Vol.4, No.3, Page 1857- 1870, 2026 https://doi.org/10.59628/jast.v4i3.2611 ISSN 2958-9568 JAST

SUN PUBLISHER

مجلة جامعة صنعاء للعلوم التطبيقية والتكنولوجيا

Sana'a University Journal of Applied Sciences and Technology

https://journals.su.edu.ye/index.php/jast/

# A Technology Adoption Framework for Digitally Transforming Automated Examination Systems in Resource-Limited Environments: Evidence from Yemeni Schools

**Ammar T. Zahary[1] *, Ishraq Sharaf[1] and Mossa Ghurab[2]**

[1]**Department of Information Technology, Faculty of Computer and Information Technology, Sana'a University, Sana'a, Yemen,**
[2]**Department of Computer Science, Faculty of Computer and Information Technology, Sana'a University, Sana'a, Yemen**

*Corresponding author: zahary@su.edu.ye

## Abstract

Automated Examination Systems (AES) are increasingly central to modern assessment, particularly as schools move toward broader digital transformation. Automated Exam Systems (AES) have emerged as transformative tools for improving assessment efficiency, accuracy, and transparency. This study examines how AES are adopted and used in resource-limited Yemeni schools, focusing on the technological, organizational, and environmental factors that shape their performance. It investigates the implementation of AES in Yemeni schools, highlighting applications, challenges, and prospects. A quantitative methodology was employed to collect data from 108 participants, comprising students, supervisors, technicians, and teachers, using structured questionnaires. The Technology-Organization-Environment (TOE) was applied to examine factors affecting AES adoption. Statistical analysis using SPSS, including Pearson correlation, Cronbach's Alpha, and multiple linear regression, revealed significant relationships between technological, organizational, and human factors and the performance of AES. Key challenges, such as infrastructure limitations, inadequate training, and resistance to change, are discussed, along with practical solutions. The findings provided insights for effective AES implementation and future research directions in the Yemeni educational context.

## Article Info

**Keywords:**
Automated Exam Systems, Yemeni Schools Automation, Technology Adoption, Assessment Quality, TOE Framework.

**Article History:**
**Received:** 06- December-2025,
**Revised:** 14-January-2026,
**Accepted:** 21-January-2026,
**Published:** 28 March 2026.

## 1. INTRODUCTION

Assessment quality is a cornerstone of educational development, shaping student learning outcomes and institutional performance [1]. Traditional paper-based exams, while widely used, often suffer from human errors, grading delays, and limited transparency [2]. Automated Exam Systems (AES) offer scalable, accurate, and efficient alternatives capable of enhancing assessment processes [3]. In Yemen, where educational infrastructure faces significant challenges, AES adoption is a strategic approach to improve exam management, increase reliability, and promote fairness [4]. This Paper presents an applied investigation of AES implementation, the TOE theoretical framework, and empirical data to evaluate factors influencing adoption and system performance.

In the past, exam correction was considered a tedious and time-consuming task that often required allocating a large number of teachers or instructors to complete the process. This created an administrative and financial burden on educational institutions. With technological advancements, new solutions emerged to ease this burden, most notably, Optical Mark Recognition (OMR) technology, which significantly contributed to accelerating and simplifying the mass assessment correction process [1]

Initially, OMR systems relied on dedicated hardware specifically designed to read paper-based answer sheets. However, over time and with the development of software technologies, digital solutions began to emerge. These software-based tools can now be operated on standard

©2026 The Author(s). This article is licensed under CC By 4.0

computers, eliminating the need for specialized equipment and making the technology more accessible and easier to use [2]

Despite these advancements, several challenges remain, such as the limited flexibility of available software, high costs, and restricted accessibility for some users. Research highlights the need for further development of these systems to better align with user requirements, improve accuracy, and reduce processing time [3]

Another notable limitation is the absence of a standardized dataset for evaluating and comparing different OMR solutions. This presents an obstacle to building more efficient and integrated systems. Therefore, researchers and developers are encouraged to address these challenges and drive innovation in electronic assessment correction to meet the evolving demands of modern education [4]. In any educational program, courses are defined based on clear learning objectives [5]. To evaluate whether students have achieved these objectives, educators design various assessments that align with academic evaluation requirements. However, creating diverse question papers that effectively meet learning goals remains a significant challenge for teachers, especially in the absence of standardized methods to ensure question paper quality [6].

Therefore, a pressing need for advanced solutions capable of automatically and rapidly generating question papers based on teacher-defined specifications. Such systems would optimize the examination preparation process by reducing time and effort, while simultaneously ensuring a balanced representation of question diversity and alignment with course objectives. Consequently, they hold the potential to significantly enhance the effectiveness and overall quality of assessment practices [7].

Currently, several commercial automatic grading systems for multiple-choice test sheets are available, typically comprising a software and scanner bundle, which results in costly solutions. With the growing use of devices such as laptops, tablets, and smartphones equipped with built-in cameras, new opportunities have emerged to perform the same task at a lower cost [8]. This study introduces an Android application called "MCTest – Multiple Choice Test," developed using the OpenCV library. The app was employed to grade hundreds of multiple-choice test sheets under real-world conditions, delivering excellent results by grading tests accurately and instantly, while also providing statistical tools for result analysis [9].

The traditional process of grading multiple-choice exams is often time-consuming, labor-intensive, and costly, especially when dealing with large numbers of answer sheets. To address these challenges, this project presents an image-processing-based Optical Mark Reader (OMR) system designed to automate the evaluation of multiple-choice tests using low-cost, commonly available devices such as webcams or document scanners [10].

The system operates by converting scanned or captured answer sheets into binary images using adaptive binarization techniques, followed by skew correction through Hough Transform. It detects specific regions, such as roll number and answer areas, using reference markers printed on the sheet [11]. The solution features two main modes: a learning mode for modeling the answer sheet format, and an operational mode for reading marked answers and calculating scores by analyzing the density of black pixels within each answer option.

Developed using MATLAB and its Image Processing Toolbox, the system offers a flexible, accurate, and cost-effective alternative to traditional OMR machines, with the ability to export results for further analysis. It proves effective even under varied lighting conditions and with imperfectly aligned or degraded answer sheets [12].

This study holds significance in revolutionizing the educational assessment landscape by introducing an Academic System (AS) tailored to streamline the creation and evaluation of standardized test questions. By incorporating cognitive levels, descriptions, and length considerations, the AS aims to elevate the qualitative assessment of student accomplishments. Through the implementation of stringent security measures, authentication protocols, and a structured schedule, the AS ensures the integrity and reliability of test question generation. The proposed approach not only enhances standardization and quality in assessments but also contributes to optimizing examination processes, ultimately paving the way for improved educational outcomes and student performance evaluation.

Although the Technology–Organization–Environment (TOE) framework serves as the foundation for this study, our contribution does not rebrand the TOE framework. Instead, we operationalize and contextualize TOE specifically for Automated Examination Systems (AES) in conflict-affected and resource-constrained school environments, where adoption conditions are very different from those in stable, high-resource settings. Specifically, we show that organizational preparedness and human capacity can have a more direct impact on AES performance than infrastructure availability alone because infrastructure limitations may be normalized and persistent in these situations.

Overall, these improvements boost the manuscript's academic rigor and practical usefulness for educational decision-makers while also improving the coherence between theory, methodology, and conclusions

**Research Scope:**

This study focuses on the development of an Academic System (AS) designed to address the challenges associated with creating and grading standardized test questions in educational institutions. The scope includes considerations of cognitive levels, question descriptions,

©2026 The Author(s). This article is licensed under CC By 4.0

and question length to enhance the assessment of student achievement. The AS system emphasizes the implementation of a structured schedule, robust security mechanisms, and authentication protocols to ensure the integrity and atomicity of test question creation. The research aims to propose a practical approach for enhancing assessment standardization and quality, with a specific focus on improving examination processes within educational settings.

The motivation behind this study lies in the need to address the challenges that educational institutions face in designing and evaluating standardized test questions. By developing an Academic System (AS) that considers cognitive levels, descriptions, and length factors, the research aims to enhance the qualitative assessment of student performance. The motivation stems from a desire to streamline the examination processes, strengthen standardization in assessments, and improve the overall quality of educational evaluations. Through the implementation of a secure and structured system, the research seeks to offer a practical solution that can positively impact the efficiency and effectiveness of test question creation and grading procedures within academic environments.

**Contribution of the Study:**

This study contributes by introducing a proposed model designed to assist educational institutions in overcoming challenges related to the creation and evaluation of standardized test questions. By incorporating considerations such as cognitive levels, descriptions, and question length, the study aims to enhance the qualitative assessment of student achievement. The contribution lies in proposing a structured approach that ensures the integrity and atomicity of test question creation through the implementation of secure mechanisms and authentication protocols. This research offers a practical method to strengthen assessment standardization and quality, ultimately leading to improvements in examination processes and the overall enhancement of educational evaluation practices.

**Theoretical contribution and positioning:**

Although the Technology, Organization, Environment (TOE) framework serves as the foundation for this study, our contribution does not rebrand the TOE framework. Instead, we operationalize and contextualize TOE specifically for Automated Examination Systems (AES) in conflict-affected and resource-constrained school environments, where adoption conditions are very different from those in stable, high-resource settings. Specifically, we show that organizational preparedness and human capacity can have a more direct impact on AES performance than infrastructure availability alone because infrastructure limitations may be normalized and persistent in these situations.

**Novelty and value addition:**

This study adds value in three ways: (1) it offers field data from Yemeni schools, a setting that is still underrepresented in research on AES adoption; (2) it provides an empirical TOE-based model specifically designed for AES, connecting TOE dimensions to quantifiable performance outcomes; and (3) it offers decision-makers in low-resource educational systems practical implementation implications, such as emphasizing operational readiness, training, and question design quality.

**Research Problem:**

The research problem lies in the absence of a comprehensive evaluation model for automated exam paper systems that measures their reliability, question quality, security, and usability, especially within resource-limited educational environments such as Yemeni schools.

**Research Objectives:**

1. Develop an integrated model for evaluating the effectiveness of electronic exam paper generation systems.

2. Enhance question quality and ensure system reliability and security.

3. Assess user experience and the ease of system use in real educational environments.

4. Provide suitable solutions for resource-limited environments such as Yemeni schools

**Research Questions:**

The present study attempts to answer the following question:

**Q1:** How does the technical infrastructure affect the performance of the examination system in Yemeni schools?

**Q2:** How does the variation in fundamental questions affect the performance of the examination system in Yemeni schools?

**Q3:** How does the variation/difference in the set of answers affect the performance of the examination system in Yemeni schools?

**Q4:** What is the relationship between the level and format of learning resources and the performance of the examination system in Yemeni schools?

**Q5:** How do the quality and difficulty of questions affect the performance of the examination system in Yemeni schools?

**Q6:** To what extent does the training of human resources (staff) affect the performance of the examination system in Yemeni schools?

**Q7:** To what extent does the amount of knowledge affect the performance of the examination system in Yemeni schools? **Research Hypotheses:**

Based on the research question and the study model shown in Section 3, hypotheses are

formulated and tested as follows:

**Hypothesis 1:** The technical structure positively affects the performance of the examination system in Yemeni schools.

**Hypothesis 2:** The diversity of core questions positively affects the performance of the examination system

©2026 The Author(s). This article is licensed under CC By 4.0

in Yemeni schools.

**Hypothesis 3:** The variation in the set of answers positively affects the performance of the examination system in Yemeni schools.

**Hypothesis 4:** The level and format of learning resources positively affect the performance of the examination system in Yemeni schools.

**Hypothesis 5:** The quality and difficulty of questions positively affect the performance of the examination system in Yemeni schools.

**Hypothesis 6:** The training of human resources (students and staff) positively affects the performance of the examination system in Yemeni schools.

**Hypothesis 7:** The amount of knowledge positively affects the performance of the examination system in Yemeni schools.

## 2. RELATED WORK

The digital transformation of educational assessment has become a central topic in recent research, particularly as schools and universities shift toward technology-supported examination processes. Automated Examination Systems (AES) have been recognized for their potential to increase grading efficiency, reduce human error, and improve transparency. Recent studies emphasize that AES can significantly enhance assessment accuracy and speed, especially in large-scale or resource-limited educational settings. Several experimental and review papers show that automated grading tools can achieve high alignment with human scoring when supported by well-designed question structures and stable technical environments [13], [14], [15].

Digital transformation studies further indicate that the adoption of automated assessment is not solely a technical shift but a broader organizational change involving policies, workflows, and user readiness. Research in higher education shows that institutions integrating digital examination platforms often experience improvements in exam quality, monitoring, and administrative coordination, provided that digital infrastructure and staff competence are adequately developed [16], [17], [18]. Similar findings are reported in low-infrastructure settings, where digital tools offer practical benefits but face adoption barriers such as limited connectivity, insufficient training, and resistance to shifting from paper-based methods to automated solutions [19], [20].

Instead of only digitizing current processes, digital transformation in school systems is increasingly portrayed as a systemic change process that modifies infrastructure, pedagogy, governance, and assessment. Digital technology integration has an impact on students, teachers, administrators, leaders, and parents at the school level. These effects range from new instructional models (online, blended, and hybrid) to better data-based decision making and more effective exam administration processes [21]. Research demonstrates that schools' "digital capacity" is dependent on interrelated elements that together impact the success of digital transformation programs, including technological infrastructure, staff competencies, leadership vision, and supportive policies [21]. This suggests that any framework for changing examination systems must incorporate organizational readiness and ecosystem support in addition to the technology platform for situations with limited resources.

Online and automated exam systems have become essential parts of e-learning ecosystems in this larger setting. In addition to cataloging 21 suggested tools, 25 current platforms, and 16 underlying techniques/algorithms utilized to provide trustworthy, equitable remote assessments, a systematic evaluation of 53 papers on online exams emphasizes important functional features (security, integrity, authentication, and usability) [22]. When choosing or creating online exam solutions for particular nations and institutions, particularly in areas with limited connectivity and resources, the review identifies four global adoption factors: network infrastructure, hardware requirements, implementation complexity, and training needs [22]. In addition, a systematic review of 135 studies on machine learning-enhanced exam systems demonstrates how supervised and unsupervised algorithms support every step of the exam cycle, including scheduling, proctoring, authentication, cheating detection, and at-risk student prediction [23]. However, it also highlights important issues with privacy, dependability, and technical capability. When taken as a whole, these studies show that enhanced functionality must be carefully balanced with maintainability and feasibility in designing contexts for automated inspection.

Recent research has shifted toward contextualized adoption frameworks for developing nations, realizing that generic technology acceptance models (such TAM and UTAUT) do not adequately incorporate constraints unique to schooling and context. The ETADC model, which was validated through meta-analysis and structural equation modeling on 30 high-impact studies (N = 8934), combines foundational adoption constructs with educational and local components within the TPACK framework to offer a reliable tool for assessing and choosing educational technologies in settings with limited resources [24]. The significance of compatibility, perceived utility, and innovative qualities in influencing institutions' intentions to adopt disruptive technologies in emerging economies is further demonstrated by empirical research on cutting-edge technologies in education, such as blockchain for smart learning environments [25].

These insights suggest that a technology adoption framework for digitally transforming automated examination systems in Yemeni schools should (i) incorporate multi-level factors (individual, organizational, infrastructural, and policy), (ii) explicitly account for resource and connectivity constraints identified in online-exam litera-

©2026 The Author(s). This article is licensed under CC By 4.0

ture [22][23],and (iii) embed education-specific and cultural dimensions as advocated in contextualized adoption models for developing countries [21][24].

**Related Work Synthesis and Thematic Organization.**

There are two primary streams of prior research on automated examination and assessment. Technical development (such as OMR accuracy, image processing, grading automation, and system design) is the main focus of the first stream. These studies focus on robustness under scanning or lighting variations, efficiency, and scoring accuracy. The second stream, which focuses on organizational adoption and digital transformation, explains why educational institutions embrace (or reject) AES in light of external pressures, readiness, skills, and policies.

By analyzing AES as an organizational innovation that necessitates stakeholder readiness, training, governance, and contextual fit in addition to being a technical solution, this study bridges these two streams. As a result, in school settings with limited resources, the TOE framework is utilized as a suitable lens to integrate organizational, environmental, and technological factors influencing AES performance.

The **Technology–Organization–Environment (TOE) framework** is widely used to understand how institutions adopt digital systems, including AES and related educational technologies. Recent studies applying the TOE model demonstrate that adoption is shaped by:

- **Technological factors** (system compatibility, usability, reliability),
- **Organizational factors** (training, leadership support, skills), and
- **Environmental factors** (infrastructure, policy, external pressure).

Technology adoption research using TOE shows that schools with stronger digital readiness and clearer institutional strategies are more successful in transitioning to automated examination environments [26], [27], [28]. In resource-constrained contexts, the TOE model helps explain why digital transformation progresses unevenly and why human capacity-building and infrastructure stability remain decisive for AES performance.

Taken together, prior work highlights two important gaps:

1 Most AES studies focus on algorithmic performance rather than **real-world adoption**, and

2 Few investigations examine **digital transformation in low-resource school systems** through a comprehensive adoption lens, such as the TOE model.

The present study contributes to filling these gaps by applying the TOE framework to evaluate AES adoption and digital transformation readiness in Yemeni schools, a context where infrastructure limitations, training shortages, and institutional constraints significantly influence system performance. Table 1 summarizes the related work of this study.

©2026 The Author(s). This article is licensed under CC By 4.0

**Table 1.** Summary of the related work

| Reference | Research Problem | Hypotheses | Independent Variables | Dependent Variables |
|---|---|---|---|---|
| Rao, V. Shanmukha, et al. "Automated exam paper process based on schedule and authenticity." International Conference of Advanced Research & Innovation (ICARI). 2020. | Challenges related to manually creating exam papers, such as security, effectiveness, and authenticity. | The technology-based system will reduce errors and enhance security. | Automation, Security, Authentication | Effectiveness of the exam paper creation process |
| Jaquez, Jesús, et al. "TecEval: An online dynamic evaluation system for engineering courses available for web browsers and tablets." 2015 IEEE Frontiers in Education Conference (FIE). IEEE, 2015. | Issues in the manual creation of exam papers, including security and reliability of the questions. | Internet-based systems will increase efficiency and security while providing continuous updates to the question bank. | Internet-based system, Continuous updates to the question bank | Access to the system, Security, and Effectiveness of exam paper creation |
| De Assis Zampirolli, Francisco, Valério Batista, and José Artur Quilici-Gonzalez. "An automatic generator and corrector of multiple-choice tests with random answer keys." 2016 IEEE Frontiers in Education Conference (FIE). IEEE, 2016. | Issues in manual question creation, such as a lack of security and vulnerability to manipulation. | Automation will contribute to improving the accuracy and reliability of exam papers. | Automation, Security | Reliability of exam papers, Security |
| de Elias, Erik Miguel, Paulo Marcelo Tasinaffo, and R. Hirata Jr. "Optical Mark Recognition: Advances, Difficulties, and Limitations." SN Computer Science 2.5 (2021): 367. | A need for systems to improve the correction of multiple-choice questions and enhance security. | The use of advanced systems and technologies will help in automatically correcting questions and reducing the possibility of manipulation. | Artificial Intelligence, Automated correction | Correction of questions, Security in the correction process |

©2026 The Author(s). This article is licensed under CC By 4.0

| Reference | Research Problem | Hypotheses | Independent Variables | Dependent Variables |
|---|---|---|---|---|
| Patel, Nirali V., Ghanshyam I. Prajapati, and Bharuch SVMIT. "Various techniques for assessment of OMR sheets through ordinary 2D scanner: a survey." International Journal of Engineering Research & Technology (IJERT) Vol 4 (2015): 2278-0181. | Problems with manual systems in creating papers, such as delays and human errors in creation. | Automated systems provide greater security and improve the speed of generating exam papers. | Automation, Security | Speed of exam paper creation, Security |
| Liu, Tong. "AI proctoring for offline examinations with 2-Longitudinal-Stream Convolutional Neural Networks." Computers and Education: Artificial Intelligence 4 (2023): 100115. | Challenges in the reliability of traditional assessments using manual monitoring methods. | The use of artificial intelligence will enhance the accuracy of assessments and reduce cheating opportunities. | Artificial Intelligence, Surveillance cameras | Accuracy of assessments, Cheating prevention |
| Kanneganti, Raghuveer, Randy Fry, and Lalit Gupta. "Detection of aberrant responses in OMR documents." Proceedings of the International Conference on Image Processing, Computer Vision, and Pattern Recognition (IPCV), 2015. | Issues with errors occurring during the manual correction of exam papers. | Automating the correction process will reduce human errors and improve correction speed. | Automation, Exam paper correction | Accuracy of correction, Speed of correction |

©2026 The Author(s). This article is licensed under CC By 4.0

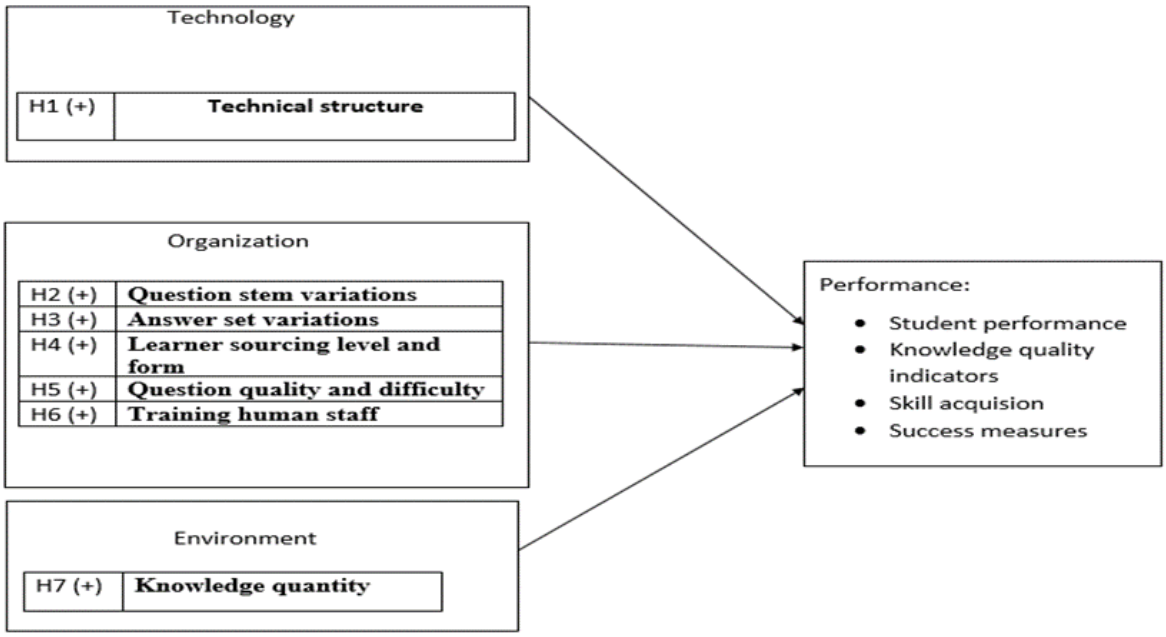



**Figure 1.** Conceptual Model Based on the TOE Model

**Table 2.** Participants' Demographic Distribution

| Role | Frequency | Percentage |
|---|---|---|
| College students | 79 | 73.2% |
| Supervisors | 15 | 13.9% |
| High school students | 6 | 5.6% |
| Technicians | 5 | 4.6% |
| Teachers | 3 | 2.8% |

**Table 3.** Gender Distribution of Participants

| Gender | Frequency | Percentage |
|---|---|---|
| Female | 73 | 67.6% |
| Male | 35 | 32.4% |

## 3. RESEARCH METHODOLOGY

The TOE model is highly applicable in assessing the adoption of automated scoring technologies for paper-based exams, particularly within educational settings that rely on traditional exam formats but seek to achieve efficiency and accuracy. The model captures essential internal capacities (training, compatibility) and external influences (policy, infrastructure), making it a useful diagnostic and implementation guide for decision-makers. The TOE model demonstrates that institutions that understand and address the TOE factors are better equipped to adopt, scale, and benefit from digital correction technologies. Figure 1 shows our c**onceptual model based on the TOE model**

**Study Design:**

This study employed a quantitative descriptive–analytical and correlational design to investigate the adoption and performance of Automated Examination Systems (AES) in Yemeni schools. The research aimed to describe the study variables, explore relationships among them, and interpret the findings in the context of existing literature [5, 6].

Table 2 presents the participants' demographic distribution according to their roles.

**Participants:**

The study sample consisted of 108 participants from selected Yemeni schools, representing different stakeholder roles. Table 2 shows the Participants' Demographic Distribution.

Table 3 shows the gender distribution of the participants.

The results indicate that most respondents were college students (73.2%), and the majority were female (67.6%), suggesting higher engagement or accessibility among female participants in the studied schools.

**Data Collection Instrument:**

Data were collected using a structured questionnaire developed based on the study objectives and prior literature. The instrument covered several dimensions, including:

· Cognitive quantity and quality
· Technical structure
· Variation of core questions
· Answer set variations
· Learning resource levels and forms
· Question quality and difficulty
· Human resource training
· performance measures (student performance, knowledge quality indicators, skill acquisition, success measures)

The validity and reliability of the instrument were established through expert review and statistical analysis.

©2026 The Author(s). This article is licensed under CC By 4.0

Construct validity was confirmed using Pearson correlation [9], while Cronbach's Alpha indicated high internal consistency ($\alpha$ = 0.958 for independent variables and $\alpha$ = 0.922 for the dependent variable) [7–10].

**Statistical Analysis:**

All data were analyzed using SPSS software (Version 27). The following statistical methods were applied:

· Skewness and Kurtosis tests to assess normality

· Pearson correlation for construct validity

· Cronbach's Alpha for reliability

· Frequencies and percentages for demographic analysis

· Arithmetic means and standard deviation to assess response levels

· Multiple linear regression to test hypotheses and identify factors influencing AES performance

**Participants and explanation of the context:**

Although the study's focus is on AES implementation in Yemeni schools, a variety of stakeholder types involved in school exams and assessment procedures make up the respondent pool. Due to their greater accessibility during data collection and their frequent participation in examination procedures and AES usage in the targeted educational environment, college students make up the majority of the sample. The Limitations section specifically discusses this distribution, which is recognized as a limitation. Crucially, supervisors, teachers, technicians, and school-level students continue to provide pertinent school-related AES perspectives in the survey.

**Ethical issues:**

This study's participation was entirely voluntary. Respondents were made aware of the study's objectives, that no personally identifiable information would be revealed, and that their answers would only be utilized for scholarly analysis. Before filling out the questionnaire, informed consent was acquired.

**Questionnaire transparency:**

The study objectives and well-established literature on the adoption of AES and TOE-based technologies served as the basis for the development of the questionnaire items. Before being deployed, items were examined for relevancy and clarity. To promote transparency and replicability, a sample set of items (or the complete questionnaire) may be made available upon request.

## 4. RESULTS ANALYSIS A. DESCRIPTIVE STATISTICS

Descriptive analysis revealed moderate to high levels across all AES-related variables, indicating positive perceptions toward system performance and adoption. Participants strongly agreed on the importance of technical infrastructure, human resource training, and question quality as essential components for effective AES implementation. The interpretation of mean scores followed the four-point Likert scale presented in Table 4, adapted from Al-Adimi (2010, p. 282 [6]) and Al-Mahmoudi (2019, pp. 46–47 [8]).

**Table 4.** Descriptive Statistics of Exam System Performance

| Mean Range | Percentage Range | Verbal Interpretation |
|---|---|---|
| <1.75 | <43.75% | Low |
| 1.75–<2.5 | 43.75%–<62.5% | Medium |
| 2.5–<3.25 | 62.5%–<81.25% | High |
| 3.25–4 | 81.25%–100% | Very High |

The overall exam system performance achieved a mean of 2.89 (72.14%), representing a high level of agreement.

The highest-rated item was PA7 (students achieving high exam scores; M = 3.06), while the lowest was PA5 (surveying students and teachers' feedback; M = 2.67).

For skill acquisition, the mean was 2.76 (69.09%), with the highest score for AS1 (improved student grades; M = 2.96) and the lowest for AS5 (developing creative thinking; M = 2.54).

Regarding success measures, the overall mean was 3.11 (77.68%), indicating very high agreement, particularly for SM6 (accuracy and speed of grading; M = 3.50).

A summary of descriptive results for all variables is shown in Table 5 .

Table 5. Summary of AES Variables' Mean Scores

**Table 5.** Summary of AES Variables' Mean Scores

| Variable | Mean | Percentage | Interpretation |
|---|---|---|---|
| Knowledge Level | 2.63 | 65.77% | High |
| Technical Infrastructure | 2.81 | 70.34% | High |
| Core Question Variety | 2.88 | 72.12% | High |
| Answer Set Variety | 2.65 | 66.15% | High |
| Learning Resources Level | 2.83 | 70.82% | High |
| Question Quality & Difficulty | 2.84 | 70.96% | High |
| Human Resource Training | 3.07 | 76.73% | Very High |
| AES Performance (overall) | 2.92 | 72.97% | High |

All variables exhibited high agreement levels, confirming strong user satisfaction and positive perceptions of AES effectiveness in Yemeni schools [6, 8].

**B. Reliability and Validity**

Instrument reliability and validity were statistically confirmed.

**Cronbach's Alpha coefficients:**

Independent variables = 0.958

©2026 The Author(s). This article is licensed under CC By 4.0

AES performance (dependent variable) = 0.922

Pearson correlation coefficients ranged from 0.688 to 0.927, all significant at $p \leq 0.01$, indicating strong internal consistency and confirming construct validity [9, 10].

**C. Correlation Analysis**

To determine the relationships between study variables, Pearson correlation analysis was performed.

As presented in Table 6, all independent variables demonstrated significant and positive correlations with AES performance ($p \leq 0.01$).

Table 6. Correlation Analysis (Pearson Coefficients)

**Table 6.** Correlation Analysis (Pearson Coefficients)

| Variable | Exam Performance | Strength of Correlation |
|---|---|---|
| Knowledge Level | 0.570** | Strong |
| Technical Infrastructure | 0.664** | Strong |
| Core Question Variety | 0.487** | Moderate |
| Answer Set Variety | 0.732** | Very Strong |
| Learning Resources | 0.643** | Strong |
| Question Quality & Difficulty | 0.768** | Very Strong |
| Human Resource Training | 0.744** | Very Strong |

Note: All correlations are statistically significant at $p \leq 0.01$.

These results confirm that improvements in question quality, answer diversity, and staff training contribute directly to higher AES performance, consistent with Pallant's (2009, p. 149) correlation strength interpretation.

**D. Multiple Regression Analysis**

A multiple linear regression model was used to examine predictors of AES performance. Assumption testing confirmed normality, linearity, homoscedasticity, and absence of multicollinearity, validating the model's reliability [11]. Table 7 shows the Multiple Linear Regression Results. The findings revealed significant effects of five factors, knowledge volume ($\beta = 0.164$, $p \leq 0.05$), variation in core questions ($\beta = 0.172$, $p \leq 0.05$), variation in answer options ($\beta = 0.277$, $p \leq 0.05$), question quality and difficulty ($\beta = 0.312$, $p \leq 0.05$), and human resource training ($\beta = 0.204$, $p \leq 0.05$), on examination system performance. In contrast, technical structure ($\beta = 0.020$, $p = 0.841$) and the level and format of learning resources ($\beta = 0.110$, $p = 0.247$) showed no significant influence. The model achieved a strong explanatory power with an R value of 0.826 and an $R^2$ of 0.683, indicating that the independent variables collectively explain 68.3% of the variance in examination system performance.

Table 7. Multiple Linear Regression Results

**Table 7.** Multiple Linear Regression Results

| Predictor Variable | $\beta$ Coefficient | p-value | p-value Significance |
|---|---|---|---|
| Knowledge volume | 0.164 | p<0.05 | Significant |
| Technical Structure | 0.020 | p>0.05 | Not Significant |
| Human Resource Training | 0.204 | p<0.05 | Significant |
| Cognitive Quantity | 0.312 | p<0.05 | Significant |
| Question Variation | 0.172 | <0.05 | Significant |
| Answer Set Diversity | 0.277 | p<0.05 | Significant |
| Learning Resource Level | 0.110 | P>0.05 | Not Significant |

The results indicate that technical structure and human resource training are the strongest predictors of AES performance, while the level of learning resources was not statistically significant, suggesting that availability alone does not ensure effective utilization. Table 8 shows the detailed effects of the Independent Variables on the Dependent Variable.

**Interpretation note for Likert-scale regression:**

Regression coefficients are interpreted in terms of direction and relative influence rather than percentage-based extrapolations because the study variables were measured using Likert-scale items. A non-significant coefficient suggests that the predictor does not exhibit a direct statistical relationship with AES performance in the model, whereas a positive and statistically significant coefficient shows that higher levels of the predictor are linked to higher AES performance.

It is evident from Table 8 that there is a significant positive effect between knowledge quantity and the examination system performance, where the regression coefficient value was ($\beta = 0.164$, $p \leq 0.05$). This indicates that a high increase in knowledge quantity will lead to a 16.40% increase in the examination system performance. This supports the study hypothesis that knowledge quantity has a positive effect on the examination system performance in Yemeni schools. Therefore, the first hypothesis (H1) was accepted.

Table 8 also shows that there is no significant effect between the technical structure and the examination system performance, as the T-value (0.201) was not statistically significant, with a corresponding significance level (Sig.) of (0.841), which is greater than the significance level of (0.05). The regression coefficient ($\beta$) was small (0.020), indicating that the technical structure does not

©2026 The Author(s). This article is licensed under CC By 4.0

**Table 8.** Detailed Effects of the Independent Variables on the Dependent Variable

| Hypothesis | The text of the sub-hypothesis | $\beta$ | T | Sig. |
|---|---|---|---|---|
| First: **H1** | Knowledge quantity has a positive effect on the performance of the examination system in Yemeni schools. | 0.164 | 2.082 | 0.040* |
| Second: **H2** | The technical structure has a positive effect on the performance of the examination system in Yemeni schools. | 0.020 | 0.201 | 0.841 |
| Third: **H3** | The variation in core questions has a positive effect on the performance of the examination system in Yemeni schools. | 0.172 | 2.299 | 0.024* |
| Fourth: **H4** | The variation/difference in the set of answers has a positive effect on the performance of the examination system in Yemeni schools. | 0.277 | 3.371 | 0.001* |
| Fifth: **H5** | The level and format of learning resources have a positive effect on the performance of the examination system in Yemeni schools. | 0.110 | 1.164 | 0.247 |
| Sixth: **H6** | The quality and difficulty of the questions have a positive effect on the performance of the examination system in Yemeni schools. | 0.312 | 2.712 | 0.008* |
| Seventh: **H7** | Human resource training has a positive effect on the performance of the examination system in Yemeni schools | 0.214 | 2.114 | 0.037* |

(*) Statistically significant at the significance level ($p \leq 0.05$)

affect the examination system performance in Yemeni schools. This does not support the study hypothesis that the technical structure affects the examination system performance. Therefore, the second hypothesis (H2) was rejected.

Additionally, Table 8 shows a significant effect between the variation in core questions and the examination system performance, where the regression coefficient value ($\beta$ = 0.172, $p \leq 0.05$). This indicates that a high increase in the variation of core questions will lead to a 17.20% increase in the examination system performance. This supports the study hypothesis that the variation in core questions has a positive effect on the examination system performance in Yemeni schools. Therefore, the third hypothesis (H3) was accepted.

Table 8 also demonstrates a significant effect between the variation/difference in answer sets and the examination system performance, with the regression coefficient value ($\beta$ = 0.277, $p \leq 0.05$). This suggests that a high increase in the variation/difference in answer sets will result in a 27.70% increase in the examination system performance in Yemeni schools. This supports the study hypothesis that variation/difference in answer sets positively affects the examination system performance. Therefore, the fourth hypothesis (H4) was accepted.

Furthermore, Table 8 shows no significant effect between the level and format of learning resources and the examination system performance, with a T-value (1.164) that was not statistically significant. The corresponding significance level (Sig.) was (0.247), which is greater than the significance level of (0.05), and the regression coefficient ($\beta$) was small (0.110). This indicates that the level and format of learning resources do not affect the examination system performance in Yemeni schools. This does not support the study hypothesis that the level and format of learning resources positively affect the examination system performance. Therefore, the fifth hypothesis (H5) was rejected.

Table 8 also indicates a significant effect between the quality and difficulty of questions and the examination system performance, where the regression coefficient value ($\beta$ = 0.312, $p \leq 0.05$). This suggests that a high increase in the quality and difficulty of questions will result in a 31.20% increase in the examination system performance in Yemeni schools. This supports the study hypothesis that the quality and difficulty of questions positively affect the examination system performance. Therefore, the sixth hypothesis (H6) was accepted.

Finally, Table 8 shows a significant effect between human resource training and the examination system performance, with the regression coefficient value ($\beta$ = 0.204, $p \leq 0.05$). This indicates that a high increase in human resource training will lead to a 20.40% increase in the examination system performance in Yemeni schools. This supports the study hypothesis that human resource training positively affects the examination system performance. Therefore, the seventh hypothesis (H7) was accepted.

**Hypothesis Testing:**

Table 9 presents the results of the hypothesis tests, which are consistent with the results of the regression analysis shown earlier in this section.

## 5. DISCUSSION

The findings of this study align with existing literature showing that successful adoption of automated assessment technologies is deeply influenced by organizational support, training, and system readiness.

Participants demonstrated generally positive perceptions of AES features, especially regarding speed, grading accuracy, and fairness. However, the results also indicate that **digital transformation cannot succeed through technology alone**; adequate training, reliable infrastructure, and supportive school policies play equally important roles.

©2026 The Author(s). This article is licensed under CC By 4.0

**Table 9.** Hypothesis Test Results

| Symbol | Hypothesis | Result |
|---|---|---|
| H1 | Knowledge quantity positively affects the performance of the examination system in Yemeni schools. | Supports |
| H2 | The technical structure positively affects the performance of the examination system in Yemeni schools. | Does not support |
| H3 | Variation in core questions positively affects the performance of the examination system in Yemeni schools. | Supports |
| H4 | Variation/difference in the set of answers positively affects the performance of the examination system in Yemeni schools. | Supports |
| H5 | The level and format of learning resources positively affect the performance of the examination system in Yemeni schools. | Does not support |
| H6 | The quality and difficulty of the questions positively affect the performance of the examination system in Yemeni schools. | Supports |
| H7 | Human resource training positively affects the performance of the examination system in Yemeni schools. | Supports |

The limited effect of learning resources on AES performance suggests that the availability of digital materials does not automatically translate to effective use. This reflects a broader issue in many resource-limited schools: technology is often introduced faster than educators can learn to integrate it. Continuous training and clear operational guidelines are therefore essential.

Infrastructure challenges, including unstable electricity, limited connectivity, and outdated devices, were consistently identified, confirming their role as major barriers to digital adoption. Resistance to change also emerged, indicating the need for awareness programs and hands-on practice to build confidence in automated systems.

A pilot deployment in several schools demonstrated clear improvements in grading speed and student satisfaction. Teachers initially struggled with system navigation, but performance improved noticeably after targeted training. These observations reinforce the quantitative results, highlighting that **human capacity building** is a decisive factor in adopting new digital examination processes.

Overall, the study reveals that digital transformation in Yemeni schools requires a balanced focus on technology, staff readiness, institutional support, and continuous monitoring. Without addressing these dimensions together, the shift from traditional to automated examination systems remains difficult to sustain.

As mentioned above, the results align with previous studies emphasizing the importance of technical readiness and human capacity in adopting educational technologies [2, 12].

Despite generally strong correlations across all variables, the insignificance of learning resources suggests that availability without pedagogical integration fails to enhance system performance.

Challenges observed include limited infrastructure, insufficient training, and resistance to change, reflecting broader systemic barriers in Yemeni education. Addressing these challenges through targeted professional development and institutional support is crucial for sustainable AES implementation.

**Reconciling infrastructure findings:**

Our regression results show that technical infrastructure does not directly predict AES performance in the current model, even though technical infrastructure is generally acknowledged as a requirement for digital systems. This does not mean that infrastructure is insignificant; rather, it implies that, in the Yemeni context, infrastructure constraints can be comparatively consistent among schools and hence offer little room for explanation. As a result, organizational and human factors, including training, question quality, and operational procedures, provide a stronger explanation for variations in AES performance.

**Case Study: Pilot Implementation in Sana'a Schools**

A pilot AES deployment conducted in selected Sana'a schools validated the quantitative findings.

**Reported outcomes included:**

Improved grading accuracy and feedback speed,

Enhanced administrative efficiency and greater student satisfaction.

Teachers initially faced challenges in system navigation, which were resolved through structured training sessions. This supports the regression results, confirming that training and technical support are key to successful AES adoption.

The findings affirm that technical readiness and human resource capacity are the pillars of AES's success. Continuous training, infrastructure improvement, and feedback mechanisms are essential for achieving reliable and equitable automated assessment in Yemeni schools.

**Implications for implementation and policy:**

The study's conclusions provide a number of useful recommendations for educational decision-makers working in settings with limited resources. First, since staff readiness and system familiarity were found to be

©2026 The Author(s). This article is licensed under CC By 4.0

stronger predictors of AES performance than infrastructure availability alone, policymakers should give priority to human resource training and capacity building before making significant infrastructure investments. Second, in order to maximize system effectiveness, implementation strategies should prioritize the quality of assessment design, including question clarity, balanced difficulty levels, and variety in answer options. Third, a phased adoption strategy is advised, beginning with pilot deployments in a few chosen schools and gradually expanding in response to feedback and performance results. Lastly, to guarantee long-term AES adoption in low-resource educational systems, ministries of education and school administrators should create explicit operational guidelines and support systems, such as technical assistance units and ongoing training initiatives.

**Limitations:**

There are a number of limitations to this study. (1) Sampling: Due to accessibility limitations, the sample distribution is biased toward college students, which may restrict the representativeness of all Yemeni school stakeholder groups. (2) Methodology: Response bias may be present because the study uses self-reported questionnaire data. (3) Design and scope: Because the study is cross-sectional and concentrates on a single country context, its applicability to other areas may be limited.

In addition, the challenges encountered in this study include designing suitable questions for all target groups, whether students, supervisors, or teachers. Additionally, most of the studies on this topic are somewhat outdated. (The practical challenges and realities when implementing the system at the level of the Republic of Yemen) Difficulty in Resisting Change, Being the First Experience in the Arab World, Providing the Infrastructure, Converting Essay Questions into Objective Questions, and Lack of a Description for Learning Outcomes of Academic Courses.

## 6. CONCLUSION

This study examined the adoption and performance of Automated Examination Systems in Yemeni schools and highlighted the conditions necessary for the successful digital transformation of examination processes. The study proposed a model based on the TOE model, which is one of the most widely used models. It includes seven independent variables: knowledge volume, technical structure, variation in core questions, variation in answer options, level and format of learning resources, question quality and difficulty, and human resource training. The dependent variable was the performance of the examination system.

The study used a quantitative approach through questionnaires to collect data. The statistical population included supervisors, teachers, and students in Yemeni schools. The proposed model was tested using multiple linear regression analysis and other statistical techniques.

The findings showed significant effects of the variables (knowledge volume, variation in core questions, variation in answer options, question quality and difficulty, and human resource training) on examination system performance. However, the results revealed no significant effect of (technical structure and level/format of learning resources). Based on these findings, several recommendations were proposed for stakeholders.

The results show that system performance is significantly influenced by factors such as question quality, answer variation, cognitive alignment, and human resource training. In contrast, technical infrastructure and the availability of learning resources did not show a strong direct impact, emphasizing the need for better integration and support mechanisms.

The research demonstrates that resource-limited schools can benefit from automated examination systems, but only when supported by structured training, improved infrastructure, and clear adoption strategies. The proposed framework provides a practical foundation for guiding digital transformation efforts and improving the quality and efficiency of school assessments.

This study is expected to contribute to a better understanding of the relationship between the factors influencing exam process adoption and its impact on examination system performance in Yemeni schools.

This study offers practical insights for policymakers and educational administrators looking to successfully implement digital examination systems in resource-constrained situations by addressing both technical and non-technical factors of AES performance.

**Future research:**

Future research should use qualitative techniques (such as focus groups or interviews) to gather more in-depth contextual explanations, use longitudinal designs to track adoption over time, and perform cross-regional or cross-school system comparisons to confirm and expand the TOE-based findings.

In addition, future work should explore additional contexts, incorporate qualitative insights, and develop more adaptable models that support the long-term sustainability of digital assessment in developing regions.

## REFERENCES

[1] M. S. Atala, “Factors affecting the quality of primary education in al-quneitra schools in light of total quality standards,” Doctoral dissertation, 2014.

[2] S. Kim, J. Song, and Y. Kim, “Assessing the quality of multiple-choice exams: A review of methods and applications,” *Educ. Technol. Res. Dev.*, vol. 70, no. 2, pp. 345–362, 2022.

[3] I. Sharaf, “Automated exam system implementation in yemeni schools,” Master’s thesis, University of Sana’a, 2025.

[4] L. G. Tornatzky and M. Fleischer, *The Processes of Technological Innovation*. Lexington Books, 1990.

©2026 The Author(s). This article is licensed under CC By 4.0

[5] V. Venkatesh and H. Bala, "Technology acceptance model 3 and a research agenda on interventions," *Decis. Sci.*, vol. 39, no. 2, pp. 273–315, 2008.

[6] A. Al-Adimi, *Research Methodology*. Sana'a: Sana'a University Press, 2010.

[7] S. Salloum et al., *Advanced Correlational Research in Educational Studies*. Academic Press, 2022.

[8] M. S. Al-Mahmoudi, *Scientific Research Methodologies*, 3rd ed. Sana'a, Yemen: Dar Al-Kutub, 2019.

[9] H. Al-Mahmoudi, *Quantitative Research Methods*. Yemen Publishing, 2019.

[10] N. Al-Qahtani et al., *Content Validity Methods in Social Research*. Riyadh: University Press, 2000, 1421 AH.

[11] U. B. Sekaran, *Research Methods for Business: A Skill-Building Approach*, 7th ed. Chichester, UK: John Wiley & Sons Ltd, 2016.

[12] M. Amini and N. J. Javid, "A multi-perspective framework established on diffusion of innovation (doi) theory and technology, organization and environment (toe) framework toward supply chain management system based on cloud computing technology for small and medium enterprises," *J. Theor. Appl. Inf. Technol.*, vol. 11, no. 8, 2023.

[13] E. Emirtekin, "Large language model-powered automated assessment: A systematic review," *Appl. Sci.*, vol. 15, no. 10, p. 5683, 2025.

[14] B. Aydın, "Automated scoring in the era of artificial intelligence," *Comput. & Educ.*, vol. 212, p. 105 987, 2025.

[15] C. H. Sekhar, P. Deekshita, and R. Kaur, "An automated examination system for evaluation of descriptive tests," *i-manager's J. Comput. Sci.*, vol. 10, no. 1, pp. 13–20, 2022.

[16] W. Kayanja et al., "Exploring digital transformation in higher education: The shift to fully automated and paperless systems," *Cogent Educ.*, vol. 12, no. 1, p. 2 489 800, 2025.

[17] V. Dhameria et al., "The impact of digital transformation in higher education management," *Int. J. Educ. Qual. Quant. Stud.*, vol. 4, no. 1, pp. 15–24, 2025.

[18] T. M. Sarker and M. K. Rahman, "Digital readiness and transformation of school assessment systems," *Heliyon*, vol. 11, no. 2, e21055, 2025.

[19] H. O. Shittu and L. Hassan, "Adoption challenges of digital exams in developing regions," *J. Educ. Technol. Syst.*, vol. 53, no. 3, pp. 349–368, 2024.

[20] L. Q. Nwosu, "Barriers to digital exam adoption in low-resource schools," *Int. J. Digit. Learn.*, vol. 13, no. 4, pp. 58–72, 2023.

[21] S. Timotheou, O. Miliou, et al., "Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review," *Educ. Inf. Technol.*, vol. 28, pp. 6695–6726, 2022.

[22] A. Muzaffar, M. Tahir, et al., "A systematic review of online exams solutions in e-learning: Techniques, tools, and global adoption," *IEEE Access*, vol. 9, pp. 32 689–32 712, 2020.

[23] S. Kaddoura, D. Popescu, and J. Hemanth, "A systematic review on machine learning models for online learning and examination systems," *PeerJ Comput. Sci.*, vol. 8, 2022.

[24] M. Sabiteka, X. Yu, and C. Sun, "Toward sustainable education: A contextualized model for educational technology adoption for developing countries," *Sustainability*, 2025.

[25] N. Ullah, W. Al-Rahmi, et al., "Blockchain technology adoption in smart learning environments," *Sustainability*, 2021.

[26] M. A. Al-Rawi and K. A. Al-Rashidi, "Adoption of educational technologies using the toe framework in developing countries," *Educ. Inf. Technol.*, vol. 29, pp. 14 567–14 589, 2024.

[27] K. K. Nguyen, "Toe-based analysis of e-learning and exam system adoption in public schools," *Asia Pac. Educ. Rev.*, vol. 25, pp. 321–337, 2024.

[28] R. B. Patel and S. Kumar, "Technology adoption for digital assessment platforms: A toe–doi integrated approach," *Sustainability*, vol. 16, no. 1, p. 455, 2024.

©2026 The Author(s). This article is licensed under CC By 4.0