The state of e-learning in radiology colleges during the COVID-19 pandemic and its future prospects

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ABSTRACT

This study evaluates the existing electronic learning (e-learning) infrastructure in Sudanese academic institutions that offer radiology education during the COVID-19 pandemic with the aim of understanding the extent and effectiveness of e-learning. By employing a descriptive cross-sectional survey from April to August 2021, data was gathered from undergraduate and postgraduate students enrolled in both public and private radiology educational institutions across Sudan. The questionnaire, created in Google Forms and distributed via email, WhatsApp, and Facebook, captured insights into the students' experiences and challenges with e-learning. The findings revealed that power outages and poor internet access were significant barriers, affecting 50% and 27% of respondents, respectively. While 33% of participants were satisfied with e-learning as a pedagogical strategy, 29% believed it hindered the achievement of educational goals. Furthermore, 78% of the respondents felt that e-learning was not suited to all medical specializations, although 46.6% supported the idea of integrating e-learning with traditional classroom instruction. Despite the adoption of e-learning due to the pandemic, students exhibited a preference for the conventional classroom setting, primarily due to challenges related to internet accessibility and the availability of the necessary technological resources. Significant infrastructure improvements and strategic planning are required to maximize the benefits of e-learning in resource-constrained countries.

Contribution/Originality: This study is the first to comprehensively evaluate the e-learning infrastructure and its associated challenges in radiology colleges and education across Sudan during the COVID-19 pandemic. It shows the significant barriers that this teaching model has faced and suggests targeted infrastructure improvements and a blended learning approach.

1. INTRODUCTION

The COVID-19 pandemic, caused by a newly identified strain of coronavirus, originated in China in December 2019 and rapidly spread around the globe in a matter of months. As of January 2021, the global incidence of COVID-19 was estimated to have affected around 94 million individuals and causing almost two million deaths. The use of social distancing measures aimed at curbing the transmission of the virus resulted in significant disruption to traditional classroom-based education. The rapid advancement of digital transformation in the field of education necessitated the implementation of suitable technology, educational materials, and human and infrastructural resources as substitutes for conventional classroom-based instructional methods. Several educational institutions made revisions to their curriculum to accommodate this rising trend; however, some institutions encountered difficulties (Kumar & Rathi, 2020; Rizvi, 2020). E-learning encompasses the utilization of internet-based platforms, computer systems, and mobile devices as tools for educational purposes and personal advancement. The utilization of audiovisual materials in e-learning facilitates the provision of instructional content, assessment techniques, pertinent critical knowledge, and, notably, an engaging interactive setting. The utilization of e-learning resources was found to be more accessible in industrialized nations, whereas low- and middle-income countries faced challenges due to inadequate infrastructure and limited teaching expertise. The educational processes of students in low- and middle-income countries, particularly in Africa, were impeded (Masic, 2008; Olum et al., 2020).

The virus outbreak in Sudan was characterized by a complex environment, mostly attributable to the concurrent presence of natural disasters, political tensions, and unfavorable economic and health conditions, which were further exacerbated by the presence of a new transitional government. The first reported case of COVID-19 in Sudan was identified on March 13, 2020. On March 16, 2020, a health emergency was officially declared by the government, leading to the subsequent closure of educational institutions in April of the same year. Sudanese universities had not yet used e-learning systems, in contrast to other nations (Huang et al., 2020; Mohammed Elhadi et al., 2020; Zhang, Liu, Liu, Huang, & Liu, 2019).

1.1. Research Questions

The research questions below were formulated for this study:

1. What was the state of e-learning infrastructure in radiology education across Sudanese academic institutions during the COVID-19 pandemic?
2. What were the main challenges faced by students and educators in the adoption of e-learning?
3. How did students and educators perceive the impact of e-learning in achieving educational goals in radiology?

1.2. Significance of the Research

This research is significant as it provides a detailed examination of the adaptability and challenges of e-learning in resource-constrained environments, such as Sudan, where educational systems face unique pressures. It is imperative to assess the perspectives of pupils during this temporal interval about the caliber of pedagogy they experienced and the assessments they were subjected to in order to comprehend the present predicament more comprehensively and formulate strategies for its amelioration. Understanding these aspects is crucial for developing strategies that enhance educational outcomes and supporting the integration of technology in education, particularly in medical fields that traditionally rely heavily on in-person instruction. The findings can offer insights for policymakers and educational leaders to improve e-learning frameworks and infrastructure, not only in Sudan but also in similar contexts globally.

2. LITERATURE REVIEW

The pandemic forced numerous institutions to transition their learning modalities from conventional classroom

learning to complex e-learning methods, testing their resilience and technical capabilities. It has been apparent that the use of e-learning modalities as an appropriate solution to sustain the education process has its pros and cons and presents issues and disparities in terms of access and the efficiency of learning among students (Gonzalez Ortega, Villalta Mendoza, Alcivar Rodríguez, Piedra Arpi, & Salamea Guevara, 2022).

Archana and Sangeetha's survey of online medical students mentioned that e-learning might be as effective as conventional learning in enhancing knowledge and functionality related to a particular subject, but it lacks those components that are imperative in the process of medical training, such as clinical session practice and interpersonal communication (Archana & Sangeetha, 2023). While presenting the effectiveness of e-learning, this study also reveals that along with theoretical knowledge, e-learning fails to impart adequate practical knowledge or training which could be considered a prerequisite to prepare experienced IT professionals. In the same context, Gonzalez Ortega et al. (2022) carried out a cross-sectional review of scientific literature to understand the influence of e-learning in health sciences education during the pandemic. They discovered that while e-learning was efficient in its delivery of educational services during the pandemic, it brought several benefits and drawbacks that were instrumental in modifying the learning process. This study further raised the necessity for policies that check these difficulties and support the e-learning process to improve student experience (Gonzalez Ortega et al., 2022).

There is a peculiar attitude toward e-learning, which Bista et al. acknowledged. On the one hand, it is convenient and provides access to numerous materials, but on the other hand, practical experience is diminished, and the students' engagement might also be problematic. The educational platforms used for e-learning in radiology lessons mainly depends on how closely the program replicates a clinical environment and how engaging and interactive the content is since the students are not physically present in a typical radiology lab or class (Bista, Basnyat, Ranjit, & Subedi, 2021).

Blended learning, which involves the use of in-depth, interactive, and student-centered learning approaches, includes the use of inverted classroom and educational games and has proved successful in increasing the level of satisfaction with the learning process. De Almeida, Da Silva, Da Costa Vicente, Abrantes, and Azevedo (2022) examine the applicability of such methodologies in European medical imaging education, where conventional lecturing practices are being replaced with interactive blended learning approaches. In addition to reinforcing the learning process with more learner engagement, these strategies could also help develop problem-solving skills that are important in medical imaging professions (De Almeida et al., 2022).

In an observational study of e-learning in a medical college, Xiberta, Boada, Thió-Henestrosa, Pedraza, and Pineda (2022) outlined the importance of understanding the practicality of e-learning through various approaches. They observed that, on the one hand, e-learning enabled students to gain knowledge and self-learning experience, but on the other hand, it was inadequate in clinical practical training and assessments. Their study also stressed the need for institutions to increase investment in infrastructure and training to fully utilize the power and potential of e-learning (Xiberta et al., 2022).

A study conducted by Chunkhare and Jadhav (2023) focuses on the psychological and technical barriers from the views of students and instructors. They said that due to the transition to online learning, there are pressures and anxieties among students, not to mention the low general technological literacy among both the students and the faculty members. These factors hindered the adoption process and the subsequent implementation of e-learning frameworks (Chunkhare & Jadhav, 2023).

A comparative analysis of these studies highlights a common theme: The need for medical colleges to progressively integrate blended and e-learning into their training methods. Applying this hybrid model should be geared toward improving interactivity and the technological support offered and developing a curriculum that will combine theoretical knowledge and practical training. This approach is not only required to overcome the challenges generated by the past global pandemic, but it also aims to prepare and strengthen the medical education system for future disruptions and to ensure uninterrupted training for the healthcare workers.

The above studies highlight the need to enhance e-learning in preparation for future trends in medical education. The introduction of e-learning platforms happened quickly, resulting in deficiencies in terms of infrastructure, availability for students, and overall education, especially in the medical field (Darras et al., 2021). Moreover, the reviewed challenges remain valid, which further asserts the need for educational institutions to factor in these issues when formulating their long-term strategic plans. For example, Gonzalez Ortega et al. (2022) described e-learning as having positive and negative implications, stating that the use of digital technologies can efficiently support theoretical knowledge but might hinder clinical training, which requires interaction between people. Such insights are important for medical faculties as the colleges should aim to find the most appropriate and cost-effective technologies capable of simulating real-life medical environments more efficiently (Gonzalez Ortega et al., 2022).

The study by Xiberta et al. (2022) provides a framework for examining real-life issues regarding e-learning, which includes the need for reliable technological support and appropriate training for faculty members on modern e-learning platforms. Educators should also be trained on how to use the tools effectively to enhance the quality of the content delivered to students and the quality of the learning process, making it more engaging and stimulating. Furthermore, it is crucial not to overlook the psychosocial implications concerning the immediate shift to online learning or from one semester to the other, as highlighted by Chunkhare and Jadhav (2023). The stress experienced when having to adapt to new teaching methods of learning could impact the students greatly and have a negative effect on their scores and overall health. Providing a robust support structure, such as counseling and an education help desk, may help ease some of these pressures in improving student performance.

It should be noted that although the subject of e-learning implementation and difficulties in medical education during the COVID-19 outbreak has been covered broadly in scientific literature. However, this topic has not been discussed enough in the context of low-resource countries such as Sudan. Studies originating from developed countries may not be representative of the issues observed in developing countries, such sufficient IT-infrastructure and accessibility, generally available internet connections, and prerequisite educational systems for optimizing e-learning systems effectiveness. Furthermore, the unique socioeconomic and cultural characteristics of students have not received sufficient attention in the literature. This has led to a gap in the literature, and there is a call for focused studies on the effectiveness, needs, challenges, and requirements of e-learning, especially in medical education in low-resource settings. This type of research would help to understand the above-mentioned difficulties and create approaches which could be useful for the improvement of education.

3. METHODOLOGY

3.1. Research Design

This research adopted a descriptive cross-sectional survey design to assess the impact and effectiveness of e-learning and its related difficulties within the radiology programs during the COVID-19 pandemic across various universities in Sudan. This design was chosen for its ability to collect data from a large sample size at a given point in time in order to evaluate the current status of e-learning. The study protocol was approved by the Faculty of Radiology and Nuclear Medicine at the National Ribat University. All participants provided their consent and had the right to opt out of the study at any given time.

3.2. Research Population

The targeted research population consisted of undergraduate and postgraduate students enrolled in radiology programs at public and private colleges at the following Sudanese universities:
- College of Medical Radiological Sciences, Sudan University of Science and Technology.
- Faculty of Radiology and Nuclear Medicine Science, National Ribat University.
- Faculty of Radiological Sciences and Medical Imaging, Alzaiem Alazhari University.

- Faculty of Radiography and Medical Imaging, National University.
- Faculty of Radiological Sciences, University of Medical Sciences and Technology.
- Faculty of Radiography, Elrazi University.
- Radiology College, Karary University.

These institutions were selected from various parts of Sudan to ensure a representative sample across the country.

3.3. Instrument

A detailed questionnaire was used as the main instrument for data collection and the questions posed were of both a quantitative and a qualitative nature. The survey comprised four specific categories. The first part of the questionnaire consisted of demographic information questions, the second segment comprised questions regarding the e-learning tools used and their modes and availability, the third assessed the challenges faced while implementing e-learning facilities, and the fourth part focused on the participants' views and level of satisfaction regarding e-learning tools. Multiple choice and Likert scale questions were used for the quantitative part of the survey.

3.4. Validity and Reliability Tests

- Content Validity: The questionnaire developed for this study was carefully reviewed by a team of e-learning experts and professors of radiology who were believed to have adequate knowledge and experience in the fields of both e-learning and radiology education.
- Pilot Testing: To eliminate possible misunderstanding and ambiguous or deceptive questions, the questionnaire was pre-tested on a sample of 25 students from one of the participating universities. The questions used in the final survey were developed from this pilot.
- Reliability Testing: Finally, reliability was ascertained by establishing the internal consistency of the questions with the use of Cronbach's alpha coefficient, where the scores were reproducible for Likert-type questions, yielding an alpha of 0. The average was calculated to be 0.84, which underscore the study's reliability.

3.5. Data Collection

The study was conducted from April to August 2021, and the participants' answers were collected via a survey. The questionnaire was sent to students via e-mail and social media applications such as WhatsApp and Facebook.

3.6. Data Analysis

The data was exported from the survey platform to SPSS version 20 for statistical analysis and was summarized using descriptive statistics, such as means, frequency distributions, and standard deviations.

4. RESULTS

The researchers obtained a total of 435 replies before the closure of the poll on June 15, 2021. A significant proportion of the participants (269; 61.8%) were within the age range of 21 to 25, and 324 (74.5%) identified as female. A significant proportion of the participants (326; 74.9%) consisted of undergraduate students. According to the data presented in Table 1, the number of participants in the private radiology institution (231; 53.1%) was higher compared to the public radiology institution (204; 46.9%).

Table 1. Demographic information of the participants.

Characteristic	Frequency, percentage (%)
Gender	
Female	(324, 74.5%)
Male	(111, 25.5%)
Age (Years)	
15–20	(63, 14.5%)
21–25	(269, 61.8%)
26–30	(53, 12.2%)
31–35	(35, 8%)
36–40	(9.0, 2.1%)
41–45	(4.0, 0.9%)
46–50	(2.0, 0.5%)
Academic level	
B.Sc.	(326, 74.9%)
Higher diploma	(6.0, 1.4%)
M.Sc.	(89, 20.5%)
Ph.D.	(14, 3.2%)
Type of academic institution	
Public institution	(204, 46.9%)
Private institution	(231, 53.1%)

The present investigation revealed that personal computers (PCs), cell phones, and televisions were the predominant electronic devices utilized for online training and teaching in the field of radiological sciences during the COVID-19 pandemic. This information is presented in Table 2. Based on the findings shown in Table 3, a significant proportion of the study's participants engaged in online education during the COVID-19 pandemic. This was achieved through the utilization of electronic applications (apps) and platforms, television broadcasting, and social media. Figure 1 depicts the usage of different electronic platforms and apps, including Telegram, Zoom, Moodle, and WhatsApp, in the context of teaching and assessing radiological sciences during the pandemic in Sudan.

Table 2. Electronic devices utilized for online instruction and training in the field of radiological sciences during the COVID-19 pandemic.

Electronic devices used in e-learning	Frequency, percentage (%)
Computers	(30, 7.0%)
Computers and smartphones	(54, 12.4%)
Computers, smartphones, TV, and radio	(1.0, 0.2%)
Radio	(2.0, 0.5%)
Smartphones	(345, 79.3%)
Smartphones and TV	(1.0, 0.2%)
Smartphones, TV, and radio	(1.0, 0.2%)
TV	(1.0, 0.2%)

Table 3. Electronic platforms and apps utilized for teaching, training, and assessing students in the field of radiological sciences during the COVID-19 pandemic.

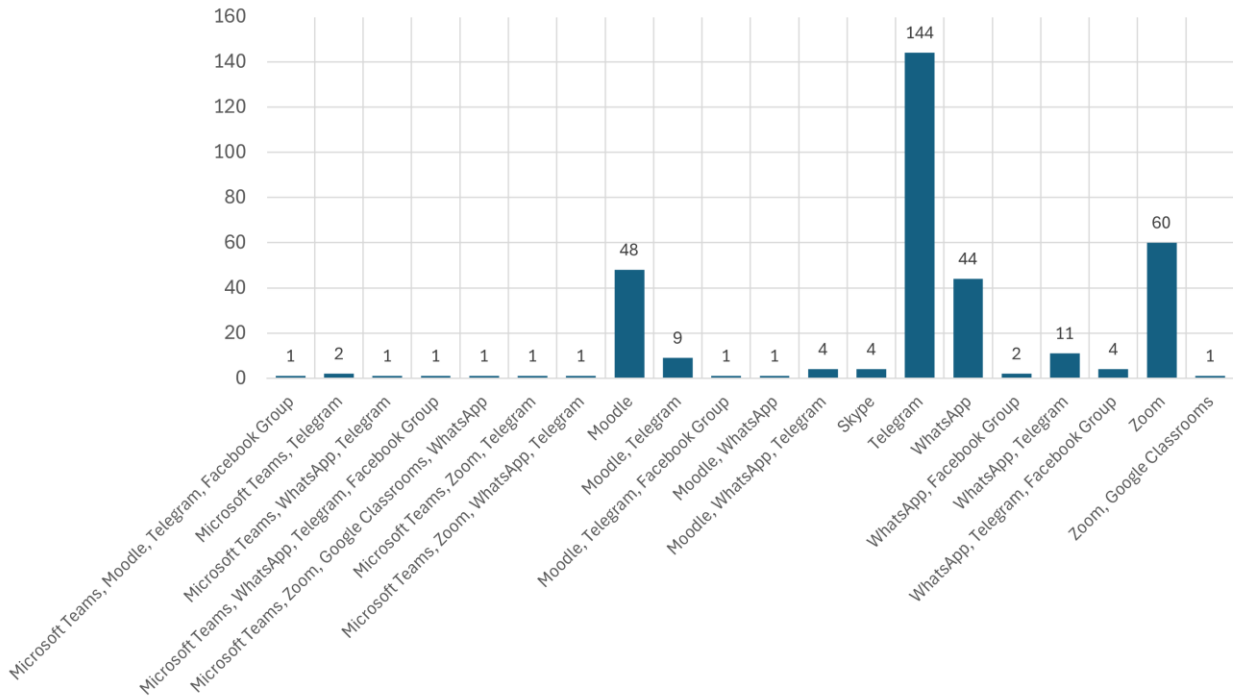| Electronic platforms and applications used	Frequency, percentage (%)
Electronic applications and platforms	(195, 44.8%)
Electronic applications, platforms, and papers	(1.0, 0.2%)
Electronic applications, platforms, and TV broadcasting	(1.0, 0.2%)
Electronic applications, platforms, and social media	(44, 10.1%)
Electronic applications, platforms, social media, and papers	(3.0, 0.7%)
Papers	(27, 6.2%)
Radio	(2.0, 0.5%)
Social media	(158, 36.3%)
TV broadcasting	(3.0, 0.7%)
TV broadcasting, social media, and papers	(1.0, 0.2%)

Figure 1. The electronic platforms and applications utilized in the teaching, training, and assessment of radiological sciences students in Sudan during the COVID-19 pandemic.

According to the findings presented in Table 4, the predominant obstacles faced in the context of online instruction, learning, and evaluation of radiological sciences students during the COVID-19 pandemic encompassed power interruptions, inadequate internet connectivity, and a dearth of electronic devices. The results revealed that a notable proportion of participants, specifically 126 individuals constituting 29% of the sample, perceived the attainment of educational objectives to be challenging when utilizing online education during the pandemic. Conversely, a comparable proportion of participants, specifically 120 individuals accounting for 28% of the sample, believed that online education facilitated the accomplishment of educational goals. According to the data shown in Table 5, a total of 61 participants, accounting for 13.9% of the sample, expressed satisfaction with the utilization of online education as a means of instruction and learning during the pandemic. Conversely, a majority of 340 participants, comprising 78.2% of the sample, held the belief that online education may not be suitable for all academic disciplines. Ultimately, a significant majority of the respondents, specifically 82 individuals, accounting for 68.3% of the total sample, expressed their endorsement of the prospective integration of traditional classroom instruction with online educational platforms.

Table 4. Challenges encountered in facilitating online teaching, learning, and assessment of radiological sciences students during the COVID-19 pandemic in Sudan.

Item	Frequency, percentage (%)
Electricity	(218, 50.1%)
Electricity and lack of electronic devices	(8.0, 1.8%)
Poor internet connectivity	(118, 27.1%)
Poor internet connectivity and electricity	(55, 12.6%)
Poor internet connectivity, electricity, and lack of electronic devices	(23, 5.3%)
Poor internet connectivity and lack of electronic devices	(1.0, 0.2%)
No response	(12, 3.0%)

Table 5. Perceptions of e-learning among participants from a radiological sciences institution in Sudan during the COVID-19 pandemic.

Questions and answers	Frequency, percentage (%)
How difficult is it to achieve educational goals through e-learning compared to classroom education?	
It has become more difficult	(126, 29%)
It has become easier	(120, 28%)
The situation is the same	(71, 16%)
Achieving goals is not possible through online education	(115, 26%)
No response	(3.0, 1.0%)
How satisfied are you with the use of e-learning in teaching?	
Very satisfied	(61, 13.9%)
Somewhat satisfied	(87, 20%)
Neither satisfied nor dissatisfied	(152, 35%)
Somewhat dissatisfied	(62, 14.1%)
Very dissatisfied	(73, 17%)
Is e-learning suitable for all academic disciplines of study?	
Suitable for all academic disciplines	(95, 21.8%)
Not suitable for all academic disciplines	(340, 78.2%)
How much do you agree or disagree with using e-learning and classroom education together in the future?	
Strongly agree	(141, 32.4%)
Agree	(4.0, 10.3%)
Neither agree nor disagree	(46, 10.6%)
Disagree	(84, 19.3%)
Strongly disagree	(119, 27.4%)

5. DISCUSSION

As a result of the imposed limitations on mobility and the implementation of social distancing measures, educational institutions were compelled to suspend their operations due to the pandemic. The abrupt cessation of operations caught numerous establishments off guard, particularly in poor nations that were hindered by the digital divide, resulting in a lack of e-learning standards (Bozkurt et al., 2023). The implementation of e-learning in educational institutions became necessary due to the unprecedented and protracted shutdown (Abbasi, Ayoob, Malik, & Memon, 2020; Bozkurt et al., 2023). Consequently, an evaluation of the influence of the pandemic on the field of radiology education was imperative. This assessment aimed to examine the unanticipated transition to e-learning approaches to effectively anticipate future events and address potential obstacles. Additionally, it sought to ascertain the feasibility of integrating this pedagogical, instructional, and evaluative approach for students studying radiological sciences alongside conventional classroom methodologies to optimize its advantages.

This research paper introduces a new sample collected from radiology students in Sudan (see Table 1) with the aim of examining the accessibility of e-learning resources (see Table 2, Table 3, and Figure 1), the attitudes of students toward e-learning, and the obstacles faced in implementing e-learning at Sudanese academic institutions specializing in radiology (see Table 4 and Table 5). The present study revealed that the participants employed a diverse range of electronic devices for e-learning, encompassing smartphone devices, personal computers, and television sets, among others (see Tables 2–5 and Figure 1). Abbasi et al. (2020) saw the same results in their study, where a majority of 345 out of 382 students (76%) utilized mobile devices for the purpose of e-learning. This phenomenon may be attributed to the heightened accessibility and cost-effectiveness of cell phones, hence enabling widespread online connectivity.

According to the findings, a significant proportion of the participants (50.1%) identified the primary obstacle encountered in implementing e-learning in Sudan during the pandemic as the insufficiency of electrical power supply (see Table 4). A study conducted among undergraduate medicine and nursing students in Uganda revealed that power outages accounted for 56% of the challenges encountered in online instruction (Rafi, Varghese, & Kuttichira, 2020). The digital divide in many developing nations has exacerbated the limited accessibility to educational resources, internet connectivity, and online learning platforms for families belonging to lower socioeconomic backgrounds. This elucidates the reason behind the internet issue as the second most prominent

obstacle faced by Sudan's online learning environment and learning resources throughout the pandemic (see Table 4). The aforementioned observation aligns with the research conducted by Rafi et al. (2020) in India, whereby they identified internet connectivity as a significant impediment to the utilization of e-learning platforms during the COVID-19 outbreak.

Educational platforms encompass a comprehensive array of interactive online services that offer instructors, students, and parents access to information, tools, and resources aimed at enhancing educational delivery and management (Basar, Mansor, Jamaludin, & Alias, 2021). Basar et al. (2021) suggested that primary platforms refer to those that are officially embraced by educators and learners within a well-organized academic framework, such as Microsoft Teams, Zoom, and Moodle (Basar et al., 2021). Conversely, secondary platforms are utilized by students and teachers in an informal and impromptu manner for supplementary instructional purposes and informal learning. A total of 195 students, accounting for 44.8% of the participants, utilize a principal platform in this research, as it serves as the designated learning management system endorsed by the universities (see Table 3). During the COVID-19 outbreak in the Philippines, a study conducted in a comparable context revealed that a significant majority of pupils (92%) utilized the primary platform available to them. The observed phenomenon may be attributed to the digital divide, as suggested in another study (Barrot, Llenares, & Del Rosario, 2021). Due to the prevailing socioeconomic conditions in Sudan, many academic institutions may face financial constraints in procuring primary online platforms for educational purposes. Additionally, the limited proficiency among students and faculty in utilizing these platforms further compounds the difficulties associated with their effective deployment and utilization. Consequently, there has been a shift in favor of secondary platforms, namely Facebook, Telegram, and WhatsApp. These platforms are predominantly free and offer a wide range of functionalities, including the transmission of large media files, such as PowerPoint presentations, videos, and photos. Additionally, they facilitate the creation of discussion groups for students and enable voice and video calls. Due to the aforementioned advantages and characteristics, a significant majority of students surveyed opted to utilize secondary channels to access online learning during the pandemic (see Table 4 and Table 5). The same findings were observed by Prokopyev, Kostikova, Kuzin, Ilina, and Tyagulskaya (2021).

A total of 126 participants, accounting for 29% of the sample, did not successfully attain their educational objectives via the utilization of e-learning in the context of this study (see Table 5). Similar findings were obtained in a prior investigation done in Uganda (Olum et al., 2020). This may be attributed to the predominant emphasis on theoretical content rather than practical components in online instructional materials for most online courses. The implementation of practical lessons in an e-learning environment poses greater challenges compared to the implementation of theoretical courses. The inclusion of practical lessons in an e-learning course requires a substantial increase in the level of premeditation, instructional designs, and simulated activities. Out of the overall sample, 120 participants (28%) expressed the belief that e-learning surpasses classroom education in terms of effectiveness for attaining educational objectives (see Table 5). The reason for this phenomenon is that the rate and rhythm of knowledge acquisition in online education are contingent upon the students themselves, in contrast to the traditional classroom setting where the instructor dictates the pace of instruction and learning. Lectures and conversations can be accessed in the form of multimedia content, such as videos and audio clips, which offer the convenience of being able to be watched/listened to, paused, and replayed multiple times according to the viewer's preference. Additionally, it offers students the advantage of having the opportunity to fully engage with course materials and allocate additional time to courses that they may see as challenging. The results obtained from the survey show that 340 participants (78.2%) held the belief that e-learning was not suitable for all academic fields (see Table 5). Medical professions, including medicine, surgery, radiography, and nursing, often require hands-on practical sessions in a laboratory, and bedside teaching that involves physical interactions with peers and faculty members. Similar findings were reported in previous studies (Elshami et al., 2021; Paechter, Maier, & Macher, 2010).

The survey found that a significant proportion of participants had a neutral stance regarding their level of satisfaction with e-learning, with a minority expressing dissatisfaction (see Table 5). Acknowledging the findings of previous studies by Elshami et al. (2021) and Wingo, Ivankova, and Moss (2017) 33% of the students were dissatisfied with the time it takes to obtain educational material from online sources. This has been observed to have a symbiotic relationship. While face-t0-face classes cater for attendance, group interaction and hands-on training, e-learning covers theory education and broader courses (Al-Balas et al., 2020; Olum et al., 2020). The results also revealed that a small number of participants endorsed the incorporation of e-learning within the traditional class setting. In contrast, in the study by Olum et al. (2020) more than three quarters of the students had a strong preference for the blended approach. The gap can therefore be explained by poor internet and communication infrastructure, which can be defined by a variety of factors including a lack of energy resources and power, low bandwidth internet connectivity, and a lack of electronic equipment, among others.

Considering these points collectively, e-learning could be an effective replacement during catastrophic times such as the COVID-19 pandemic. However, careful consideration must be given to the design of the curriculum to embrace synchronous and asynchronous modes of learning in addition to the establishment of technologies that support the setting of curricula in a hybrid environment and strategies used to facilitate engagement and support for students. As such, educational institutions should consider these aspects to enhance their preparedness for future teaching approaches. Such a strategy would not only help ensure the preservation of students' education in the case of pandemics, but also the overall improvement of the standards as well as the progress of the subsequent generation of medical professionals who can work effectively in both conventional and virtual environments.

One weakness of this study is its exclusive focus on radiology institutions in Sudan. It is suggested that future research endeavors on the implementation and reception of e-learning inside higher education establishments across Sudan should encompass a diverse range of participants from a wider range of universities. Furthermore, the study's scope could be expanded to encompass all supplementary participants engaged in the teaching and learning process, including teachers. This inclusion may unveil specific teacher-related variables that impact students' experiences with online learning. Given the nature of this cross-sectional study, it is important to acknowledge that opinions have the potential to evolve over time. Hence, future studies should aim to further investigate the integration of e-learning in radiology education, with a particular focus on evaluating the long-term outcomes and effectiveness of blended learning models that combine online and traditional classroom teaching. Additionally, research exploring innovative, low-cost technological solutions designed to enhance e-learning accessibility in resource-limited settings could offer valuable insights. Investigating the psychological impact of e-learning on students and educators, as well as developing strategies to improve digital literacy and engagement in virtual learning environments, will be crucial for optimizing e-learning practices in the field of radiology and beyond.

6. CONCLUSIONS

This study has highlighted significant challenges and opportunities associated with the employment of e-learning in radiology education across Sudan during the COVID-19 pandemic. The findings reveal a complex landscape where, despite the rapid adoption of e-learning methods due to necessity, a significant proportion of students continue to express a preference for traditional classroom settings. Specifically, 50.1% of respondents cited power outages as a major barrier to effective e-learning, while 27.1% were hindered by poor internet access.

Interestingly, while 33.9% of participants felt satisfied with e-learning as an instructional strategy, 29% believed that it detracted from their educational achievements, underscoring the need for a more nuanced approach to its integration. Notably, despite widespread skepticism, with 78.2% of respondents doubting its suitability for all medical specializations, there is an openness to integrating e-learning with traditional methods, as 46.6% of the students supported a blended approach.

These findings suggest that while e-learning has potential as a complementary educational tool, significant

infrastructure improvements and strategic planning are required to maximize its benefits. This study advocates for a balanced approach that combines the strengths of both traditional and digital learning environments to enhance the resilience and effectiveness of radiology education in facing future challenges.

6.1. Policy Suggestions

Enhancing Infrastructure: Based on the factors identified in relation to e-learning for radiology education, we advocate for enhanced support structures to drive the use of this form of technology in teaching. It is suggested that institutions of higher learning and counterparts in the government provide robust power supplies and efficient and reliable internet connection. Such investments are crucial in eradicating restraints that results in power outages and poor internet accessibility, which greatly affect e-learning, as pointed out by many of the participants.

Training and Support for Educators and Students: In order to enhance the utility of e-learning technologies, it should be mandatory to include beneficial training sessions focused on educators and students. These programs should concentrate on the management of digital technology, the promotion of online learning approaches and the enhancement of digital competence. By making sure that every learner, faculty, and student understands and can effectively employ e-learning applications, the quality and utility of online learning will be improved.

Regular Assessment and Feedback Mechanisms: Department chairs and administrators should incorporate continuous assessment mechanisms that evaluate the achievements of e-learning programs. In this process, feedback forms can be particularly helpful to monitor development and the implementation of improvements based on the experiences of both students and teachers.

Policy Frameworks to Support E-learning Integration: It is suggested that the government and educational authorities should develop sound policies aimed at fostering adoption of e-learning as a part of mainstream educational processes. These frameworks should cover issues of licensing, accreditation, and quality assurance to ensure that online learning provisions meet education standards.

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