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INTRODUCTION

This Proceedings present the articles delivered at the international conference Information Technology and Education Development (ITRO 2024), held for the jubilee fifteenth time on November 29, 2024. This international event was conducted in a hybrid format, combining in-person and online participation. The conference continues its tradition of bridging science, professional practice, and educational experiences, with this year's focus on the conditions and perspectives of teachers' digital competencies.

The thematic fields of the conference reflect contemporary trends in education, addressing topics such as: the digitalization of education, education in crisis situations, educational challenges, theoretical and methodological issues in contemporary pedagogy, digital didactics and media, modern communication strategies in teaching, curriculum development for contemporary education, advancements in e-learning, education management practices, methodological approaches in teaching natural and technical sciences, and the integration of information and communication technologies in education.

The conference featured three plenary lectures that explored various aspects of the main topic, with the corresponding articles included at the beginning of this volume.

In total, this edition comprises 57 peer-reviewed articles, evaluated through a double-blind review process. These contributions represent the latest research and advancements in the field.

The conference received financial support from the Provincial Secretariat for Higher Education and Scientific Research, Novi Sad. Hosting and technical support were generously provided by the Technical Faculty "Mihajlo Pupin." We extend our sincere gratitude for this invaluable assistance.

The Organizing Committee expresses its heartfelt thanks to the authors, reviewers, and participants for their contributions, which ensure the success and continued tradition of this event.

We look forward to welcoming you to the next ITRO Conference!

On behalf of the ITRO Organizing Committee

Jelena Stojanov

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Online Exam Proctoring System – Student Perspective

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Abstract. Online proctoring systems have become increasingly prevalent as educational institutions shift towards remote learning and assessments. However, while these systems offer significant benefits in terms of maintaining academic integrity, their impact on students' experiences remains underexplored. This study aims to evaluate an online proctoring system from the student perspective, focusing on factors such as usability, fairness, data privacy, and the psychological impact of surveillance during exams. A survey was conducted with students who experienced the proctoring system during online exams, with questions addressing various aspects of the system's effectiveness, usability, and perceived fairness. Results are discussed and conclusions are drawn.

Keywords and phrases: Proctoring system, online exam, artificial intelligence, Safe Exam Browser**.**

1 Introduction

In the rapidly evolving landscape of digital education, online examinations have emerged as a critical component of academic assessment, particularly in the conditions of global disruptions such as the COVID-19 pandemic. The unprecedented shift towards remote learning and digital assessment methodologies has fundamentally transformed traditional educational evaluation paradigms, presenting both unprecedented opportunities and significant challenges. In addition, rapid development of AI and its wide range of application in multiple sectors such as medicine (Chabra et at., 2013), (Stojanov & Koceski, 2014), (Kotevski et al., 2024), healthcare (Devedžić et al., 2021), (Stojanova et al., 2019), social care (Koceski & Koceska, 2016), (Koceska et al., 2019), robotics (Koceska et al., 2013), (Velinov et al., 2024), finance, business (Kirovska & Koceski, 2015), is significantly changing the entire sector of education (Duh et al., 2017), (Koceski & Koceska, 2022), (Koceska et al., 2024). While digital assessment methods offer unprecedented flexibility, accessibility, and potential for innovative evaluation techniques, they simultaneously raise complex questions about academic integrity, student privacy, technological equity, and the psychological well-being of learners.

The global transition to online examinations has been accelerated by technological advancements, institutional adaptability, and external pressures such as global health crises. However, this rapid transformation has not been uniformly smooth or successful across different educational contexts. Varying technological infrastructures, institutional readiness, and student preparedness have created a complex ecosystem of digital assessment practices that demand rigorous scholarly investigation. Research from diverse educational settings has revealed significant disparities in the implementation, effectiveness, and student experience of online examination platforms.

The landscape of academic integrity is increasingly complex, with student cheating behaviors evolving in tandem with technological advancements. Empirical research consistently demonstrates the persistent challenge of academic dishonesty in online examination environments. A study by McCabe et al. (2001) revealed that approximately 64% of undergraduate students engage in some form of academic cheating, a trend that has been exacerbated by digital technologies. More recent investigations suggest that online examination platforms create unique opportunities for academic misconduct, including sophisticated cheating strategies that leverage technological tools.

Contemporary cheating behaviors have become increasingly sophisticated, transcending traditional methods of plagiarism and unauthorized collaboration. Students now employ a range of technological strategies, including:

- Use of hidden communication devices
- Advanced screen-sharing techniques
- AI-powered answer generation
- Collaborative online platforms for real-time problem-solving
- Sophisticated impersonation methods
- Exploitation of proctoring system vulnerabilities

In addition, technological safety emerges as an additional concern in this digital assessment landscape. Cybersecurity threats, potential data breaches, authentication challenges, and the risk of academic misconduct represent critical areas of research. Moreover, the psychological dimensions of online examinations—including student stress, anxiety, technological self-efficacy, and perceived fairness—are equally crucial in understanding the holistic experience of digital assessment. These multifaceted challenges necessitate a comprehensive, student-centered approach to understanding and improving online examination practices.

Existing literature demonstrates varied perspectives on online examination safety. Some studies have emphasized technological solutions, focusing on robust authentication mechanisms, secure browser technologies, and advanced proctoring techniques. Others have explored psychological and pedagogical dimensions, investigating how digital assessment formats impact student performance, stress levels, and learning outcomes. However, a significant research gap persists in synthesizing these perspectives and centering the student voice in understanding what constitutes a "safe" online examination experience.

This research aims to bridge this critical knowledge gap by conducting a comprehensive, mixed-methods investigation into students' perspectives on online examination safety. This seeks to provide a nuanced understanding of the multiple dimensions of safety in digital assessment. In the following the developed system for proctored online examination is described and evaluated. The conclusions are derived and discussed.

2 STATE OF THE ART

Research has consistently highlighted concerns regarding academic integrity in online learning environments. Studies across different academic settings have demonstrated that students perceive online environments as more conducive to academic dishonesty (King et al., 2009). This perception is supported by quantitative data, with Watson and Sottile's (2010) comprehensive study of 635 participants revealing students' self-reported likelihood of engaging in dishonest behavior was approximately four times higher in online settings. These findings align with multiple research efforts documenting elevated rates of academic misconduct in virtual learning environments (Lanier, 2006; Harmon & Lambrinos, 2008; Dietz-Uhler & Hurn, 2011).

Recent research has focused on integrating multiple detection channels to create comprehensive proctoring solutions. A notable advancement in this field employs a cost-effective dual-camera setup combined with audio monitoring. An approach that synthesizes six fundamental detection elements: identity verification, textual content analysis, audio monitoring, browser activity tracking, gaze tracking, and mobile device detection (Atoum at al., 2017). With the development of technology other methodologies are tested. In order to investigate the usage of the 360-degree security camera over the traditional webcam, practical study was conducted (Turani et al., 2020). It claims that this approach can enhance the exam security and minimize the stressful restrictions.

Significant developments have emerged in the application of visual analytics for examination monitoring. Sophisticated algorithms to analyze both head movements and cursor activity patterns were developed (Li at al., 2021). These systems provide educators with intuitive visualization tools that enable efficient monitoring of student behavior during online assessments. The integration of behavioral analysis has proven particularly effective in identifying suspicious patterns that may indicate academic dishonesty.

The shift toward online learning has necessitated innovative approaches to maintaining academic integrity. Holden et al. (2021) emphasize the unique challenges inherent in online education, where student autonomy and physical separation from instructors create verification difficulties. Modern automated proctoring solutions have evolved to incorporate comprehensive monitoring capabilities. Awaghade et al. (2022) introduced a framework providing a versatile, fully computerized system accessible to both administrators and test takers. Current systems feature:

- Real-time screenshot capture
- Environmental audio analysis
- Tab switching detection
- Copy-paste restriction mechanisms
- Advanced head movement tracking
- Facial feature analysis
- Multi-person detection
- Continuous presence verification

The implementation of deep learning techniques has marked a significant advancement in online proctoring systems. Ahmad and Mehmood demonstrated the effectiveness of biometric techniques using OpenCV face recognition and HOG detection (Ahmad et al., 2021). Yadav and Singh (2016) further showed how computer vision techniques could be effectively integrated into proctoring systems incorporating:

- Object framing and recognition
- Image processing algorithms
- Scale-invariant detection methods
- Movement tracking
- Environmental analysis

Research examining the relationship between proctoring methods and academic performance presents varied conclusions. Several studies report significantly higher performance in non-proctored online examinations compared to proctored settings (Schultz et al., 2007; Alessio et al., 2017; Richardson & North, 2013). However, contrasting research has found no significant performance variations between proctored and non-proctored online assessments (Ladyshewsky, 2015; Yates & Beaudrie, 2009; Beck, 2014).

Ingram et al. (2018) identifies three critical selection factors for institutions:

- Financial considerations
- Security requirements
- Technology accessibility for faculty and students

Secreto et al. (2015) emphasized the importance of integrating technological solutions with institutional support structures. Tripathi et al. (2024) further highlighted how remote investigation and monitoring are becoming increasingly crucial for maintaining credibility in MOOCs and credit-based certifications. Daffin & Jones (2018) developed a comprehensive comparison framework examining various aspects of online proctoring services.

3 SYSTEM ARCHITECTURE

Our comprehensive proctoring system for remote examination integrates multiple security layers to enhance assessment validity. The system architecture (Figure 1) combines three primary components: custom made examination system, a specialized secure browser environment based on Safe Exam Browser, and advanced real-time video monitoring and alerting system. The main aim of this system is to help professors to facilitate and automate the process of examination of big groups of students at the Faculty of Computer Science at Goce Delcev University. Moreover, it is aimed at helping students to facilitate the examination process, especially in subjects where coding is needed to solve practical problems. Solving coding problems during exam using pen and paper is really difficult for students as they are not aware of any bugs and syntax errors. Therefore, we build a custom examination system that includes online compilers and enables real-time preview of the results on various test cases.

The examination platform employs a specialized secure browser Safe Exam Browser that provides comprehensive system control by restricting access to external applications and preventing concurrent browser sessions. This secure environment actively blocks background processes while disabling clipboard functionality to prevent unauthorized data transfer. The system maintains secure communication channels with the examination server via internet or local network connectivity to ensure continuous monitoring integrity. The system supports flexible device configurations while maintaining strict security protocols across various hardware platforms. The primary monitoring interface operates seamlessly across desktop computers, laptops, and mobile devices.

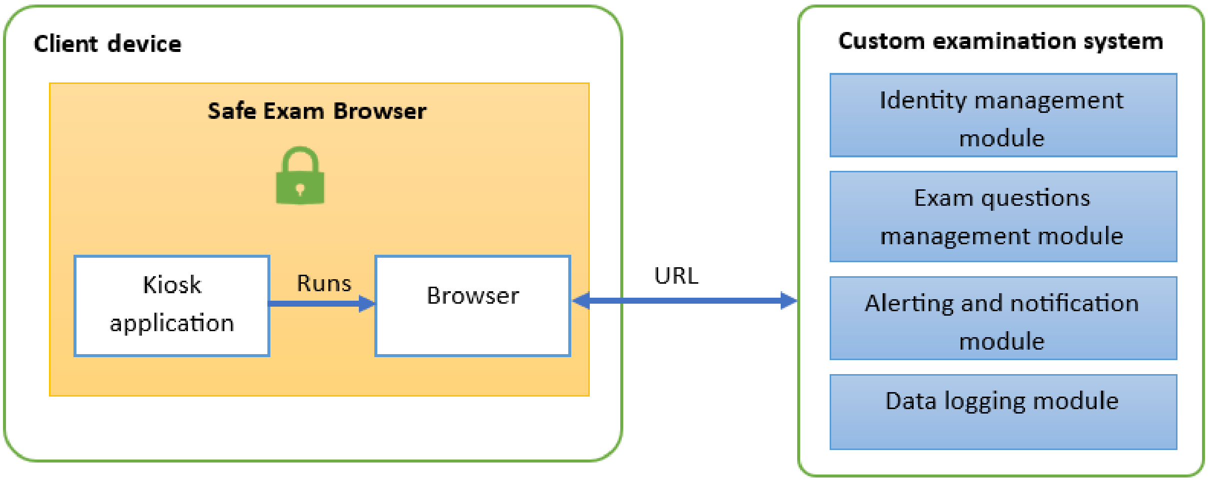

Figure 1. System architecture overview

To provide monitoring coverage, the system enables recording the students with primary web camera that is capturing the student's face. In order to protect students' privacy, the video capture is analyzed on client side and just information about the head pose and sound events are streamed to the server. Moreover, the system is rising alarms directly on client side as well as on the supervisor's side. This kind of alerting system should interrupt an attempt for cheating and should prevent potential academic integrity violations.

Faculty members can conduct real-time monitoring of examination sessions while the system maintains robust authentication protocols throughout the assessment period. This real-time monitoring approach ensures immediate detection of potential integrity concerns while providing a secure and controlled examination environment.

The system employs a sophisticated combination of identity verification and continuous monitoring protocols. The mandatory front-facing camera serves dual purposes, facilitating both initial authentication and ongoing behavioral observation. This integrated approach ensures consistent verification of student identity while maintaining the integrity of the examination process through continuous surveillance.

The platform's design accommodates various educational contexts and technical requirements while maintaining rigorous security standards. This flexibility allows institutions to implement custom monitoring configurations based on specific assessment needs while ensuring consistent security protocols across all examination scenarios.

4 SYSTEM EVALUATION AND DISCUSSION

The system was evaluated on a group of 60 students (28 females and 32 males) attending the course Basics of computer science taught in first year of bachelor studies in both Macedonian and English languages at the Faculty of Computer Science, at Goce Delcev University. All the students were following this course for the first time. The system was tested during mid-term course evaluation related to Web Development Fundamentals. This module forms a core component of the BSc curriculum, introducing students to essential client-side web technologies. This assessment framework evaluates students' practical understanding of HTML, CSS, and JavaScript while emphasizing industry-relevant application. Before the exam all the students were introduced to the Safe Exam Browser environment and the way it works. They have all logged in to the examination system and tried the system several times before the examination, solving similar practical problems during their laboratory exercises' hours.

All the students were informed that the web cams will be capturing their face, but no recording will be stored on the local devices nor on the server. Instead, just numerical parameters will be calculated and eventually stored during the examination process. Once the Safe Exam Browser loads the web application on the dedicated address, all students were able to authenticate and the examination environment was active. It consists of navigation toolbar with basic commands to contemporary save the answers, to compile and run the solution, as well as to select one of the given problems. The central portion of the application is divided in two main panels: the left one containing basic text editor to write the code, and the right one aimed at previewing the result after compile. The system is auto-saving the current version of the solution each minute. On the top bar a red visual indicator for eventual suspicious behavior of the student is placed. It starts blinking whenever the AI algorithm for head pose estimation combined with sounds analyzer detects potentially irregular behavior (Figure 2). The algorithms are based on MediaPipe and OpenCV and implemented in Javascript.

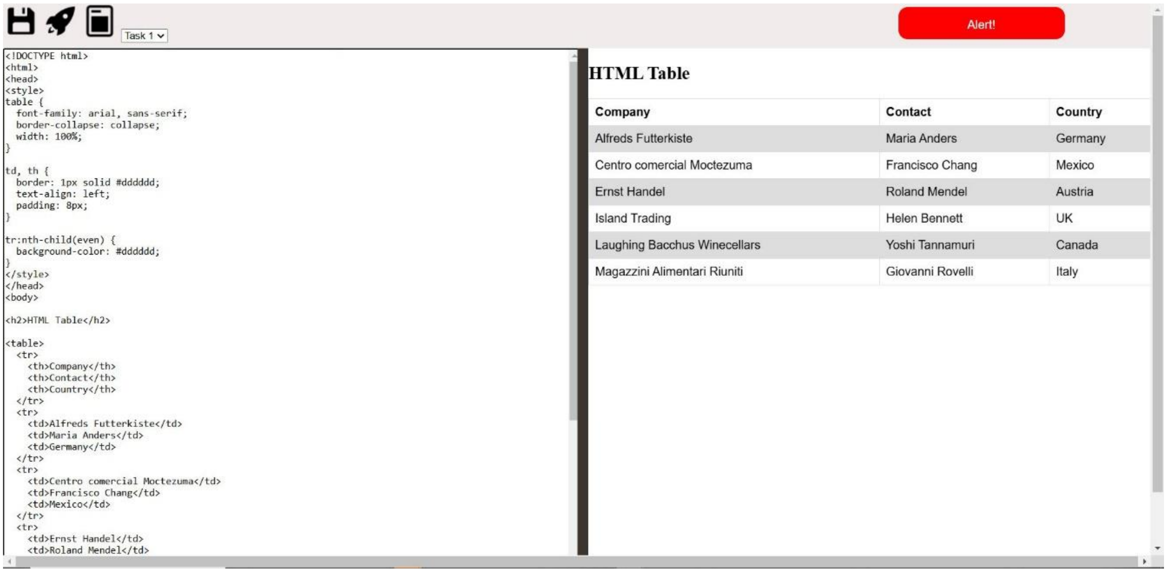

Figure 2. Examination platform screen

The examination session was lasting for 45 minutes and after its end each student was asked to fill in a questionary with several questions. All the students without exception have answered all the questions and all of them were taken into consideration for the analysis. The questions (Table 1) were divided in multiple categories each of them aiming at collecting the students' viewpoints on different aspects of the system. Students were asked to answer each question using the Liker scale from 1-5 (1 meaning low and 5 meaning high). Detailed descriptive statistics for the questions 5-13 is presented in Figure 3.

	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
count	60	60	60	60	60	60	60	60	60
mean	4.2	3.8	4.9	1.8	3.2	3.5	4.6	3.8	4.2
std	0.65871	0.731842	0.354152	1.176032	0.879137	0.624364	0.643086	0.65871	0.65871
min	3	2	3	1	2	2	3	3	3
25%	4	3	5	1	3	3	4	3	4
50%	4	4	5	1	3	3	5	4	4
75%	5	4	5	2	4	4	5	4	5
max	5	5	5	5	5	5	5	5	5

Figure 3. Descriptive statistics for questions 5-13

The distribution of the given responses is given in Figure 4, while the correlation heatmap of the responses given by the students is presented in Figure 5.

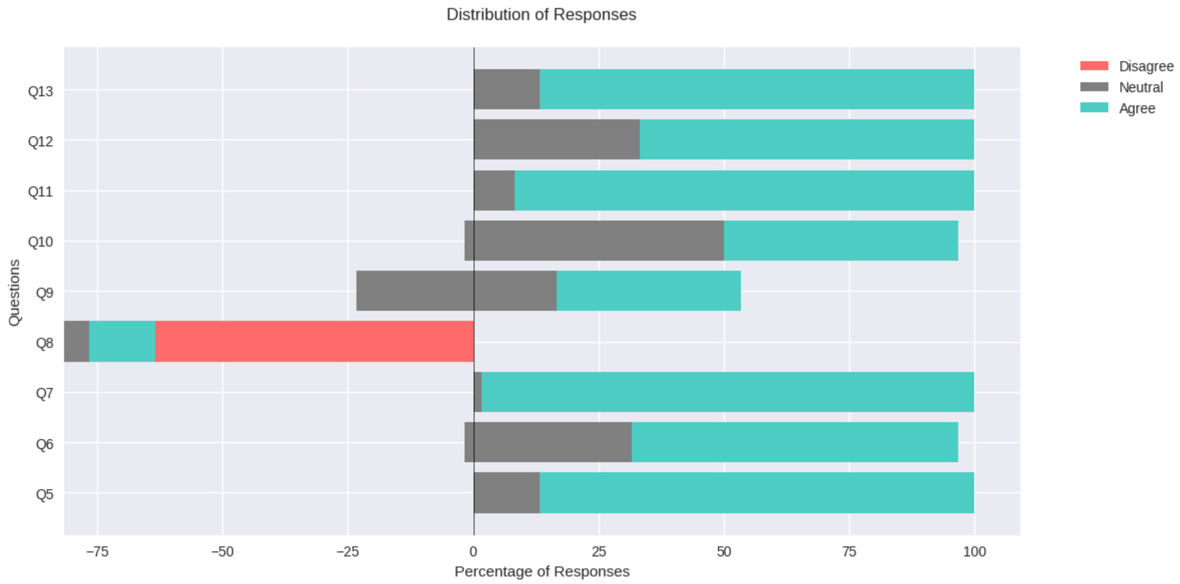

Figure 4. Distribution of responses

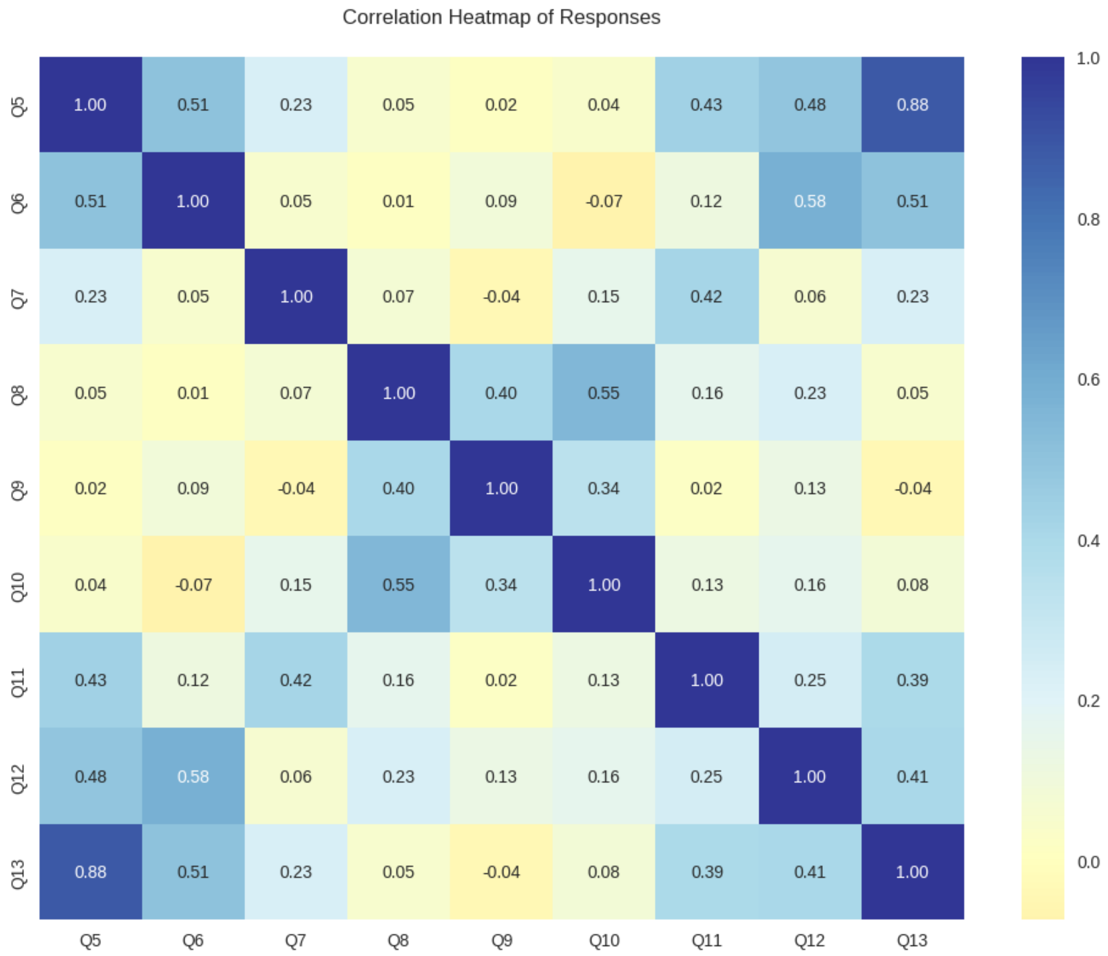

Figure 5. Correlation heatmap of responses

The average grade provided by the students on all the questions from the first group (1-4) was 5. Firstly, this unanimous high rating could indicate that the system is user-friendly and accessible, as students found it easy to set up and operate on their devices without encountering significant technical barriers. This ease of use likely reflects well-designed software and user interfaces, which may have minimized common issues like device compatibility, connectivity disruptions, or complex setup requirements. Additionally, such high ratings suggest that the system's instructions were likely clear and intuitive, empowering students to feel confident in using the proctoring technology during the exam process.

The high usability score also implies a positive overall user experience, as students were able to focus on their exams without unnecessary technical distractions or interruptions. The lack of reported issues during setup and throughout the exam indicates that the system likely maintained a stable connection and functioned reliably under exam conditions, which is crucial for high-stakes testing environments.

Table 1. Evaluation questions

Question No.	***Category / Questions***	***Average score***
	Technical usability	
1	How easy was it to set up the proctoring system on your device?	5
2	Did you experience any technical difficulties (e.g., camera or microphone issues, internet connectivity) during the exam?	5
3	How reliable was the system in terms of staying connected throughout the entire exam?	5
4	Were the instructions for using the proctoring system clear and easy to follow?	5
	Privacy and security	
5	How comfortable did you feel with the level of surveillance during the exam?	4.2
6	Do you have any concerns about the data being collected and how it is stored or used?	3.8
7	Were you informed about the data privacy policy of the proctoring system before using it?	4.9
	Exam experience	
8	Did the presence of the proctoring system impact your ability to focus on the exam?	1.8
9	How stressed or anxious did the proctoring system make you feel during the exam?	3.2
10	Did you feel that the proctoring system was fair and unbiased in monitoring your actions?	3.5
11	Was online exam convenient and flexible?	4.6
	System Efficiency and Accuracy	
12	Were there any false alerts or misunderstandings by the proctoring system regarding your behavior?	3.8
13	Did the proctoring system successfully identify and prevent any cheating attempts as far as you know?	4.2

A relatively high score of 4.2 on question 5 indicates that students generally felt comfortable with the level of surveillance during the exam. This comfort level suggests that the proctoring system's design, transparency, or unobtrusive nature likely contributed to a positive perception. Students may have perceived the monitoring as necessary for maintaining integrity, and it appears that this monitoring did not excessively impact their sense of privacy. With a slightly lower score of 3.8 on question 6, some students expressed moderate concerns about data collection and its usage or storage. This score suggests that while students accepted surveillance during the exam, there may still be underlying apprehensions regarding how their data is handled post-exam. Addressing these concerns, such as by reinforcing transparency about data use, could further alleviate student reservations. A near-perfect score of 4.9 on question 7 shows that students felt well-informed about the data privacy policy. This high score reflects that the proctoring system or institution took effective steps to educate students on privacy practices, which likely contributed to their overall comfort. It underscores the importance of clear communication and transparency regarding data handling, a critical factor in fostering trust in proctoring systems.

An average score of 1.6 on the question 8, suggests that the proctoring system had a minimal impact on students' concentration during the exam. This low score implies that most students felt the proctoring system did not distract or hinder their focus, which is a positive indication of the system's unobtrusiveness. A non-intrusive proctoring environment is crucial, as it allows students to remain focused on their tasks without feeling overly monitored or stressed by the system's presence. This minimal perceived impact may indicate that the proctoring system operates quietly in the background and does not involve frequent prompts, notifications, or invasive checks that could otherwise disrupt students' attention.

With a score of 3.2 on question 9, students experienced a moderate level of stress or anxiety due to the proctoring system during the exam. This indicates that, while the system may not have been overwhelmingly anxiety-inducing, it did cause some degree of discomfort. This could be due to factors like the awareness of constant monitoring, which may have heightened students' self-consciousness or concern about being misunderstood by the system. To reduce stress, adjustments like providing familiarization sessions or incorporating a less intrusive setup could be considered. A score of 3.5 on question 10 reflects a moderate level of confidence in the fairness and objectivity of the proctoring system. While some students likely trusted the system to monitor them fairly, others may have been unsure, potentially due to concerns about misinterpretation of actions or potential biases in the technology. This score suggests that while fairness was generally accepted, there is room for improvement. Increased transparency about how the system detects and evaluates student actions, along with safeguards to ensure impartiality, may enhance perceptions of fairness. A score of 4.6 on the question 11 regarding the convenience and flexibility of online exams indicates a very high level of satisfaction among students. This suggests that students greatly appreciate the adaptability and ease that online exams provide, likely valuing the ability to test the codes and preview results and avoid spelling or syntax errors. A score of 3.8 for the question 12 about false alerts or misunderstandings indicates a moderate level of concern among students regarding the accuracy of the proctoring system. While it suggests that the system generally performed well, occasional misinterpretations of student behavior may have occurred, potentially leading to a few unwarranted alerts. On the other hand, a score of 4.2 for the question 13 about the system's ability to identify and prevent cheating attempts reflects a high level of confidence in the effectiveness of the proctoring system. Students generally feel that the system is successful in monitoring exam integrity, which suggests they trust its role in ensuring fairness. This positive response indicates that, despite some minor issues with false alerts, the proctoring system is perceived as effective in fulfilling its main purpose of preventing cheating, contributing to a more secure and trustworthy exam environment.

By centering student experiences and perspectives, this research aspires to contribute to a more holistic, empathetic, and strategically informed approach to digital assessment in contemporary educational landscapes.

5 Conclusion

Based on the evaluation of the online proctoring system, several key recommendations can be drawn for the development and enhancement of future proctoring systems, ensuring they are both effective and user-friendly. It is crucial that users are clearly informed about how their data will be collected, stored, and used. Providing transparent privacy policies and clear communication about data handling practices is essential in building trust with users. Systems that offer easy access to privacy-related information and ensure compliance with data protection regulations (e.g., GDPR) will foster a more secure and trustworthy environment for students. Although the system was generally perceived as minimally stressful, it is important to design proctoring systems that limit any potential anxiety associated with surveillance. Offering students reassurance through transparent communication about the purpose and fairness of the monitoring system, as well as providing an option for students to ask questions or seek clarification, can help reduce feelings of unease. False alerts and misunderstandings by the system can cause unnecessary distractions for students. Proctoring systems must be equipped with highly accurate algorithms to differentiate between legitimate behavior and potential violations, ensuring that the monitoring process is as seamless and error-free as possible. Regular updates and training of AI models can help to improve accuracy and reduce false positives. Maintaining fairness in the proctoring process is vital. Students should feel confident that the system is unbiased and equally effective for all exam-takers, regardless of their backgrounds. It is important to implement regular checks and balances to ensure that monitoring does not disproportionately target certain groups of students or introduce any form of bias. Proctoring systems should be designed with flexibility in mind, allowing students to take exams with minimal interference while ensuring integrity. High system availability, low resource usage, and easy integration with existing learning management platforms can enhance the overall user experience. Additionally, providing users with control over minor preferences and offering support channels for technical issues will further improve satisfaction. It is essential to continuously assess the effectiveness of proctoring systems through user feedback and performance data. Regular monitoring and updates based on real-world user experiences will help to fine-tune the system, address emerging challenges, and improve its overall reliability over time.

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