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Design and Implementation of a Web-Based Online Exam System with Screen Monitoring for Academic Integrity

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Abstract

The widespread use of online exams has exacerbated academic integrity issues due to limited visibility of proctoring in a digital environment. This study designed and implemented a web-based exam system that integrates screen-monitoring features to support transparency in proctoring between proctors and students. The system was developed using a Waterfall approach, encompassing needs analysis, system design, implementation, and functional testing. System evaluation was conducted through a limited pilot test involving 4 participants, with quantitative data obtained from system logs that recorded successful answer saving, exam time control, tab-switching detection, and real-time screen monitoring. Descriptive analysis showed that 100% of participants' answers were saved without data loss, all exam sessions ended with automatic access lockout, and tab-switching activity was detected and acted upon with up to 3 warnings before the exam was disabled. The screen monitoring feature operated stably under standard internet network conditions, although performance was affected by user bandwidth. These findings confirm that integrating screen monitoring into online exam systems is a viable, globally replicable proctoring solution, particularly for educational institutions that require technology-based academic integrity mechanisms without relying on complex AI-based proctoring.

Keywords: Online Exams; Screen Monitoring; Academic Integrity; Web-Based Systems; Functional Evaluation.

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Introduction

The digital transformation in education has fundamentally changed the way institutions design, deliver, and evaluate learning processes. One of the most significant changes is the adoption of online examinations as part of the academic assessment system, which offers flexibility, administrative efficiency, and scalability across time and space (Bilan et al., 2023; Dalimunthe et al., 2023; Ratheeswari, 2018). In a global context, online exams are no longer positioned as an emergency solution, but rather as a permanent component of the digital education ecosystem, both in higher education and secondary education (Fluck, 2019; Lee & Fanguy, 2022; Muzaffar et al., 2021).

However, the widespread use of online exams has raised fundamental issues that have not yet been fully addressed: reduced visibility of proctors and increased risk of academic integrity violations. Unlike face-to-face exams, which allow for direct and simultaneous proctoring, the digital exam environment limits proctors' ability to comprehensively monitor participant behavior (Garg & Goel, 2022; Gudiño Paredes et al., 2021; Judi, 2022). Several studies have shown that cheating in online exams is often related to a lack of control over screen activity, the use of external resources, and switching between applications or tabs during the exam (Baseer et al., 2022; Ghizlane et al., 2019; Moukhliss et al., 2023).

In response to these challenges, various online proctoring technology approaches have been developed, ranging from video recording, artificial intelligence-based behavioral analysis, to automatic detection systems using machine learning (Mahmood et al., 2022; Moukhliss et al., 2023). While this approach promises to improve oversight, recent studies have also highlighted its limitations, including high infrastructure requirements, implementation complexity, potential system bias, and privacy and user acceptance issues (Kaddoura & Gumaei, 2022; Lee & Fanguy, 2022; Tweissi et al., 2022). This situation shows that sophisticated proctoring solutions are not always aligned with the capacity of educational institutions, especially in developing countries or institutions with limited resources.

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In this context, a screen-sharing-based screen monitoring approach emerges as a more lightweight and realistic alternative. Previous research has shown that live screen activity monitoring can increase student awareness of proctoring and help proctors detect risky behavior during exams (Engel & Agustinus, 2023; Jia & He, 2022). However, existing studies generally focus on developing separate features or evaluating specific proctoring systems, without integrating screen monitoring, time-based exam management, activity logging, and violation response mechanisms into a single, easily replicable online exam system.

Therefore, the research gap in this study lies in the lack of studies on web-based exam system design that explicitly integrate real-time screen monitoring and participant activity logs as supporting mechanisms for academic integrity, particularly those evaluated through operational quantitative indicators of system performance. Most previous studies emphasize the effectiveness of AI-based proctoring or discuss the concept of online exams, thereby failing to provide an implementable alternative that balances proctoring effectiveness, technological affordability, and user acceptance.

Based on this gap, this study contributes to two main aspects. Methodologically, this study develops and documents the design process for a web-based examination system using the Waterfall approach, integrating real-time screen monitoring, tab-switching detection, and activity logging as design artifacts. Theoretically and practically, this study enriches the discourse on academic integrity in digital assessment by demonstrating that a simpler and more transparent oversight mechanism can be a viable solution, especially for educational institutions that have not adopted an artificial intelligence-based proctoring system. Therefore, the results of this study are expected to serve as a reference for system developers, educators, and policymakers in designing more accountable and sustainable online examinations.

Method

Research Design

This research uses a system design and development (DDR) approach with the Waterfall software development model, which emphasizes sequential, systematically documented work stages. This model was chosen because it is appropriate for developing an online examination system that requires clear specifications, functional stability, and validation at each development phase (Ali & Yahaya, 2023; Goudie, 2020; Pradana & Wibowo, 2025; Senarath, 2021). The Waterfall stages applied include requirements analysis, system design, implementation, and functional testing, with each stage being fully completed before moving on to the next.

System Requirements Analysis

A needs analysis was conducted to identify the functional and non-functional requirements of a web-based online examination system, with a primary focus on the proctoring mechanism and exam integrity. Functional requirements include role-based user authentication (proctor and participant), question management, time-based exam administration, automatic answer storage, and monitoring of participant activity during the exam. Non-functional requirements include access security, data storage reliability, and the system's ability to record and track participant activity in real time. The needs analysis process was conducted through observation and limited interviews with stakeholders to identify critical features that support online exam integrity, in line with web-based exam system development practices that emphasize accountability in the assessment process (Abass et al., 2017; Atthayuwat et al., 2022; Oluwaseun et al., 2017).

System Design

The system design phase focused on developing the system architecture and modeling user interactions to ensure consistency of the exam flow and traceability of participant activities. The system was designed with a three-layer architecture comprising a user interface (frontend), an application server (backend), and a database. A screen-monitoring mechanism was designed using screen sharing to enable the exam proctor to monitor participants' screens in real time. The system process modeling was visualized in the form of flowcharts and use case diagrams as design artifacts to represent the operational flow and user role boundaries. Figure 1 presents a flowchart of the exam implementation from authentication to result storage, while Figure 2 models the interactions between the proctor and participant roles for question management, exam administration, answer submission, and result review.

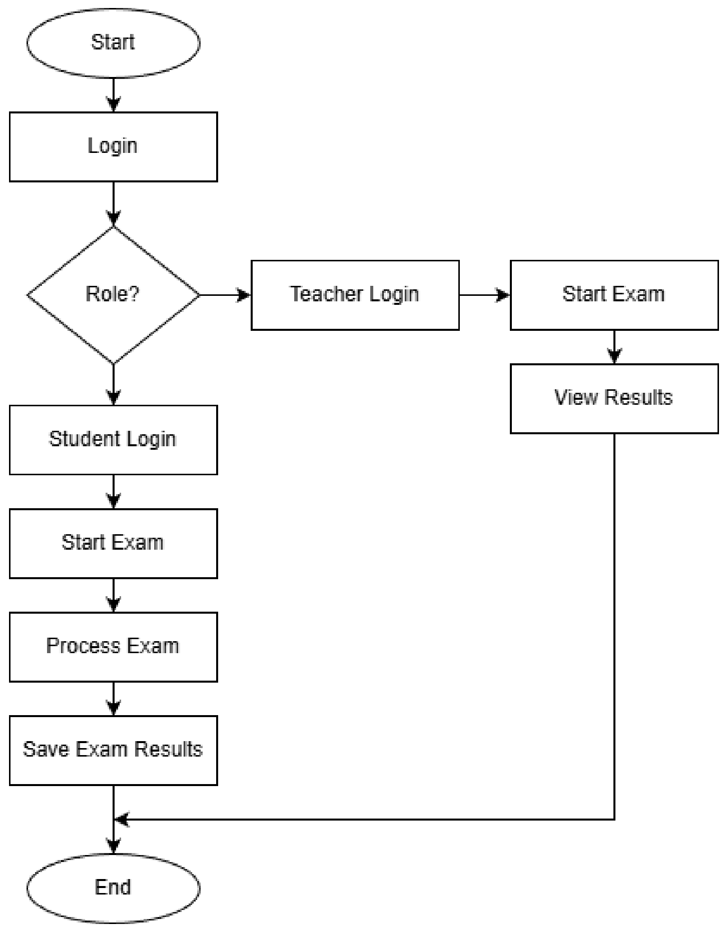

Figure 1. System flowchart

Figure 2 further displays a use case diagram that models the interaction between the proctor and the participant, including question management, exam administration, answer submission, and result review. This design artifact is used to ensure alignment between system requirements and functional implementation.

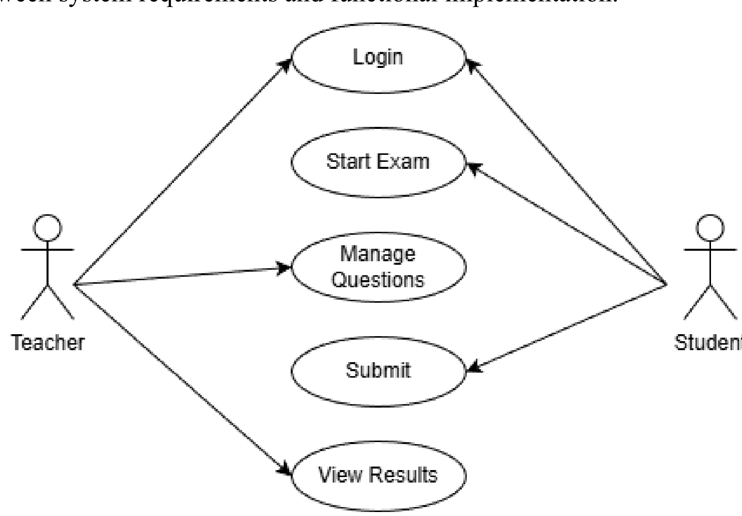

Figure 2. Use case

Implementation and Testing

The implementation phase involved building a web-based exam system in accordance with the design specifications. The system used web technologies on the frontend and backend, as well as cloud-based database services for data storage and real-time synchronization. A screen monitoring feature was integrated to allow proctors to monitor participants' screen activity during the exam. System testing was conducted using a black-box testing approach to verify that the system's functionality met the formulated requirements. Testing focused on authentication, timed exam execution, answer storage, participant activity recording, and screen monitoring stability.

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Subject and Context of Evaluation

The system evaluation was conducted through a limited trial within an online exam simulation in a higher education setting. The evaluation subjects consisted of four participants acting as exam takers, with one proctor account used to monitor the exam through a monitoring dashboard. The number of subjects was chosen to support the initial evaluation objectives, which focused on functional feasibility, system stability, and the reliability of the proctoring mechanism, rather than to test learning effectiveness in a broader population.

Data Collection and Analysis

Research data was obtained from automated system logs generated during the exam. Data included successful retention of participant responses, exam time control, and access lockout, tab or screen switching detection, and real-time screen monitoring. Data analysis used quantitative descriptive methods to evaluate the system's operational performance and the consistency of its monitoring mechanisms.

Results and Discussion

Result

System Functional Performance

Functional performance evaluation was conducted on a simulated exam scenario involving four participants and one proctor account. All key system functions, including authentication, question loading, exam time management, answer storage, and participant activity recording, operated as specified. The system recorded a 100% success rate in storing answers without data loss, even during temporary internet connection disruptions. The exam time lock mechanism was automatic throughout the session, consistently halting participant access when the exam time limit was reached.

System Functional Performance

Functional performance evaluation was conducted on a simulated exam scenario involving four participants and one proctor account. All key system functions, including user authentication, question loading, exam time management, answer storage, and participant activity recording, operated according to the system design specifications. During the trial, the system recorded a 100% success rate in storing answers, with no data loss even during temporary disruptions in internet connectivity. The exam time lock mechanism was automatic throughout the session, consistently halting participant access when the exam time limit was reached. The system also maintained intact exam data after the session ended. A summary of the system's functional performance indicators is presented in Table 1.

Table 1. Functional Performance Indicators of the SmartExam System

Indicator	Result
Answer storage success rate	100%
Automatic exam time enforcement	Enabled (all sessions)
Data persistence during connection loss	Maintained
Post-exam access lock	Activated

System Architecture and Technology Implementation

The SmartExam system is implemented using a three-layer architecture comprising a frontend, a backend, and a database. Exam data storage, including participant data, questions, exam results, and activity logs, is managed through a cloud-based database that supports real-time synchronization. Screen monitoring integration is implemented via WebRTC and connected to the LiveKit service to support screen sharing during exams. The system implements role-based authentication, limiting access to screen monitoring and activity logs to proctor accounts, as shown in Table 2.

Table 2. Technologies Used in the SmartExam System

Component	Technology Used
Frontend	HTML, CSS, JavaScript
Backend	Node.js
Database	Firebase Realtime Database / Firestore
Screen Monitoring	LiveKit (WebRTC)
Hosting	VPS / Firebase Hosting + SSL
Authentication	Firebase Authentication

Monitoring Interface and Activity Detection

The proctor interface serves as a central monitoring point for participant activity during the exam. Figure 3 displays the login page and the proctor dashboard, which provide participant status information, including tab-switching indicators and the time of the last activity. The screen-monitoring feature requires participants to share their screen during the exam, while the system records activity and sends a notification to the proctor if tab switching or leaving the exam screen is detected.

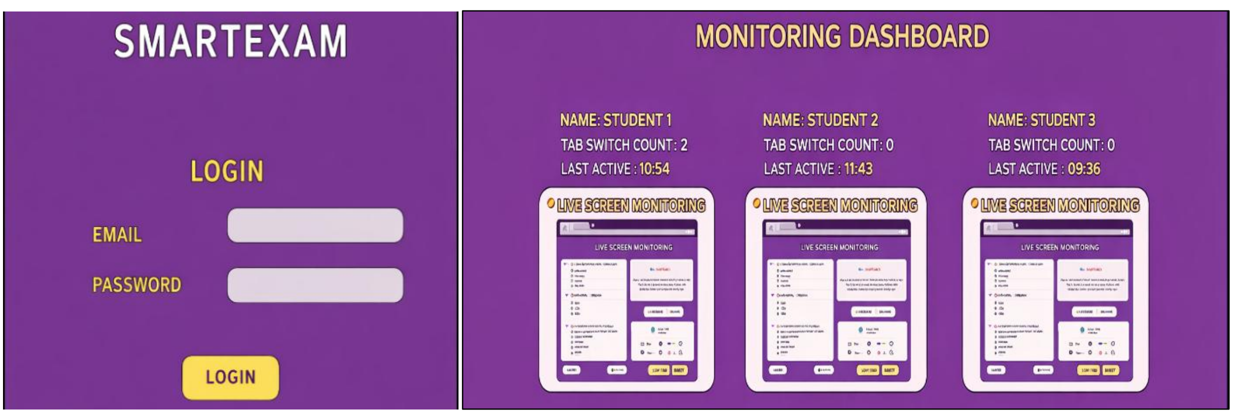

Figure 3. Login page and dashboard

The live screen monitoring feature requires participants to share their screens during the exam. The system automatically records participant activity and sends a notification to the proctor if it detects switching tabs or exiting the exam screen. This activity log is stored as part of the post-exam evaluation data.

Exam Execution and Logging Results

The exam is administered through the participant interface shown in Figure 4. The exam page displays questions, answer options, the user ID, a screen-monitoring reminder, and an exam timer. System logs indicate that tab-switching activity is detected and acted upon via a mechanism that issues up to 3 warnings before automatically disabling the exam. Exam data is maintained even during temporary internet connection interruptions, with synchronization occurring when the connection is stable again.

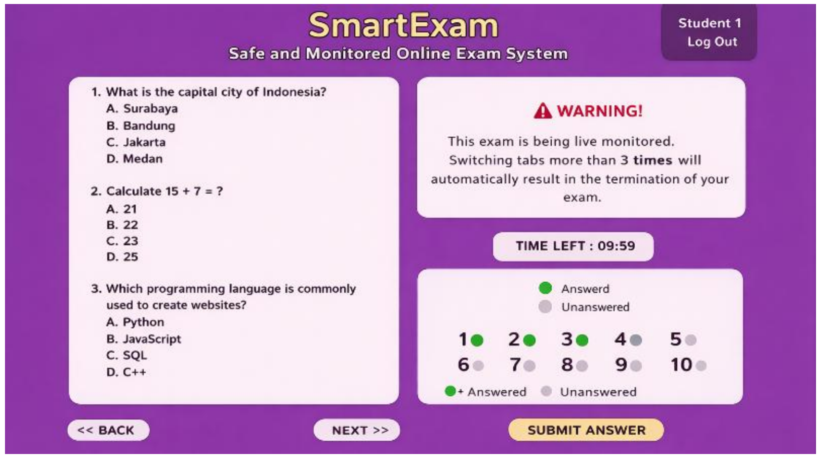

Figure 4. Exam question page

Discussion

The results of this study demonstrate that SmartExam functions reliably at both the implementation and operational levels as a proctored online exam platform. Its 100% answer retention rate and automatic time lock across all sessions meet the basic requirements for accountable and controlled digital assessment (Fluck, 2019; Muzaffar et al., 2021; Palinggi et al., 2022). The integration of screen monitoring and participant activity recording provides greater visibility into proctoring than conventional online exams, particularly through tab-switching detection and a tiered response mechanism, which aligns with the literature on integrity strategies in online assessments (Garg & Goel, 2022; Gudiño Paredes et al., 2021).

Compared to AI-based proctoring, a screen-sharing-based screen monitoring approach offers a more pragmatic option because it does not require complex behavioral analytics and is transparent to users. These findings are consistent with reports (Engel & Agustinus, 2023) regarding the use of tab/window detection for fraud prevention, as well as findings (Jia & He, 2022) which emphasizes the value of behavioral logs in maintaining participant focus. However, the pilot with four participants limits generalizability, so the primary contribution of this study is more appropriately positioned as evidence of the feasibility of the system's design and implementation rather than its causal effectiveness in reducing fraud (Tweissi et al., 2022). Within this framework, SmartExam can be viewed as a relevant design artifact for institutions seeking a technology-based academic integrity solution that is lightweight, scalable, and easily replicated. By combining screen monitoring, activity logging, and web-based exam management, this research offers an implementable alternative for educational institutions seeking a transparent, controlled, and adaptable online exam solution that aligns with available technological capabilities.

Conclusions and Suggestions

Conclusions

This research demonstrates that a web-based exam system that integrates screen-monitoring features can be reliably implemented as a supporting mechanism for academic integrity in a digital assessment environment. Using a Waterfall design approach, the SmartExam system was successfully developed, with key capabilities including time-based exam management, consistent answer storage, participant activity recording, and real-time screen monitoring between proctors and students.

The functional evaluation results of a limited trial indicate that the system is capable of maintaining operational reliability, including successful data storage without loss of information, automatic access locking after the exam time is over, and detection of risky activities such as tab switching, which is followed up through a multi-level alert mechanism. These findings confirm that a screen-sharing-based screen-monitoring approach can serve as a transparent, relatively lightweight proctoring alternative to complex, expensive AI-based systems.

Conceptually, this research contributes to the global discourse on academic integrity in online examinations by demonstrating that increased oversight visibility does not necessarily rely on AI-based analytics. Methodologically, this research provides an example of the implementation of design and development research in the development of a digital assessment system that can be replicated and adapted to suit institutional contexts. Thus, SmartExam can serve as a foundation for developing a more accountable, secure, and sustainable online examination system.

Suggestions

Based on the research findings and identified limitations, further development and research should be directed toward broader system evaluation to test the performance and stability of screen monitoring under simultaneous use with a larger number of participants. This approach would enable more in-depth statistical analysis of participants' behavior patterns and the effectiveness of the monitoring mechanism. Furthermore, enriching quantitative indicators, such as tab-switching frequency per participant, inactivity duration, and screen-monitoring latency, could strengthen the system's analytical capabilities as a basis for post-exam academic decision-making.

On the other hand, ethical and privacy aspects require special attention through the formulation of standard operating procedures, informed consent mechanisms, and data retention policies that align with data protection regulations. Integrating SmartExam with existing Learning Management Systems, such as Moodle or similar platforms, can also improve the efficiency of learning and assessment management while expanding accessibility by developing adaptive versions for mobile devices and under limited network conditions. Going forward, selective exploration of a combination of screen monitoring and AI-based behavioral analytics can be considered to enhance detection capabilities, without compromising system transparency and technological affordability.

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