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Analysis and challenges of robust E-exams performance under COVID-19

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A B S T R A C T

Nowadays under COVID 2019, e-learning has become a potential prop approach of technology in education that provides contemporary learners with authentic knowledge acquisitions. As a practical contribution, electronic examination (e-exam) is a novel approach in e-learning designed to solve traditional examination issues. It is a combination of assorted questions designed by specialized software to detect an individual’s performance. Despite intensive research in this area, the performance of e-exams faces challenges such as authentication of the examinee’s identity and answered papers. This paper aims to present the experiences of educational organizations in e-exam and e-evaluation as an essential tool of e-learning in various countries. The paper recommends that under the global pandemic COVID 2019 evaluating students using intensive continuous evaluation, including e-exam supported by authentication methods, which may help detect and reduce or even prevent student violations. The results show that the most used LMS tools were the Moodle and proprietary solutions which were 75\% both among many other LMS tools i.e., Blackboard and eFront. The least develop countries are prefer to use open source and proprietary due to the zero cost of these solutions. The internet speed, cost and authenticity were the most challenges faced e-exams centers, which were 99\%, 82\%, and 68\%, respectively.

I n t r o d u c t i o n

E-learning is a promising approach in education that is capable of effectively conveying knowledge to learners. It relies on the use of modern means of communication, including computers, computer networks, multimedia, audio-visual aids, graphics, handheld mobile devices, search engines, and online e-libraries [1]. Therefore, e-learning means using all kinds of technologies to convey knowledge with efficient interaction between teachers and learners to achieve maximum benefit in a short time and with less effort [2–6] (Fig. 1).

In response to this growing exchange of data, education systems (mainly during the pandemic COVID-19) have followed new methods of delivering distance education in millions of schools and higher education institutes. Many researchers expecting that the education after COVID-19 will never return to conventional education as it was before.

A curriculum change to e-learning involves many steps, including academic content preparation, lecturing plan creation, a grouping of targeted students, learning process management, student assessment, report compilation, and statistics collection. This means e-learning requires the utilization of new forms of data to support administrative and organizational positions, prompting the necessity for new trends in compiling student and teacher data. This new system will open a wide range of educational options to students. It is an extensive change, from the classical concentric organization of school and class to a new, open form of education, and depends mainly on the learner and the desire of the teacher, wherever he/she is [7,8].

In general, assessment is a fundamental stage in education. so, educators are concerned with finding a reliable and appropriate method of assessment using techniques of e-learning in the layout and distribution of examinations to students worldwide. The method must ensure credibility and transparency [9]; indeed, this will facilitate interactions between students and teachers while offering a tool for continuous assessment. The results of such interaction may elevate academic achievement (including the learning outcomes of the course, such as knowledge, cognition, interpersonal skills, responsibility, communication, and information technology skills).

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An e-exam is a combination of assorted questions including multiple-choice, true or false, matching, arrangement, fill in the blank, essays, etc. It is designed by specialized software to detect the performance of an individual in all relevant aspects. It must be noted that there is a difference between an e-exam and a computer-based assessment (CBA), which depends on using a special kind of software without being connected to any network [10]. On the other hand, network-based assessment (NBA) depends on using internet techniques such as a remote exam network, taking into consideration the range of its coverage. Researchers in this field have provided solutions for a loss of connection that occurs during the test; the Time-Adaptive for Mobile E-Exam (TAMEx) model is designed to improve the availability of an e-exam carried out over a wireless network, especially a WLAN IEEE.802.11. This model automatically provides additional time to make up for the duration of the connection interruption during a particular exam that experienced a loss of connection [11].

The remainder of this paper is organized as follows. Section 2 reveals the merits and challenges of e-exams. In section 3, challenges faced when designing e-exams are explained. Section 4 covers the experiences of countries in applying the electronic exam, including the most prominent challenges they faced and how these were solved. We discuss the results and conclude our work in section 5.

### Merits and challenges of e-exams

When COVID 2019 is spread all over the world in early 2020, fortunately, many new technologies have been serving education consistently and helping faculties improve the teaching-learning process. Technology is also used nowadays for assessment purposes. Fortunately, the e-exam has benefited in the 21st century since test-takers are used to seeing and using new technologies. Their daily usage of smartphones and other computerized systems makes the execution of such exams easier for them. Moreover, the technology minimizes expenses for complex elements of the testing cycle, renders scoring immediate, ensures more accurate marking than that done by humans, avoids biased scoring related to handwriting and student identity, and lessens the impact of student spelling errors.

Due to the dramatic development of technology, problems with e-exams have dramatically decreased. However, there are still possible drawbacks that this system might face, such as interoperability, which may challenge the reliability of students’ answers; a need for adequate facilities; testing security (cheating prevention); a need for back-up in case of unexpected problems; and limitations in student/user technological skills. These problems have occurred during the examination and remain the focus of further studies aimed at prevention.

Many studies indicate that e-exam is widely accepted among students and has a positive effect on the assessment of faculties, in addition to increasing the number of students supervised by a faculty member. Studies by Natt [12], Masei [13], and Martin [14] stated that a large number of medical students are in favor of e-exam and believe that this kind of assessment is objective and has a high-quality standard. Shun-dong [15] asserted in his study that there is a general desire for the adoption of e-exam throughout the US and that it might become the essential tool of assessment shortly.

This desire depends on many studies, such as that of Johnson [16], which stated that students who took e-exams achieved high academic scores. The desire for the adoption of e-exam is not confined to developed nations only; even West African countries are planning to introduce it in their educational systems. In Nigeria, a multiple-choice e-exam has been implemented in universities and schools [17], and the West African Council of Examination has already put it into practice [18].

### The challenges of e-exam design

After being prepared and properly formulated and thoroughly revised, the examination will be ready for answers by students. Before the examination, all necessary student data is fed into the computer for later use, and this is why it is essential to use appropriate and high-quality software [19]. E-exam enables the provision of new kinds of questions through the use of multimedia, easy ways to gather feedback, instant support, assistance, and aids during the examination, distribution of results, easy use of data, and flexibility of examination timing. Moreover, it is easy to prepare equivalent forms of examination at one or various times for a large number of people/examinees in different places and to submit them by mail or through websites.

E-exam gives immediate results after all questions are completed and can provide a direct analysis of examination performance for a group of people/examinees. A question bank can be established to form a source of selection for future examinations. It is a low-cost method in terms of work, time, and money [20]. Additionally, e-exam allows for monitoring students from the examiner’s computer during the examination, entering students’ particulars before starting, printing or saving a direct report to a student, preserving equality between students, assessing students accurately, attaching video or audio clips to questions and specifying a time for examination [14,21].

### Categories of E-exams

E-Exams can be categorized into three types: diagnostic, formative, and summative test [22,23]. A diagnostic test is given before the lesson proper to assess students’ prior knowledge. A formative test is given during the discussion to identify whether further discussion or revision is needed. A summative test is given after the course to define the student’s grade. Currently, e-exams are usually given at the end of the course.

### Outlying E-exams

There are many types of questions in the e-exam that has been exercised during COVID 2019, including multiple-choice, sequencing, matching, true or false, fill-in-the-blank, and identification [15,24]. It is worth mentioning that many factors affect the layout of an e-exam, such as the objective of the educational stage, the specialty of the learners, skills of the learners, the purpose of the examination, and forms of electronic assessment.

### Compatible operating facilities

Indeed, there are four overlapping requirements of e-exam. These requirements are a learner of examination and topics, a software package, electronic display sets, and a fully equipped facility. Fig. 2 depicts these requirements.
When preparing for an e-exam, the following elements should be considered: the purpose of the examination, table of examination specifications and wording, determination of examination date, and communication of this date to students with sufficient time. It is essential to consider accuracy when formulating questions and answers to ensure fairness and transparency and to determine the right answer, time, and several trials for each question with random mixing of answers. Technically, clear and appropriate questions, provision of support, and a clear display of questions and answers on the screen should be considered. Also, the introduction of a timer and audio alert for the beginning and end of the examination must be checked and secured.

An e-exam passes through several developmental phases, including both theoretical and practical aspects. On the one hand, its theoretical aspects consist of underlying concepts of examination; general and special objectives of examination; and its building blocks, the properties of various examination sections, and the theoretical and technical principles of question formulation. On the other hand, its practical training phase may cover demonstration and discussion of all types of questions. To consolidate theoretical concepts and technical specifications, both group training in writing questions that represent all sections of the examination and individual question writing (outside workshop) are offered.

**Review of the challenges of E-exams and the trials of certain countries**

No doubt, e-exams facilitate the process of evaluating student capabilities. They help both administrative staff and students to shorten the time spent preparing and managing the exam period. However, challenges still face administrations attempting to improve authentication for e-exams. Our review has a twofold objective: first, we shed light on the experiences and trials of e-exam system implementation in several countries, both developed and developing. Second, we reveal new studies to try to solve the challenges of the electronic exam.

The School of Business Administration of Athabasca University in Canada has developed an e-exam system that relies on Lotus Notes [27]. The system is designed to automate the processes of examination, correction, and information/results storage in a database dedicated for this purpose. To maintain the security and confidentiality of the examination, access to exams and results is allowed only during the period of examination and not throughout the semester. Also, information about all activities about the examination and the results is placed in one database. The biggest problem with this system is confirmation of student identities and monitoring difficulties, as many students are taking the examination from all over the world. In the European trial, British Open University uses the internet regularly to transmit homework and other materials between students, instructors, and the university [28,29]. Homework, which is corrected by the instructor or lecturer, is an essential part of the university’s assessment system. Moreover, all study programmers include a three-hour closed-book examination performed under the supervision of an invigilator. The university’s goal is to have a fully automated examination process. This study discussed two trials of e-exam in distance education. The first trial was implemented in 1997 when students took a monitored examination. Answered papers and students’ results were transferred between the university and the examination location using the internet.

In this trial, students used an ordinary word processor to write their answers, which were then encrypted and securely sent online by an invigilator at the end of the examination [30]. The second trial was performed in 1999 when students sat for an online mock exam as part of a subject revision. It was a trial designed to test the technical possibility of preparing an at-home examination without surveillance. The students accessed the examination paper through an internet website and delivered their answers in the same way. These trials indicated the ease of taking a traditional examination electronically. Principally, they are cost-effective and can be taken from the home. Furthermore, to most students, it is a positive experience to take an exam from home.

Carswell et al [31] stated that all their studies of examination focused on the free-text-entry style answer rather than multiple-choice and fill-in-the-blank, which are regularly used.

In the United States, many universities have been using online examinations, such as the Massachusetts Institute of Technology (MIT), Stanford, and Berkeley. These institutions offer Massive Open Online Courses (MOOCs), which offer online courses and examinations [32]. Another study of the development and implementation process of e-exams in a blended-learning engineering study program was executed at Aschaffenburg University of Applied Sciences [33]. This institution has consistently seen good results and continuously proves that the use of technology and computers can be a great tool to assess students’ performance. However, controversy continues because the examination is not conducted inside a monitored classroom.

The University of King Abdul Aziz was the first university in the Middle East to implement this system of examination. The university conducted training courses for the faculties covering modern trends in the examination, assessment, preparation of e-exams, faculty guidance about how to measure and assess students scientifically, proper ways to formulate examinations, and studies of examination programmers prepared by the department overseeing distance examination [34,35]. The experience of King Abdul Aziz University with e-exam has contributed to the achievement of significant educational benefits, including the elimination of forgery and cheating. Besides, it established fairness of opportunities to achieve excellence among students regarding difficulty or ease of the questions, giving students a chance to focus on the subject matter. The university surveyed students in the colleges of medicine and science, with participation by 400 students in total. The survey reflected a high percentage of satisfaction with most of the questions regarding acceptance of generalization of e-exam to all university examinations, display of results immediately after test completion, and facilitation of answer revision [35].

In Sudan, many universities and colleges have started using e-exam, such as the Academy of Medical Sciences and Technology, the new Ph.D. programmers of the Sudan University of Science and Technology and Medicine College, and some Literary Colleges of Neelain University. Neelain University has proven successful at applying e-exams and has benefited from its advantages. There, 100,000 students sit for the final exam and answer the questions using iPads; this exam takes place in closed classrooms. The experiment has successfully reduced cheating, and the benefits of the e-exam for electronic correction and the speed of issuing the results are apparent, especially with a large number of students. Now the Ministry of Education in Sudan is seeking to submit a question bank to pave the way for future implementation of e-exams for final examinations [36].

Research in Nigeria was conducted in a few universities using e-exam. Some of these universities are using internet while others, such as the Federal University of Technology Minna (FUTMINNA), University of Ilorin, Covenant University of Ota, and the University of Nigeria (NOUN), are using the internet. Particularly, more than 100 students were interviewed regarding their acceptance of the system. The interviews indicated that 40 students accepted the system, 77 stated that it needs improvement and 7 students were indifferent. The research showed that there are still challenges to the new system, such as security and human interference. The solution being formulated is the...
use of biometric fingerprint authentication that will recognize students taking encrypted examinations and ensure that questions remain unchanged after being submitted by the professor [37,38]. Recently study in certain Nigerian Universities indicated that psychological distress factors have been considered in preparing E-Exam [39].

The second part of this review will be devoted to the new studies attempting to solve the challenges of e-exams. Indeed, despite intensive efforts by researchers to solve the problems involved in designing and taking electronic exams, the main problems with e-exams still result from authentication and cheating. Recent studies of this trend have proposed methods that can offer means of authentication when taking e-exams. In [40], researchers modified some protocols to solve these problems. Another study [41] suggested that all information on the exam should be in digital format; it proposed that a cryptographic scheme be implemented to achieve the required security levels at each exam stage.

In [18] presented Creating a new e-Exam stage to improve the college scholastic examinations: the case of Lebanese French College, a Data Flow Diagram (DFD) may be a graphical representation of capacities performed by a framework, the information stream among the capacities, and the relationship between the substances. Fig. 3 presents the information stream chart for our created e-Exam stage and Fig. 4 shows the results of students/staff satisfaction questionnaire.

On the other hand, the authors in [42] proposed a multimodal biometric framework; this framework provides the Exam Shield platform, which includes live video streaming, recording of exam environments, and essential exam management services. Another framework for a secure online examination system is designed in [43]; the authors in this work designed a web page and network that uses a firewall in the server and a proxy in the client system. By these means or others, examiners can guarantee the security of the online examination system against both malicious individuals and cheating examinees.

Moreover, an enhanced secure online exam management environment was proposed in [44]; the main functions of this system are to prevent and detect cheating using e-monitoring. The recent developments in face recognition technology may offer an effective solution to this problem in the future [44,45]. The study proposed by [46] to try solving the problem of cheating during online exams; their method is based on online protocols and continuous authentication. The research came up with solutions to detect and prevent cheating such as using a fingerprint authenticator and an Eye Tribe tracker during the examination. Total time-out screens and the number of times a computer was on a time-out screen can also identify whether the student is cheating or not [47]. Table 1 reveals a comparison study of experiments in countries that attempted to solve the problems of e-exams.

### Results and analysis of the studies

In considering all these trials, we can easily conclude that the real experiences are those of Canadian, British and American Universities; this is due to widespread participation in distance education and the vast dispersion of students all over the world. However, there is a question of reliability regarding student’s answers and identities, which constitutes a core challenge of open e-exam. Regarding the experiences of some trials, such as those of King Abdul Aziz University and Neelain University [48], those universities used e-exam in a closed system of rooms, which helped them control the problem of cheating that occurs in the traditional examination. This is definite merit of e-exam in a confined environment. In this way, the universities benefited from e-exam by increasing academic attainment through repetition of exams and by promoting continuous communication with the faculty.

New technologies have been added at some universities to solve the challenges of e-exam authentication. These technologies include browser software, fingerprint authenticators and Eye Tribe trackers, a multimodal biometric framework and Data Guard, and WEB application server load balancing. Despite these efforts, we can say that e-exam authentication will remain a partially unresolved issue.

As a result of a data survey for 120 different e-exam centers around Khartoum, the survey shows that there was a challenge of almost all the requirements. Especially in the learner of the examination.

A learning management system (LMS) is a computer program application for the organization, documentation, following, announcing, robotization and conveyance of instructive courses, preparing programs, or learning and improvement programs [1]. The learning administration system concept developed specifically from e-Learning. In spite of the fact that the primary LMS showed up within the higher instruction segment, the larger part of the LMSs nowadays center on the corporate market. Learning Administration Frameworks make up the largest section of the learning framework advertise. The primary presentation of the LMS was within the late 1990s [49].

Learning administration frameworks were planned to distinguish preparing and learning holes, utilizing expository information and detailing. LMSs are centered on online learning conveyance but bolster a run of employments, acting as a stage for online substance, counting courses, both nonconcurrent based and synchronous based. An LMS may offer classroom administration for instructor-led preparing or a flipped classroom, utilized in higher instruction, but not within the corporate space. Cutting edge LMSs include brilliant calculations to create mechanized suggestions for courses based on a user’s expertise profile as well as extricate meta-data from learning materials in arrange to create such suggestions indeed more precisely.

Fig. 5 illustrates the percentages of each requirement. Technological improvements of learning management systems (LMSs) that are used for distance and electronics education platforms and systems such Blackboard, Moodle, ATutor, Claroline, Dokes, Desire2Learn (D2L), eFront, OLAT, etc., have been a driving force yielding new delivery methods. Among the others, Blackboard and Moodle are the two most well-known web-based LMSs increasingly being used in institutes, schools, and higher education platforms. These new learning methods used to deliver distance learning (DL) are thriving dramatically in different learning programs, and leading researchers and experts to expect that the

![Fig. 3. The model of e-Exam platform.](image-url)
conventional face to face (F2F) based model of education, in the form of students attending classes at predefined times and space, would dissolve shortly. These techniques are rapidly progressing with various forms of DL in concept, practice, and experience from anywhere, to an anytime, to any mode delivery method convenience with an instructor as well as the learners. Fig. 6 shows the most available platforms in the surveyed 120 centers. Some of the centers are preferred to use proprietary and custom-made e-exam platforms, which are software packages that have been locally developed. The main advantage of these packages it giving you exactly the functions and are fully adapted to meet the stakeholder’s need with a high level of authenticity and security that may not be ensured in the ready-made standard LMSs.

Although by end of 2020 the internet [40] penetration should exceed 50% of the global population, there is a need for greater broadband connectivity and telecommunication services in communities, rural and remote areas that are underserved. The distance learning and e-exam would work properly in urban areas and rich cities due to high Internet penetration. To cope with the special requirements of e-exam methods for students living in rural communities, the Internet needs to operate in acceptable quality. Fig. 7 shows some of the challenges faced the centers
for conducting e-exams.

Conclusion

The increase in implementation of e-education during COVID – 2019 has resulted in the invention and generalization of various methods of assessment. Indeed, the system of e-exam is a valid method of evaluation due to its continuous availability and interactivity through the internet. In this paper, various studies indicated the positive effects of continuous electronic assessment on academic attainment. The combination of an electronic system and a closed system of assessment implemented by King Abdul Aziz University is worth studying from April to June 2020 in the mid waves of COVID 2019. This is because of its effect of increasing student attainment and solution to the problem of cheating on examinations in close systems. As well, the experiences of the Sudanese College of Medicine are similar to those of King Abdul Aziz University, joining closed education with a closed assessment to use e-exam for continuous assessment.

The studies from these various universities show that technology is worth using, but that there are still some challenges. This paper suggests conducting the exam inside a closed environment if necessary, only for final exams during the final year. Otherwise, intensive continuous e-exams supported by all available authentication algorithms in place of final exams may be a good solution to this dilemma. The results show that the internet speed, cost and authenticity were the most challenges faced e-exams centers, which were 99%, 82%, and 68%, respectively. More studies comparing the final results of students’ evaluation using this solution and the closed environment solution are needed. The use of facial recognition technology may be accepted as a secure means of e-exam authentication in the future.

CRediT authorship contribution statement

Fatima Rayan Awad Ahmed: Conceptualization, Investigation, Resources, Software, Visualization, Writing - review & editing. Thowiba E. Ahmed: Conceptualization, Project administration, Resources, Visualization, Writing - review & editing. Rashid A. Saeed: Data curation, Investigation, Software, Validation, Writing - review & editing. Hesham Alhumaydi: Data curation, Funding acquisition, Project administration, Validation, Writing - review & editing. S. Abdel-Khalek: Formal analysis, Methodology, Supervision, Writing - original draft, Writing - review & editing. Hanaa Abu-Zinadah: Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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