Airman

Journal of Transportation Engineering and Safety

ISSN: 2622-0105 (print) | 2716-1196 (online)
http://jurnal.poltekbangmakassar.ac.id/

EVALUATION OF THE QUALITY OF LEARNING MANAGEMENT SYSTEM WITH REAL-TIME SUPERVISION USING ISO/IEC 25010 IN AVIATION VOCATIONAL EDUCATION

Fatmawati Sabur[1], Abdul Salam[2], Mulyadi Nur[3], Heru Kusdarwanto[4], Sahrul[5]
[1,2,5] Makassar Aviation Polytechnic
[3]Jayapura Aviation Polytechnic
[4]Palembang Aviation Polytechnic

***Correspondence:**
fatmawati.sabur@poltekbangmakassar.ac.id

Article Info

Accepted: 15-06-2026
Final Revision: 29-06-2026
Accepted: 29-06-2026
Available online 30-06-2026

Keywords:

Learning Management System, Real-Time Exam Proctor, ISO/IEC 25010, CBT, Digital Evaluation, Research and Development

.

ABSTRACT

Development of a web-based learning management system that is integrated with real-time exam supervision to overcome problems of academic integrity, operational efficiency, and quality of digital learning evaluation in vocational universities. The increasing use of computer-based exam systems poses challenges related to participant supervision, the validity of exam results, and the inefficiency of academic administration processes. In contrast to previous studies that only evaluated LMS or proctoring systems separately, this study integrates LMS modules, real-time monitoring, and software quality evaluation using ISO/IEC 25010. The research method uses (R&D) with four main stages, namely needs analysis, system design, prototype development, and system quality evaluation. There were 75 respondents, including students, supervisors, study program organizers, and CBT laboratory managers. The system evaluation is carried out using the ISO/IEC 25010 standard to comprehensively measure the quality of the software. The results showed that user needs were dominated by the ease of use of the system (96.0%), automatic recapitulation of scores (93.3%), and recording of participant activities (90.7%). The evaluation of system quality obtained an average score of 88.4% with the category of excellent. The results of the evaluation showed functional suitability (91.2%), usability (93.6%), safety (89.6%), reliability (88.0%), performance efficiency (87.5%), compatibility (85.1%), maintenance (86.7%), and portability (85.9%). The results of the efficiency test showed a significant improvement, characterized by a decrease in the recapitulation time of the value from 120 minutes to 15 minutes and a decrease in input error from 8 cases to 1 case. These findings prove that the integration of LMS with a real-time exam proctoring system can improve operational efficiency, data accuracy, and the integrity of the academic evaluation process. The developed system contributes to the development of a more reliable, standardized, and applicable digital evaluation model in vocational higher education environments.

Suggested Quotes:

WHAT Style

INTRODUCTION

With the advancement of technology in the current era, the form of evaluation used in higher education has also undergone many changes, from conventional types of exams to computer-based, online-based assessments, and learning management systems (LMS). In this learning management system, learning is not only carried out online, but also fully integrated with the learning management system (Turnbull et al., 2020) . This change is important for universities because reputable universities must provide a fast, accessible, and accountable evaluation system. The development of digital learning systems should prioritize effectiveness, interactivity, and ease of use to improve both learning quality and assessment processes. (Nur & Sabur, 2026) reported that interactive learning modules significantly enhance learning outcomes, providing a strong foundation for the development of Learning Management Systems (LMS) that support digital assessment.

While the various uses of digital-based or online-based evaluation systems have various advantages, there are also some challenges in implementing them that negatively impact academic integrity. (Holden et al., 2021a)This shows that online assessment is a complex system and has many dimensions. Academic integrity is greatly influenced by various factors confirmed by researchers regarding aspects of the online evaluation system.

Academic violations in the online evaluation system can be in the form of various violations, such as impersonation, collusion between examinees, using external resources, using additional devices, or manipulating one's own digital identity (Bilen, E., & Matros, 2021); Eaton, S.E., & Turner, 2020). Advances in information technology are calling on managers and organizers to provide more unsupervised and semi-supervised online evaluations. (Newton, 2020) Stating that cheating in online evaluations shows an increasing trend when evaluations are not well-designed against authentication systems. The difficulty of conducting online evaluations in an uncontrolled environment provides room for individuals to commit unethical and unstructured evaluation system violations.

The issue also shows that the implementation of online Final Semester Exams has been supported by the availability of CBT laboratories, Mythware applications, smartboards, and cloud-based e-ujian.com applications. However, exam supervision still relies on direct and administrative supervision by space supervisors, so the system's ability to automatically detect violations is still limited. In addition, the processing of scores and analysis of exam results still requires a manual process in several parts, thus slowing down the recapitulation of results and increasing the risk of human error.

The impact of the limitations of the digital exam system not only appears on the technical operational aspect, but also has structural implications for academic governance and the quality of evaluative decisions of educational institutions, where the integrity of assessment is a central issue because it is directly related to the validity of learning outcomes and the credibility of universities. First, the limitations of the system in detecting violations in real-time can interfere with the validity of the construction of test results. When the system is unable to identify dishonest behavior during the assessment process, the resulting score potentially does not represent the actual abilities of the participants. (Henderson, M., Awdry, R., Chung, J., Bryant, M., & Ashford, 2022) This shows that a fully integrated digital surveillance mechanism has only a partial effect on fraud prevention, so the validity of the evaluation results is still influenced by external factors that are not controlled. (Dendir, S., & Maxwell, 2020) Asserts that the online exam environment inherently increases the risk of academic dishonesty that cannot always be detected by technology-based systems. Second, inefficiencies in the recapitulation and verification process of grades have a direct impact on data-based academic decision-making, such as graduation determination, curriculum evaluation, and mapping learning outcomes. (Allen, J., Young, J., & Steger, 2021) The integration of suboptimal digital assessment systems has been shown to create administrative bottlenecks that slow down the academic evaluation cycle, especially in institutions with large student volumes. Third, the transformation of proctoring from a conventional model to a digital model increases the cognitive and operational burden of exam proctors. Simultaneous surveillance in a virtual environment demands attention on multiple data streams (video, activity logs, and system interactions), which significantly increases the workload compared to traditional surveillance. (Whitelock, D., Twiner, A., & Delgado, 2020) Reinforcing this principle by stating that the effectiveness of online surveillance is highly dependent on the design of monitoring systems that can reduce the manual burden of supervisors through analytics-based automation. Fourth, from a student experience perspective, unclear systems related to identity authentication, breach warnings, and exam status can reduce the perception of reasonableness and increase the cognitive burden of participants. In the context of the theory of usability of digital evaluation systems, the lack

of transparency in the monitoring process has the potential to disrupt trust in the assessment system and affect the performance of the exam indirectly (Mollenkopf, DA, 2021).

Online exam proctoring needs to combine pedagogical and technological strategies. (Hilliger, I., Ruipérez-Valiente, J.A., Alexandron, G., & Gašević, 2022) Propose a trustworthy remote assessment approach that combines assessment design, authentication, oversight, and process transparency. (Heinrich, E., Milne, J., & Moore, 2025) It also emphasizes that online oversight can help maintain the integrity of assessments when face-to-face oversight is not possible, but its implementation should consider privacy, data security, and system decision-making transparency. Therefore, the supervisory system developed must not only detect violations but also be designed as an evaluation tool that is fair, secure, auditable, and easy to use.

Table 1. Comparison of Previous Research and Proposed Research Positions on Digital Exam Proctoring System

Research	System	Pros	Limitations	Research Gap
ProctorU	AI + Human	High accuracy	Paid	Have not evaluated the quality of the software using ISO/IEC 25010
Respondus	Lockdown Browser	Stable	Limited LMS integrations	Focus on securing the browser, not a thorough evaluation of the system
OpenProctor	Open Source	Flexible	Lack of analytics	Has not provided integrated quality evaluation and monitoring
This research	LMS + Real-Time Monitoring + ISO/IEC 25010	Integration of monitoring, LMS, and system quality evaluation	Implementation is still in aviation vocational education	Offers integration of supervision, learning management, and software quality evaluation in a single platform

Table 1 shows that most of the existing research and exam proctoring systems focus on improving security and supervision during the exam. However, there have not been many studies that integrate Learning Management System (LMS) functions, *real-time* exam proctoring, and software quality evaluation using the ISO/IEC 25010 standard in one platform. Therefore, this study offers a more comprehensive approach by combining these three aspects to support academic integrity while evaluating the quality of the system in the context of aviation vocational education.

Research on digital learning evaluation has been carried out extensively, but there are still some gaps. (Holden et al., 2021b) focuses on academic integrity in online assessments, but has not evaluated the quality of the software used. (Hilliger et al., 2022) Developing a concept, *Trusted Remote Assessment*, but have not yet integrated the *Learning Management System* (LMS) into one platform. Meanwhile, (Heinrich, 2025) Review the system *Online Proctoring* with emphasis on privacy and transparency aspects, but has not yet adopted the ISO/IEC 25010 software quality standard. Based on these gaps, this study integrates LMS, real-time exam proctoring, and software quality evaluation using ISO/IEC 25010, resulting in a more comprehensive approach to support the integrity of digital evaluation in aviation vocational education.

METHODS

This study uses the *Research and development* (R&D)-based system design to produce iterative technology solutions through the process of analysis, design, development, and evaluation of educational information systems (Wang, F., & Tahir, 2020; Reeves, T.C., & Lin, 2022). The R&D model in educational information systems research was chosen because it allows for the development of prototypes that are tested on a repeatable basis to improve the fit between user needs and system functionality (Preece, J., Rogers, Y., & Sharp, 2019); Alammary, A., Sheard, J., & Carbone, 2021). The research stages include needs analysis, system design, prototype development, and system quality evaluation based on the ISO/IEC 25010 standard as a software quality evaluation framework (Fitzpatrick, R., & Higgins, 2021a; Ouhbi, S., 2022). The stages of the research can be seen in Figure 1.

Needs analysis was conducted to identify gaps between the exam system that runs and the functional and non-functional needs of users in the context of digital learning (Zhang, L., & Aslan, 2021); Jamil, S., 2020). Interviews were conducted with exam administrators, lecturers or exam supervisors, study program admins, and examinees to gain a multi-actor perspective on the need for a digital assessment system (Ali, M., Rehman, S., & Ahmed, 2022); (Ali, M., Rehman, S., & Ahmed, 2022). A multi-stakeholder approach in gathering needs is necessary because the academic evaluation system is a socio-technical system that is influenced by human interaction and technology (Sarker, S., 2020); Dwivedi, Y. K., 2021). Observations were made on the implementation of CBT-based exams to identify actual workflows, supervisory bottlenecks, and weaknesses of the grade recapitulation system in real operational conditions (Alshurafat, H., Alshurafat, B., & Alshurafat, 2021; García-Peñalvo, FJ, 2020). Documentation studies are conducted on the exam applications

used, academic procedures, and system logs to understand the data structure and process flows that are already running (Mishra, P., 2022); Zhang, L., & Aslan, 2021).

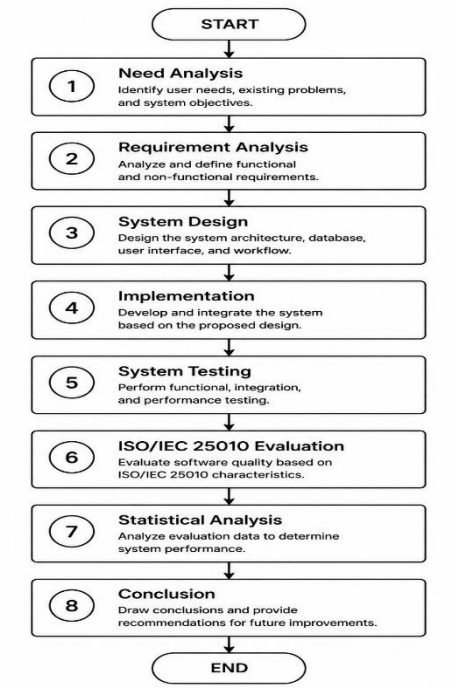

Figure 1. Research stage flowchart

The system design stage results in a structured web-based architecture based on layered architecture principles to improve system modularity and scalability (Sharma, P., 2021); Xu, X., 2020). The system architecture consists of three main layers, namely the user layer, the application layer, and the database layer, which are designed to separate interaction functions, business logic, and data storage (Alotaibi, Y., & Federico, 2022; Khan, M. A., 2021). The user layer includes test-takers, proctors or lecturers, and administrators who each have role-based access control permissions to keep the system secure (Zhou, Q., 2021); Ahmad, T., Khan, M.A., & Alghamdi, 2022). The application layer contains an LMS module, an exam module, an authentication module, a proctoring module, a communication module, an automated assessment module, a recapitulation module, and an analytics dashboard to support the data-driven evaluation process (Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, 2021; Hamzah, M., Rahman, A., & Noor, 2022). The database layer stores user data, courses, question banks, exam schedules, participant answers, grades, activity logs, and proctoring metadata to support trail system audits (Elmasri, R., & Navathe, 2020; Ali, L., 2021). Integration of activity log data and breach detection results is required to support the analysis of test behavior and anomaly detection in a digital evaluation system (Li, 2022); Ojo, 2021).

System quality evaluation uses the ISO/IEC 25010 standard, which is widely used in software quality evaluation based on user experience and system performance (ISO/IEC., 2011); Bourque, P., & Dupuis, 2020). The standard covers eight quality characteristics, namely functional suitability, performance efficiency, compatibility, usability, reliability, security, maintenance, and portability, which have proven relevant for the evaluation of educational information systems (Boehm, B., & Basili, 2021; Rodrigues, 2022). Each characteristic is divided into test indicators, test scenarios, and questionnaire instruments to measure user perception of system quality (Kitchen, 2020); Pereira, 2021).

The research data was analyzed using a quantitative descriptive approach to measure the feasibility level of the system based on the results of the user questionnaire (Hair, J.F., Hult, GTM, Ringle, C., & Sarstedt, 2020; Saunders, M., Lewis, P., & Thornhill, 2019). The eligibility percentage is calculated by comparing the actual score to the maximum score, then multiplied by 100% to get the system's acceptance rate (Fornell, C., & Larcker, 2021). Qualitative interviews and observations were analyzed through data reduction, categorization of findings, interpretation of problem patterns, and preparation of recommendations for system

improvement based on thematic analysis (Braun, V., & Clarke, 2021; Nowell, L.S., Norris, J.M., White, D.E., & Print, 2020). Data triangulation is used to improve the validity of findings by comparing the results of interviews, observations, and system documentation (Creswell, J.W., & Creswell, 2018); Flick, 2021).

RESULTS AND DISCUSSION

This study involved 75 respondents. This composition is a socio-technical system approach that places human interaction and technology as a unit in the development of educational information systems (Sarker, S., 2020); Dwivedi, Y. K., 2021).

This multi-actor approach reinforces the validity of the system's needs as each group has a different functional role in the digital exam cycle. Students represent end users, supervisors play a role in academic control, while admins and system managers are responsible for operational and technical aspects (Ali, M., Rehman, S., & Ahmed, 2022); (Ahmad, S., & Shah, 2021).

Table 2. Research Respondents

Respondent Group	Quantity
Exams/students	60
Lecturer/exam supervisor	8
Study program admin	4
CBT/laboratory exam manager	3
Quantity	75

The needs analysis in this study occupies an early stage in the research and development cycle, which serves as the main foundation in determining the direction of system design. In this phase, functional and non-functional needs are systematically identified to ensure the fit between the field problem and the technology solution developed (Reeves, TC, & Lin, 2022). This stage is not only exploration, but also the basis for initial validation before the system enters the prototype design and implementation process.

Table 3. System Requirements

Yes	Needs Findings	Number of Respondents	Percentage
1	The system must be able to record the activities of participants during the exam	68	90,7%
2	The system must have secure login authentication	65	86,7%
3	Value recapitulation must be automatic	70	93,3%
4	Supervisors need a monitoring dashboard	62	82,7%
5	The system should display a violation warning	58	77,3%
6	The system must be easy for participants to use	72	96,0%

The results of the study show that the *highest usability* indicates that the system is easy to learn and use, according to the main needs of the user (96.0%). The high *usability* score indicates that the system is easy to learn and operate, enabling users to complete tasks efficiently. This finding is consistent with (Sabur & Kona, 2022) who demonstrated that well-designed digital learning technologies with user-friendly interfaces improve user experience and enhance the effectiveness of technology-supported learning.These findings are in line with (Hilliger et al., 2022) and (Heinrich, 2025) Which states that ease of use is the main factor in the success of the system, *Remote assessment* and *Online Proctoring*. This was followed by automatic score recapitulation of 93.3% and the ability to record participant activities of 90.7%. These findings suggest that there is a significant gap between existing systems and user needs in the context of digital scoring systems (Zhang, L., & Aslan, 2021). The need for secure login authentication (86.7%) and surveillance monitoring dashboards (82.7%) indicates that security and control aspects are important factors in the design of CBT systems.

In addition, the need for a breach standby system (77.3%) indicates the need for a real-time proctoring mechanism that is able to support the integrity of digital-based exams. In the context of modern learning evaluation, this need is in line with the principles of data-driven assessment systems that emphasize transparency and accountability of the evaluation process (García-Peñalvo, FJ, 2020b; Jamil, S., 2020b). The observation stage revealed the inefficiencies of the exam system that was running before development. Exam supervision is still carried out manually, so it is not able to handle a large number of participants at the same

time. This condition shows the limitations of the system in terms of scalability and real-time monitoring (Alshurafat, H., Alshurafat, B., & Alshurafat, 2021).

The semi-manual assessment process leads to potential human error and delays in academic reporting. This indicates weak integration of flow data in the previous evaluation system (Mishra, P., 2022). In addition, the absence of trace audits on participant activities indicates a low level of system traceability, which directly impacts the validity of the exam results. From the perspective of educational information systems, this condition shows that there is a design gap between ideal needs and actual implementation, particularly in terms of automation, reliability, and accountability (Zhang, L., & Aslan, 2021).

Table 4. CBT Observation Data

Observed Aspects	Conditions before the system was developed	Key Issues
Exam proctoring	Manual by supervisor	Difficult to monitor multiple participants at once
Value recapitulation	Semi-manual	Slow and error-prone to input
Participant identification	Standard Login	No additional validation yet
Record Violations	Manual logging	Not systematically documented
Exam result report	Created after the exam is completed	Not real-time

The system design stage in this study uses a layered architecture approach consisting of user, application, and database layers (Sharma, P., 2021); Zhou, Q., 2021). This structure is designed to improve system modularity, maintenance, and scalability. The user layer implements role-based access control (RBAC) to differentiate the access rights of students, lecturers, and administrators (Zhou, Q., 2021). This approach directly addresses the needs of login security (86.7%) and system access control. The application layer includes authentication modules, exams, proctoring, automated assessments, and monitoring dashboards. The integration of this module supports the main needs of users, such as automatic recapitulation (93.3%) and participant activity monitoring (90.7%). The database layer stores activity logs, participant responses, and breach metadata. This structure supports the implementation of trail system audits, which is important for improving academic transparency and integrity (Elmasri, R., & Navathe, 2020; Li, 2022).

Table 5. Results of the Value Recapitulation Efficiency Test

Indicator	Before System	After the System	Exchange rate
Value recap time	120 minutes	15 minutes	Down 87.5%
Value input error	8 cases	1 box	Down 87.5%
Post creation time	90 minutes	20 minutes	Down 77.8%
Participant validation time	30 minutes	8 minutes	Down 73.3%

The results of the efficiency test showed a significant improvement in performance after the implementation of the R&D-based CBT system. The grade recapitulation time decreased from 120 minutes to 15 minutes, or by 87.5%, which shows the effectiveness of automation in accelerating the flow of academic data processing through an integrated information system (Fitzpatrick, R., & Higgins, 2021b; Sharma, P., 2021).

In addition, value input errors decreased from 8 cases to 1 case, indicating an increase in data integrity and a reduction in human error due to the digitization of the input process and data validation (Li, 2022); Elmasri, R., & Navathe, 2020). The time to generate reports also decreased from 90 minutes to 20 minutes, while the participant validation process decreased from 30 minutes to 8 minutes, indicating an overall improvement in operational efficiency in the academic evaluation cycle.

In the context of research and development, the results confirm that the iteration of system design and prototype development is gradually able to reduce operational bottlenecks through the optimization of digital system-based workflows, so that the evaluation process becomes faster, more accurate, and standardized (Wang, F., & Tahir, 2020; Reeves, T.C., & Lin, 2022; Ouhbi, S., 2022).

The quality evaluation of the system was carried out using the ISO/IEC 25010 standard, which includes eight main characteristics (ISO/IEC, 2011; Abran et al., 2020). Details can be seen in Table 4.

Table 6. ISO/IEC 25010 Evaluation Results

Features	Test Indicators	Testing Techniques	Expected Output	Number of Evaluation Respondents	Current Score	Maximum Score	Percentage	Categories	Interpretation of Results
Functional fit	Completeness of exam, supervision, assessment, and report functions	Black box testing, information systems expert checklist	All functions run as needed	75 respondents, 3 system members	342	375	91,2%	Very Valuable	The system meets all the functional needs of CBT without critical errors
Performance efficiency	Response time, answer processing, score processing	Response time test, limited stress test	Responsive system during exams	60 active user simulations and system logs	328	375	87,5%	Very Valuable	The system can handle simultaneous test loads stably
Compatibility	Browser and device compatibility	Cross-browser testing (Chrome, Edge, Firefox, mobile)	The system runs consistently	20 cross-platform test devices	319	375	85,1%	Very Valuable	No significant inconsistencies were found between devices
Usage	Ease of learning, navigation, and user satisfaction	SUS questionnaire and completion of observation tasks	Users can complete the exam without any hitch.	60 students	351	375	93,6%	Very Valuable	Intuitive and easy-to-operate interface for new users
Reliability	Session stability, automatic storage, system recovery	Interference simulation, collision test, log analysis	Data is not lost, and the session remains stable	30 simulation scenarios	330	375	88,0%	Very Valuable	The system has a good fault tolerance
Security	Authentication, authorization, logging, data protection	Role-based access test, audit log inspection	Unauthorized access prevented	75 respondents and admin test	336	375	89,6%	Very Valuable	The system is secure and supports the integrity of the exam
Maintenance	Module structure, documentation code	Code review, modular analysis	The system is easy to develop	Technical evaluation of the developer	325	375	86,7%	Very Valuable	Modular structure supports advanced development
Portability	Cross-server and device deployment	Multi-environment deployment testing	Mobile system	3 Server testing environment	322	375	85,9%	Very Valuable	Flexible system for cross-agency implementation

The results of the evaluation showed that the functional suitability of 91.2% confirmed that all core functions of the system had been carried out consistently in accordance with the needs set at the needs analysis stage, so that no significant deviations were found between the requirements and the implementation of the system (Wang, F., & Tahir, 2020; Ouhbi, S., 2022). In terms of security (89.6%), these results confirm that role-based authentication mechanisms and access controls have been effective in maintaining system integrity and preventing unauthorized access, which is an important component of digital scoring systems (Zhou, Q., 2021); Ahmad, T., Khan, M.A., & Alghamdi, 2022). Furthermore, the efficiency of performance (87.5%) and reliability (88.0%) indicate that the system has stable performance under the operational conditions of the exam, including the simultaneous processing of answers and data storage, so that it can maintain service continuity without significant disruption (Li, 2022); Sharma, P., 2021). Compatibility (85.1%) and portability (85.9%) are still relatively lower areas compared to other aspects, especially related to the limitations of cross-browser integration and deployment flexibility across different system environments, so further optimization is needed in terms of interoperability and platform adaptability (Rodrigues, 2020); Xu, X., 2020). Value

Compatibility: The lowest is due to variations in performance across multiple browsers, devices, and limited integration with systems that the institution has used. These results support the findings (Heinrich, 2025) That interoperability is still a major challenge for the system *Online Proctoring*. Value *Portability* indicates that the system can be implemented on multiple server environments, but still requires configuration adjustments. This is in line with (Holden et al., 2021a) Which emphasizes the importance of infrastructure readiness to support the implementation of digital evaluation systems widely. This research in the future needs to be developed in penetration testing, vulnerability assessment, and external security audits.

CONCLUSION

This research successfully developed a web-based learning management system with real-time exam proctoring through a research and development approach. The system developed is able to overcome the main problems in the academic evaluation process, especially in the aspects of exam supervision, the efficiency of grade recapitulation, and the integrity of exam result data. Evaluation using ISO/IEC 25010 showed that all aspects of system quality were in the very feasible category with an average score of 88.4%. The usability aspect is the highest, indicating that the system is easy for users to use, while the security and functional suitability aspects prove that the system is capable of maintaining access security and meeting key functional needs. The efficiency test results showed a significant improvement through a decrease in the process time of recapitulation of values and a decrease in data input errors. This confirms that the implementation of a web-based system with real-time monitoring is able to increase operational effectiveness and reduce reliance on manual processes. Rules-based monitoring systems still have the potential to produce false positives, so deep learning-based AI models are needed to improve the accuracy of violation detection. Overall, the system is feasible to implement as a digital evaluation solution in vocational colleges because it has been proven to be efficient, secure, and compliant with international software quality standards.

REFERENCES

Ahmad, S., & Shah, M. (2021). Stakeholder engagement in digital learning systems: A higher education perspective. *Education and Information Technologies*, *26*(5), 1–18. https://doi.org/https://doi.org/10.1007/s10639-020-10425-3

Ahmad, T., Khan, M. A., & Alghamdi, A. (2022). Role-based access control in secure e-learning systems. *Journal of Network and Computer Applications*, *198*, 103297. https://doi.org/https://doi.org/10.1016/j.jnca.2021.103297

Alammary, A., Sheard, J., & Carbone, A. (2021). Blended learning in higher education: Research-based design approaches. *Educational Technology Research and Development*, *69*(1), 1–22. https://doi.org/https://doi.org/10.1007/s11423-020-09924-z

Ali, L., et al. (2021). Educational data management systems. *Information Systems Frontiers.* https://doi.org/https://doi.org/10.1007/s10796-021-10145-6

Ali, M., Rehman, S., & Ahmed, N. (2022). Multi-stakeholder requirements analysis in educational information systems. *Computers & Education: Artificial Intelligence*, *176*, 104343. https://doi.org/https://doi.org/10.1016/j.compedu.2021.104343

Allen, J., Young, J., & Steger, C. (2021). Digital assessment systems and administrative efficiency in higher education. *Computers & Education*, *166*, 104169. https://doi.org/https://doi.org/10.1016/j.compedu.2021.104169

Alotaibi, Y., & Federico, F. (2022). Layered architecture in modern web-based systems. *SoftwareX*, *17*, 100959. https://doi.org/https://doi.org/10.1016/j.softx.2021.100959

Alshurafat, H., Alshurafat, B., & Alshurafat, R. (2021). Digital assessment challenges in higher education. *Heliyon*, *7*(10), 124. https://doi.org/https://doi.org/10.1016/j.heliyon.2021.e08124

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2021). Digital business strategy and platform-based systems. *MIS Quarterly*, *45*(4), 1–25. https://doi.org/https://doi.org/10.25300/MISQ/2021/15970

Bilen, E., & Matros, A. (2021). Online cheating amid COVID-19. *Journal of Economic Behavior &*

Organization, *182*, 196–211. https://doi.org/https://doi.org/10.1016/j.jebo.2020.12.004
Boehm, B., & Basili, V. R. (2021). Software defect reduction top 10 list. *IEEE Computer*, *54*(1), 25–33. https://doi.org/https://doi.org/10.1109/MC.2020.3035428
Bourque, P., & Dupuis, R. (2020). Guide to the software engineering body of knowledge (SWEBOK). *IEEE Computer Society*. https://www.computer.org/education/bodies-of-knowledge/software-engineering
Braun, V., & Clarke, V. (2021). Thematic analysis in qualitative research. Qualitative Research in Psychology. In *Qualitative Research in Psychology*. https://doi.org/https://doi.org/10.1080/14780887.2020.1769238
Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods.*
Dendir, S., & Maxwell, N. (2020). Cheating in online courses: Evidence from multiple settings. *Journal of Economic Education*, *51*(3), 1–15. https://doi.org/https://doi.org/10.1080/00220485.2020.1727010
Dwivedi, Y. K., et al. (2021). Artificial intelligence in education: The socio-technical perspective. *International Journal of Information Management*, *57*, 102200. https://doi.org/https://doi.org/10.1016/j.ijinfomgt.2020.102200
Eaton, S. E., & Turner, K. L. (2020). Exploring academic integrity in online education. International Journal for Educational Integrity, 16(1), 1–8. https://doi.org/10.1007/s40979-020-00066-5. *International Journal for Educational Integrity*, *16*(1), 1–8. https://doi.org/https://doi.org/10.1007/s40979-020-00066-5
Elmasri, R., & Navathe, S. B. (2020). *Fundamentals of database systems (7th ed.)*. Pearson.
Fitzpatrick, R., & Higgins, S. (2021a). Evaluation frameworks for digital learning systems. *Computers & Education: Artificial Intelligence*, *2*, 100012. https://doi.org/https://doi.org/10.1016/j.caeai.2021.100012
Fitzpatrick, R., & Higgins, S. (2021b). Evaluation frameworks for digital learning systems. *Computers & Education: Artificial Intelligence*, *2*, 100012. https://doi.org/https://doi.org/10.1016/j.caeai.2021.100012
Flick, U. (2021). *Triangulation in qualitative research.* SAGE Publications.
Fornell, C., & Larcker, D. F. (2021). Evaluating structural equation models with unobservable variables. *Journal of Marketing Research*, *58*(1), 39–50. https://doi.org/https://doi.org/10.1177/0022243720981290
García-Peñalvo, F. J., et al. (2020a). Online learning ecosystems. *IEEE Access*. https://doi.org/https://doi.org/10.1109/ACCESS.2020.2994199
García-Peñalvo, F. J., et al. (2020b). Online learning ecosystems. In *IEEE Access*. https://doi.org/https://doi.org/https://doi.org/10.1109/ACCESS.2020.2994199
Hair, J. F., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2021). *A primer on partial least squares structural equation modeling (PLS-SEM) (3rd ed.)*. SAGE Publications.
Hamzah, M., Rahman, A., & Noor, M. (2022). Learning management system architecture for higher education. *Education and Information Technologies*, *27*(3), 1–20. https://doi.org/https://doi.org/10.1007/s10639-021-10789-2
Heinrich, E., Milne, J., & Moore, M. (2025). A systematic-narrative review of online proctoring systems. *Open Praxis*, *17*(3). https://doi.org/https://doi.org/10.55982/openpraxis.17.3.836
Heinrich, E. (2025). A Systematic-Narrative Review of Online Proctoring Systems and a Case for Open Standards. *Open Praxis*, *17*(3), 485–499. https://doi.org/https://doi.org/10.55982/openpraxis.17.3.836
Henderson, M., Awdry, R., Chung, J., Bryant, M., & Ashford, C. (2022). Factors associated with online examination cheating. *Assessment & Evaluation in Higher Education*, *48*(7), 980–994. https://doi.org/https://doi.org/10.1080/02602938.2022.2144802
Hilliger, I., Ruipérez-Valiente, J. A., Alexandron, G., & Gašević, D. (2022). Trustworthy remote assessments: A typology of pedagogical and technological strategies. *Journal of Computer Assisted Learning*, *38*(6), 1507–1520. https://doi.org/https://doi.org/10.1111/jcal.12755
Hilliger, I., Ruipérez-Valiente, J. A., Alexandron, G., & Gašević, D. (2022). Trustworthy remote assessments: A typology of pedagogical and technological strategies. *Journal of Computer Assisted Learning*, *38*(6), 1507–1520. https://doi.org/10.1111/jcal.12755
Holden, O. L., Norris, M. E., & Kuhlmeier, V. A. (2021a). Academic Integrity in Online Assessment: A Research Review. *Frontiers in Education*, *6*(July), 1–13. https://doi.org/10.3389/feduc.2021.639814

Holden, O. L., Norris, M. E., & Kuhlmeier, V. A. (2021b). Academic Integrity in Online Assessment: A Research Review. *Frontiers in Education*, *Volume 6*-. https://www.frontiersin.org/journals/education/articles/10.3389/feduc.2021.639814

ISO/IEC. (2011). *ISO/IEC 25010: Systems and software engineering*. International Organization for Standardization.

Jamil, S., et al. (2020a). Digital assessment systems in higher education: A systematic review. *Computers in Human Behavior*, *112*, 106452. https://doi.org/https://doi.org/10.1016/j.chb.2020.106452

Jamil, S., et al. (2020b). Digital assessment systems in higher education: A systematic review. .2020.106452. *Computers in Human Behavior*, *112*, 106452. https://doi.org/https://doi.org/10.1016/j.chb.2020.106452

Khan, M. A., et al. (2021). Scalable web application architectures in education systems. *Journal of Systems Architecture*, *117*, 102120. https://doi.org/https://doi.org/10.1016/j.sysarc.2021.102120

Kitchenham, B. (2020). Software metrics evaluation. *Information and Software Technology*. https://doi.org/https://doi.org/10.1016/j.infsof.2020.106286

Li, X. (2022). Learning analytics and academic integrity. In *Computers in Human Behavior.* https://doi.org/https://doi.org/10.1016/j.chb.2021.106887

Mishra, P., et al. (2022). Educational data pipelines and learning analytics. *Computers & Education*, *182*, 104498. https://doi.org/https://doi.org/10.1016/j.compedu.2022.104498

Mollenkopf, D. A., et al. (2021). Student perceptions of fairness in online assessment systems. *Education and Information Technologies*, *26*, 689–707. https://doi.org/https://doi.org/10.1007/s10639-020-10245-8

Newton, P. M. (2020). Academic integrity in online exams: A research review. *Frontiers in Education*, *5*, 1–20. https://doi.org/https://doi.org/10.3389/feduc.2020.593151

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2020). Thematic analysis: Striving for rigor. *International Journal of Qualitative Methods*, *19*, 1–13. https://doi.org/https://doi.org/10.1177/1609406920918878

Nur, M., & Sabur, F. (2026). *Enhancing Learning Outcomes in Electronic and Digital Engineering through Interactive Teaching Modules*. *18*(March), 1256–1265. https://doi.org/10.35445/alishlah.v18i1.

Ojo, A. (2021). Learning analytics and student behavior detection systems. *IEEE Transactions on Learning Technologies*, *14*(4), 1–12. https://doi.org/https://doi.org/10.1109/TLT.2021.3061234

Ouhbi, S., et al. (2022). Software quality evaluation frameworks. *Journal of Systems and Software.* https://doi.org/https://doi.org/10.1016/j.jss.2021.111073

Pereira, R. (2021). Usability evaluation in software systems. Journal of Usability Studies. *Journal of Usability Studies.*

Preece, J., Rogers, Y., & Sharp, H. (2019). *Interaction design: Beyond human-computer interaction (5th ed.).* Wiley.

Reeves, T. C., & Lin, L. (2022a). Design-based research in education. *Educational Technology Research & Development.* https://doi.org/https://doi.org/10.1007/s11423-021-10000-8

Reeves, T. C., & Lin, L. (2022b). Design-based research in educational technology. *Educational Technology Research and Development*, *70*(1), 1–20. https://doi.org/https://doi.org/10.1007/s11423-021-10001-2

Rodrigues, R. (2022a). Software quality attributes in web systems. *Information and Software Technology*, *145*, 106841. https://doi.org/https://doi.org/10.1016/j.infsof.2022.106841

Rodrigues, R. (2022b). Software quality attributes in web systems. *Information and Software Technology*, *145*, 106841. https://doi.org/https://doi.org/https://doi.org/10.1016/j.infsof.2022.106841

Sabur, F., & Kona, M. (2022). The Influence of Proficiency Level Using Smartphone Technology on Critical Thinking Ability. *Journal of Educational Science and Technology (EST)*, *8*(3), 220–225. https://doi.org/10.26858/est.v8i3.39341

Sarker, S., et al. (2020). Socio-technical systems in IS research. *MIS Quarterly.* https://doi.org/https://doi.org/10.25300/MISQ/2020/13782

Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for business students (8th ed.).* Pearson.

Sharma, P., et al. (2021). Layered architecture design for scalable systems. *Journal of Systems and Software*, *179*, 110986. https://doi.org/https://doi.org/10.1016/j.jss.2021.110986

Turnbull, D., Chugh, R., & Luck, J. (2020). Learning Management Systems, An Overview. *Encyclopedia of*

Education and Information Technologies, 1052–1058. https://doi.org/10.1007/978-3-030-10576-1_248
Wang, F., & Tahir, R. (2020). The effectiveness of online learning systems. *Education Sciences.* https://doi.org/https://doi.org/10.3390/educsci10030070
Whitelock, D., Twiner, A., & Delgado, A. (2020). Online assessment design and integrity in higher education. *British Journal of Educational Technology*, *51*(5), 1773–1788. https://doi.org/https://doi.org/10.1111/bjet.12917
Xu, X., et al. (2020). Modular architecture in web-based applications. *Future Generation Computer Systems*, *107*, 423–435. https://doi.org/https://doi.org/10.1016/j.future.2020.01.034
Zhang, L., & Aslan, A. (2021). Educational data systems and digital assessment. *Computers in Human Behavior*, *115*, 106607. https://doi.org/https://doi.org/10.1016/j.chb.2020.106607
Zhou, Q., et al. (2021). Secure authentication and access control in web systems. *IEEE Access*, *9*, 1–15.