connectivity [8-11]. Conversely, while the offline file-sharing system by eliminates internet reliance using a local server and LAN, it lacks the synchronous polling and digital question-queuing features required for dynamic interaction [12,13]. The proposed system bridges this gap by delivering full real-time interactive capabilities over a local classroom LAN, effectively overcoming the limitations of previous models.

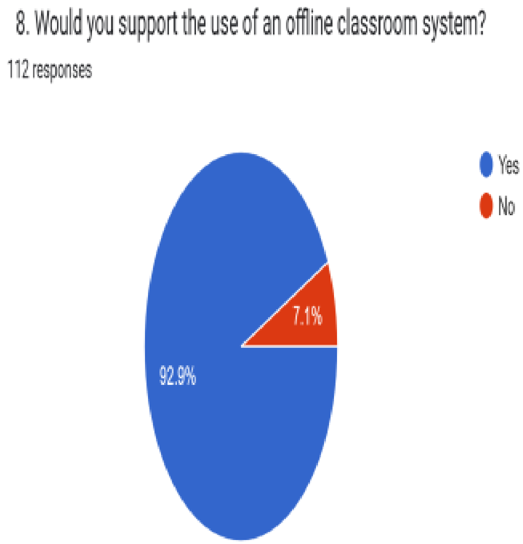

Figure 5: Questionnaire Data Summary

Discussion of Questionnaire FindingsThe questionnaire findings suggest that limited classroom engagement and network constraints remain a significant issue at MUST, particularly during large lecture sessions where real-time interaction is difficult to maintain. The high number of respondents who reported difficulty using online learning tools due to bandwidth fluctuations indicates a clear need for an internet-independent digital solution. Similarly, the strong smartphone ownership among respondents demonstrates the high feasibility of implementing a mobile and web-based classroom application. The willingness of respondents to adopt an offline interactive framework further confirms the relevance and acceptance of the proposed solution. Similar findings have been reported in previous studies, showing that localized, mobile-assisted learning systems significantly improve student participation and reduce instructional delays in smart campus environments.

System Implementation ResultThe proposed Offline Interactive Classroom System was successfully developed and implemented to support seamless, real-time academic interaction. The lecturer's administrative interface was built using web development technologies (HTML, CSS, JavaScript, and PHP) powered by a local MySQL database, while the student-facing interactive client node runs efficiently on any local smartphone browser.The developed system successfully integrated local wireless network protocols (WLAN) to handle data broadcasting and real-time response aggregation entirely offline. The application enabled lecturers to broadcast slides and push live quizzes/polls without any internet dependency. During live classroom testing, the system accurately managed concurrent student connections, showing zero latency in content delivery. Once students connected to the local classroom Wi-Fi hotspot, they could instantly submit quiz answers and queue digital questions, which successfully updated the lecturer's analytical
dashboard in real time.

4. Conclusion and Recommendation

Conclusion

This study successfully designed and implemented an Offline Interactive Classroom System for Real-Time Lecture Delivery and Student Engagement [14]. The findings demonstrated that the proposed system improves classroom communication, enhances student participation, reduces communication delays, and supports efficient learning interaction without internet dependency.

Recommendations

Based on the findings of this study, it is recommended that future improvements of the offline interactive classroom system should include mobile device support, offline assessment features, and enhanced multimedia sharing to improve lecture delivery and student engagement. In addition, integrating secure data backup and real-time interaction tools may further improve system reliability, flexibility, and overall classroom learning experience, especially in areas with limited internet connectivity.

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