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The effectiveness of emergency remote learning during COVID-19 crisis, did we achieve the learning outcomes?

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As a result of the unique COVID-19 crisis, universities have converted to emergency remote learning (ERL). The goal of this study will be whether ERL can achieve the attended learning outcome and the based-on learning domain. This was investigated by comparing student performance (PLO assessment) and perceptions of quality in ERL to regular face-to-face classes for undergraduate students in medical laboratory technology department. The findings revealed that students who used the ERL outperformed their peers in the knowledge, cognitive, and psychomotor domains. However, students and faculty members found that ELR was ineffective for delivering learning outcomes in the psychomotor domain. Subsequently, ERL was successful in achieving learning objectives in the knowledge and cognitive domains but not in the psychomotor domain, and it could not replace clinical rotation, that is essential for acquiring a variety of social and personal skills.

Keywords: COVID-19, Education, Learning outcome, Emergency remote learning, medical education

INTRODUCTION

The World Health Organization (WHO) declared the novel coronavirus disease (COVID-19) a global pandemic in early spring 2020 (Orgnazation, 2021). The virus causes an extremely contagious respiratory infection with a spectrum that ranges from asymptomatic spread to severe respiratory disease that can cause fatal complications (Sharma et al. 2020). The global pandemic of COVID-19 compelled the world to implement significant changes in public policies (Ebrahim et al. 2020). Given the prompt and pervasive spread, governments mandated social distancing followed by quarantine measures that prohibited activities in public spaces such as schools, businesses, workplaces and even travel and transportation restrictions (Ebrahim et al. 2020). Education was one of the major sectors heavily affected by the pandemic. One of the first decisions made during the crisis was to close educational institutions as a measure of social distance.

Technology and the use of internet-based technologies have revolutionized education at all levels globally in the last decade (Rajab, Gazal and Alkattan, 2020) As a result, to reform the education system and continue the academic year in safe and secure measures, emergency remote learning (ERL) has been presented globally to students and educational institutions, including King Abdulaziz University in Jeddah, Saudi Arabia (Bozkurt

et al. 2020). "Emergency remote learning" implies that what educators are doing currently is an unexpected and alternate manner of giving education from a distance since they are unable to be physically present in a classroom with their pupils. On the other hand, online learning is based on a completely new philosophical and conceptual paradigm of learning that has always envisioned the delivery of education over the internet. In other words, emergency remote learning occurs online and has similar components as online learning, but it is designed differently (Hodges et al. 2020).

However, some challenges may impact the prompt shift to ERL that including economic resources, lack of internet access, slow or unreliable internet, insufficient technological skills, and technophobia (Alvarez, 2020; Rajab et al. 2020). Besides these, ERL posits a challenge for educators to create an interactive virtual classroom that allows them to instruct, monitor, assess and motivate students (Alvarez, 2020; Lynch, 2020). To help those in need overcome some of these obstacles, the Saudi government provided free tablets. Furthermore, the Ministry of Education was supported by the Communication and Information Technology Commission, which provided a low-student discount on internet and data services.

Learning Outcomes LOS define what students should know and be able to do after completing a specific course

subject or curriculum (Donnelly and Fitzmaurice, 2005). "Learning Outcomes (LOS) are measurable statements of student knowledge and skills expected upon graduation" according to the definition (Donnelly and Fitzmaurice, 2005). Furthermore, LOS will aid in ensuring that students understand what is expected of them and that learning and evaluation are constructively aligned (Michael, Stanley and Bolton, 1957). Recent advancement in educational practices has further classified LOS into more 5 major domains. Saudi Arabia's National Qualification Framework (NQF) adopted the European Qualification Framework model, which categorizes learning outcomes into five major domains: knowledge skills, cognitive skills, interpersonal skills & responsibility, communication skills, and psychomotor skills. (NCAAA, 2009).

Several studies have described the education process during the pandemic and defined the ERL for medical students (Mehta et al. 2020), or investigated the effectiveness of the ERL as reviewed (Wilcha, 2020), but further studies are required to thoroughly study and evaluate ERL by education assessment methods.

The current study's primary research question is whether the ERL has effectively replaced traditional education methods by evaluating the ERL as a teaching strategy by assessing each program's learning outcome (PLOs). The PLOs will be directly assessed by comparing the performance of students who used ERL to that of regular face-to-face students enrolled in the same courses taught by the same instructor before the crisis. Or, more indirectly, by faculty and student satisfaction with ERL.

Hypothesis H1: When ERL was used, program learning outcomes were achieved and students' performance was not changed

Hypothesis H2: Both students and faculty members agree that ERL was an effective instructional tool.

MATERIALS AND METHODS

COVID-19 crisis had a huge impact on education, this impact on students' performance and achieving the learning outcome were assessed at King Abdulaziz University, Faculty of Applied Medical Science (FAMS), department of Medical Laboratory Technology MLT. Ethical approval was obtained from the ethical approval committee in FAMS alongside each course coordinator's consent. Members of the faculty and student participants in this study agreed to participate voluntarily before taking the survey. All participants were instructed on the study's objectives, assured of the anonymity of their data, and that all data would be used solely for academic purposes.

The medical lab technology department provides a four-year program that educates students to become medical lab specialists. The student will have a broad medical foundation year in the first year, then study core knowledge topics in the second year, more specific job area-related subjects in the third year, and clinical rotation year in the King Abdulaziz University Hospital's medical labs in the fourth year. Normally, the program is taught

face-to-face, using a formal program specification that lists all the PLOs and how they are allocated throughout the courses.

The department of (MLT) at King Abdulaziz University switched from face-to-face to ERL learning. Virtual classes were delivered using various educational platforms such as Blackboard, Zoom, and Google Classroom. In addition, all assignments were given and submitted electronically to evaluate students regularly. Practical laboratory sessions, on the other hand, have been replaced by online sessions that include demo videos, pictures, and group discussions.

At the end of the semester, all students took online exams via Blackboard as the final assessment of their performance. In response to the emergency status, students' grade distribution has also been updated, so that more grades are assigned to assignments. As a result, the final written online exam marks were reduced to only 20% of the final grade. The format of the practical exams has also changed to include case studies, laboratory calculations, and result interpretations. Completion of the virtual courses and summative assessment where required.

Control group:

The control group in this study was conducted up of MLT department undergrad students from the academic years 2017/2018 (n= 166) and 2018/2019 (n=136), from the second, third, and fourth years.

Experimental group:

The experimental group in this study consisted of MLT department undergrad students from the 2019/2020 academic year (n=158), from the second, third, and fourth years.

The aggregate grade data for ERL completers during the COVID-19 crisis, specifically the second semester (2019/20), where ERL was first applied. Students' performance during that semester was compared to students who took traditional face-to-face courses during the same semesters in the 2018/19 and 2017/18 academic years. The MLT department has an approved PLOs assessment plan, under which the department measures students' performance and PLO achievements annually and then suggests required action plans. The performance index (Pi) for each PLO is calculated and recorded in the PLO assessment section of the department's annual program report (APR). The MLT PLOs assessment plan is summarized in Tables 1 and 2.

Students' achievement in five learning domains is measured by the MLT PLOs assessment plan: knowledge, cognitive skills, interpersonal skills, and responsibility, psychomotor and communication, information technology, and numerical skills (table2). This assessment plan is based on reports provided by each departmental course coordinator. Exams, quizzes, practical exams, lab reports, presentations, assignment grades, rubrics and blueprints

used in these evaluations are all detailed assessment methods used throughout the course.

Table 1: PLO assessment calculation method

Steps	Person in charge	Submitted documents
1. The performance level for each assessment method is calculated at the end of the semester/year. 2. All indices used to investigate specific course learning outcomes (CLO) are averaged. 3. The weighted index is computed using the proportional weight. 4. The performance index of a CLO is calculated by adding all its weighted indices. One or more of the instruments is not used to assess a CLO; the proportional weights of the instruments are adjusted before the adding up.	Each course coordinator	Course report (for each course)
5. The indices of all the CLOs contributing towards the achievement of a particular PLO are then added up to produce the performance index of the PLO (PLO/KPI) 6. Benchmarking and performance indicators. 7. Review and approval: The external evaluator will assess the APR and then be discussed and review it in department meetings.	APR writing team / Head of department / External evaluator	APR

Table 2: PLO assessment plan for each PLO

Domain	PLO	Assessment time	Assessment tool	Assessment plan
Knowledge	1.1	Annually starting from 2017/18	MCQs Blueprint	50% of students pass the with B or above in the knowledge domain of core subjects (selected courses from second and third year)
	1.2	Annually starting from 2017/18	Final exams	80% of students pass the with B or above in the knowledge domain of core subjects (selected courses from second and third year)
Cognitive Skills	2.1	Annually starting from 2017/18	1. Student project 2. Seminars 3. Elective course 4. CES of 3rd year (specifically critical)	1. 70% of students completed student seminars, projects, and the elective course with B+ or above. 2. course evaluation survey (CES) satisfaction level above 3.5 in Q21 on average for all courses
	2.2	Annually starting from 2017/18	1. Student project 2. Seminars 3. Case study questions in final exams 4. Lab final exam	1. 70% of students completed student seminars and project courses with B+ or above. 2. 70% of students get 70% or above in final exam case study questions in selected courses from the third year 3. 50% of students get 70% or above in the lab final exam for 2nd and 3rd-year courses.
interpersonal skills & responsibility	3.1	Annually starting from 2017/18	1. Clinical rotation. 2. Internship year successfully 3. Oral presentations in 4th-year courses	1. 80 % of students completed the clinical rotation successfully with an A or B grade. 2. 90 % of students completed the internship year successfully 3. 70% of 4th-year students get 70% or above in oral presentations in 4th-year courses
	3.2	Annually starting from 2017/18	1. Student project 2. Course Evaluation Survey 3. Internship year	1. 70% of students completed the student project course with B+ or above. 2. Satisfaction level above 3.5 in 3rd-year Courses Evaluation Survey Q22 3. 90 % of students completed the internship year successfully

Communication, information technology, and numerical skills	4.1	Annually starting from 2017/18	1. Student seminar 2. Oral exams in 4th year 3. Clinical rotation evaluation 4. Course Evaluation Survey of 3rd year	80 % of students completed the student seminar successfully with an A or B grade 70% of 4th-year students get 70% or above in oral presentations in 4th-year courses 80 % of students completed the clinical rotation successfully with an A or B grade. Satisfaction level above 3.5 in 3rd-year Courses Evaluation Survey Q23
	4.2	Annually starting from 2017/18	1. Lab reports 2. Assignment	70% of students completed lab reports and assignments, with at least 70% in second and third-year courses
psychomotor skills	5.1	Annually starting from 2017/18	1. Lab final exam second 3rd year (wet labs) 2. Clinical rotation evaluation	1. 50% of students get 70% or above in the lab final exam for 2nd and 3rd-year courses. 2. 80 % of students completed the clinical rotation successfully with an A or B grade.
	5.2	Annually starting from 2017/18	1. lab final exam 3rd year (wet labs) 2. Clinical rotation evaluation 3. Internship year evaluation	1. 50% of students get 70% or above in the lab final exam for 2nd and 3rd-year courses. 2. 80 % of students completed the clinical rotation successfully with an A or B grade. 3. 90 % of students completed the internship year successfully

These assessment methods were developed following the guidelines of King Abdulaziz University and with the assistance of several resources (Cornell University, 2022)(Deanship of Quality Assurance & Development, 2021). In this study, the results of this PLOs assessment plan were used to compare and analyse students' achievement before and during ERL application.

For this study, courses delivered at the start of the crisis and shifted to ERL were chosen for PLO assessment. The performance of the students in the immunology, haematology, histology, and molecular biology courses were chosen to assess knowledge domain. These are the program's core knowledge subjects, and they have all been shifted to ERL. Similarly, subjects that rely on the student's cognitive abilities and whose delivery has been adversely affected by the crisis were chosen to assess the cognitive domain. The selected courses were students' projects, seminars, and elective rotations, according to the MLT PLOs alignment mapping. During the fourth academic year, these three subjects are covered. For student projects and seminars, students prepare graduation projects, write a thesis, and present their findings in an oral presentation or a poster. During the elective course, students choose a specialized lab that is not on their original academic rotation, such as forensic labs or tissue typing labs, to attend and present a summary of what they learned there. The psychomotor domain was presented using clinical rotation subjects.

The second research question is to estimate the level of quality perception in ERL versus traditional face-to-face classes. As a result, surveys of students and faculty members were conducted as part of the university's annual survey to measure their degree of satisfaction with their ERL experience. This was revealed by an anonymous questionnaire distributed to students and faculty at the end of each academic semester. The survey included a 5-point Likert scale approval score.

Students question:
Are the teaching methods suitable for the virtual classroom environment?
Did you find the virtual classroom environment motivates learning?
Did you find assessment methods suitable for the virtual classroom environment?
Are you satisfied with e-learning and distance learning services
Staff questions:
Was the PLOs achievement affected by the crisis?
Did you find emergency remote teaching useful?
Would you use virtual learning in the future after the crisis is resolved?
Which learning domain was affected by the crisis?

Statistical analysis was carried out using Statistical Package for the Social Sciences (SPSS) version 20 (IBM Corp., Armonk, NY), A P value < .05 was considered statistically significant. A one-way ANOVA analysis was used to compare changes in student performance and satisfaction levels across academic years.

RESULTS

Student's performance during COVID-19:

COVID-19 had a significant impact on education; many higher education institutes and universities around the world have switched to ERL. The purpose of this study is to investigate the efficacy of ERL by measuring student performance as well as student and faculty member satisfaction with the ERL experience.

The achievement of students in learning domains for each subject was calculated PLO assessment plan(table 2). Figure 1 illustrates the subjects evaluated in this study.

The graph depicts the academic year for each course and students' performance during the COVID-19 crisis. There was no significant difference between this year's performance results and the previous two years' results ($P > .05$).

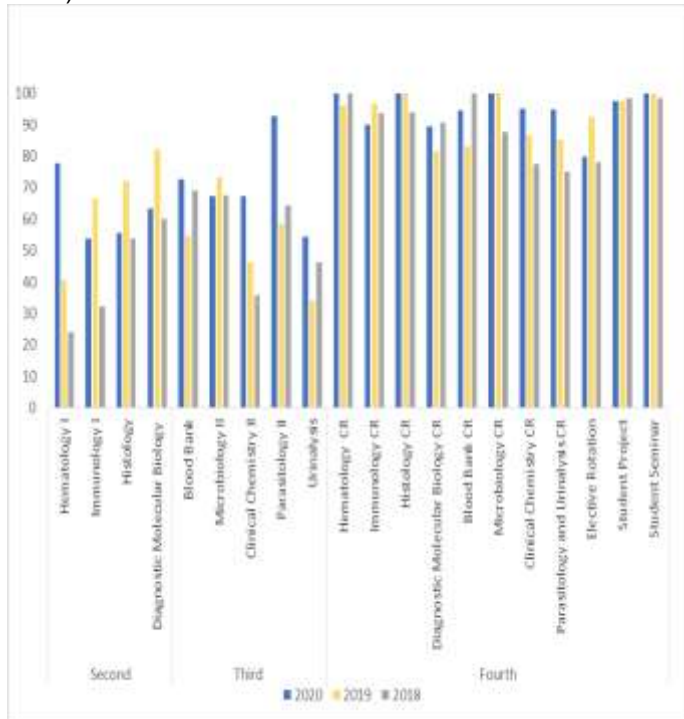


Figure 1: Students' performance for each subject during the last three years.

The performance of students in each domain was investigated using the PLO's assessment plan (Table 2). Courses delivered at the start of the crisis and shifted to ERL were chosen for PLO assessment. The results showed no significant difference ($P > .05$) in student performance between this year and last year, indicating that ERL is an effective tool for knowledge and cognitive domain teaching. This result could be related to reducing the stress of face-to-face presentations and making more free time available for students to focus on their work. Furthermore, it may imply that ERL may facilitate student motivation and communication.

The psychomotor domain was presented using clinical rotation subjects. Despite a significant change in teaching and assessment methods, this year's results showed a slight improvement.

The COVID-19 crisis effect on the subjects that rely on interpersonal skills and responsibility, communication, information technology, and numerical skills was not measurable. As these subjects were taught in the first semester of 2019/20, before the COVID-19 crisis and the ERL shift. As a result, their findings were not presented.

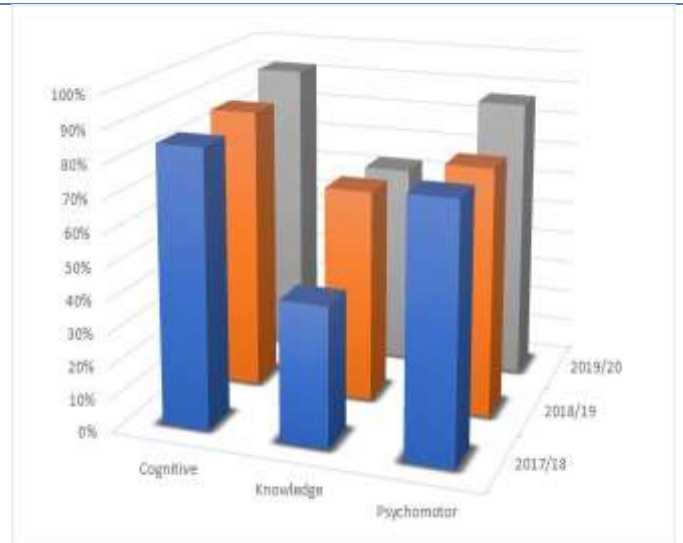


Figure 2: Students performance in each domain,

Students and faculty members' satisfaction levels:

It was critical to investigate faculty and student satisfaction with the ERL experience. According to Figure 3, 69% of faculty members support the transition to virtual learning following the crisis, and 73% find ERL to be a useful teaching tool. However, 47% believe that the COVID-19 crisis-affected PLOs achievement.

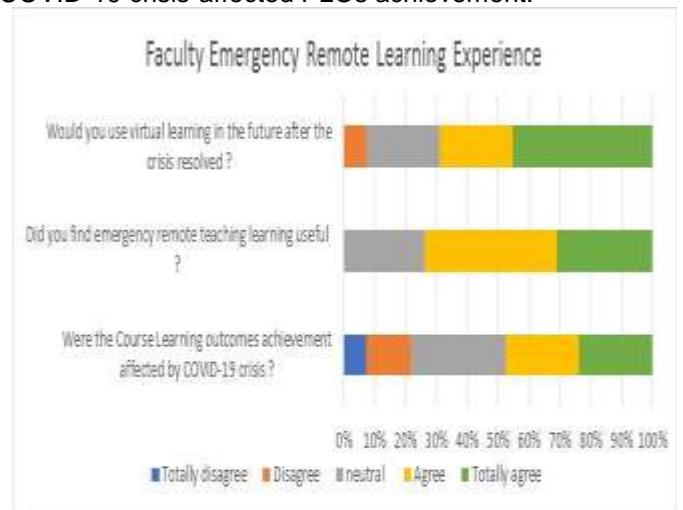


Figure 3: Faculty members ERL experience.

Further, the crisis affect on course learning outcomes as reported by faculty members was investigated. According to the findings, approximately 21% of faculty members believe the crisis did not affect course learning outcomes (see Figure 4). In contrast, 60% believe the psychomotor domain was the most affected, while 10% believe the crisis impacted interpersonal skills and responsibilities. Except for the psychomotor domain, most faculty members found ERL to be a useful educational tool.

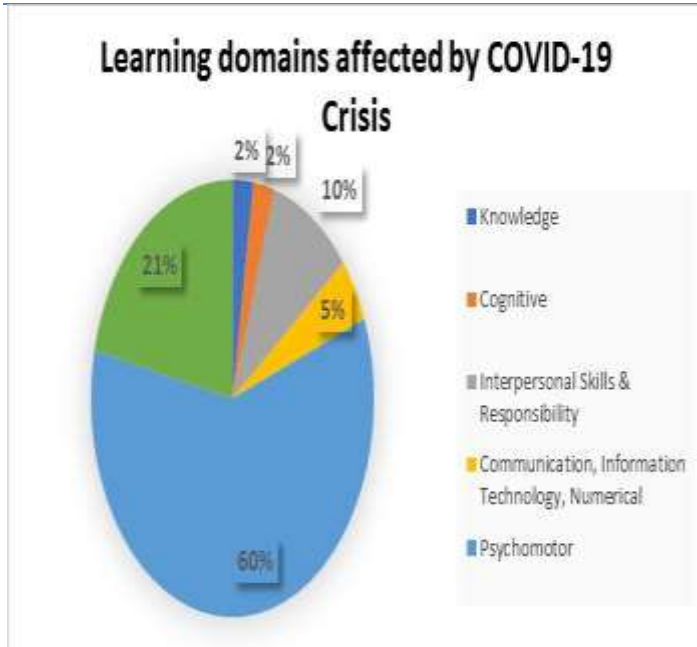


Figure 4: The learning domains that were affected by COVID-19 crisis, according to faculty survey.

In general, most students were pleased with the ERL, the teaching and assessment methods, and the virtual learning classroom environment.

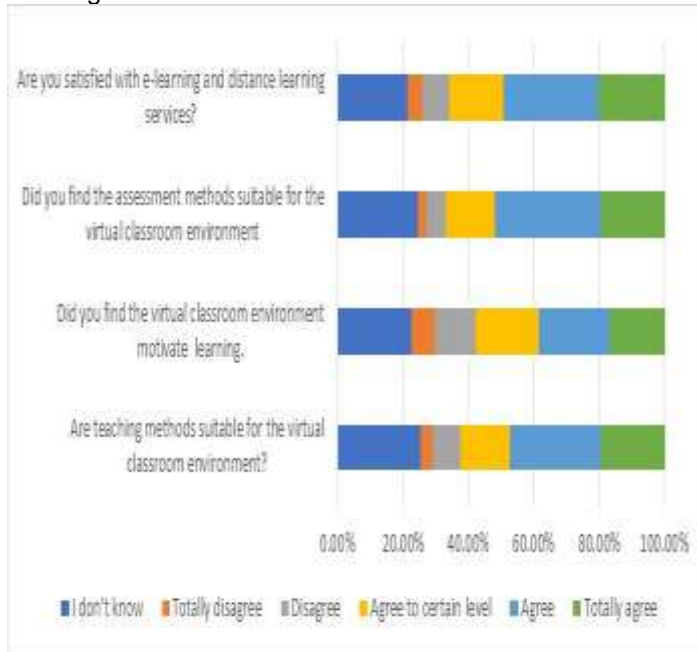


Figure 5: Students satisfaction level about ERL.

Figure 6 presents the students' level of satisfaction. In the general stratification of ERL, one-way ANOVA revealed a significant difference between second, third, and fourth-year students. This difference, however, may be due to the nature of the fourth-year courses, which are primarily clinical rotations that have been replaced with

theoretical objectives taught via ERL.

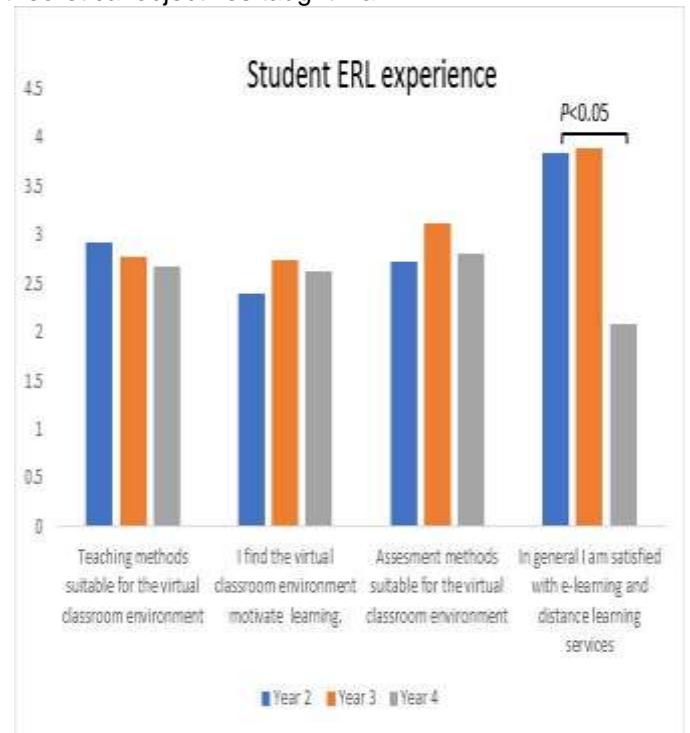


Figure 6: The students satisfaction level with ERL for each year.

DISCUSSION

The purpose of this study was to estimate the COVID-19 crisis's impact on higher education, either directly by assessing students' performance in various learning domains or indirectly by measuring students' and faculty members' satisfaction levels with ERL.

This study compared students' performance during the 2019/2020 academic year (experimental group) to students' performance during the previous two academic years (control group), which had similar circumstances, teaching strategies, and assessment methods. The 2019/2020 academic year was divided into two distinct phases, the first of which was similar to previous years before the COVID-19 crisis. Those circumstances changed dramatically in the second phase, and all teaching and learning activities were restricted to ERL.

The findings revealed that students' performance in knowledge and cognitive domains remained unchanged. The COVID-19 crisis effect on interpersonal skills, responsibility, and communication, as well as information technology and numerical skills was not measured, because most of the teaching strategies aligned with these domains were implemented before the crisis. While student performance in the psychomotor domain has improved slightly

According to survey results, both students and faculty members enjoyed the distance learning experience, and faculty members intend to use distance learning methods

in the future. Although most faculty members (60 percent) believed ERL did not adequately cover the psychomotor domain, this result is consistent with students' findings, as the lowest levels of satisfaction were reported by fourth-year students, the academic year that is solely focused on clinical rotations and the psychomotor domain.

Our results suggested that ERL achieved most of the learning outcomes across three learning domains. Virtual learning may be a promising educational tool in basic level classes based on knowledge and cognitive domains. These levels of classes do not necessitate social interaction (Govindarajan and Srivastava, 2020). However, changes in the educational process during the COVID-19 crisis may be confinement that explains any improvement in their learning performance (Gonzalez et al. 2020). Therefore, it is important to point out that the changes in the students' performance during the COVID-19 crisis might be due to a change in teaching strategy or assessment methods or any other reason (Seifert et al. 2021),

Virtual learning has shown to be very promising to achieve the psychomotor domain learning outcome, and teaching skills required for the laboratory (Fox et al. 2020; Torda, 2020). Because the psychomotor domain is based on practical sessions, the learning objectives of these sessions are either primarily theoretical science, primarily skills, or primarily both theory and skills. During the ERL, however, many faculty members shifted their learning objective to be primarily focused on reinforcing concepts and theoretical science

This is consistent with previous research, which discovered online laboratories are more focused on learning physics concepts (i.e., content and theory) while traditional hands-on laboratories are more focused on design skills and collaborative skills (Brinson, 2015; Fox et al. 2020). Furthermore, the findings do not identify the cause of the students' low satisfaction level with psychomotor domain, although students are pleased with both the teaching strategy and the assessment methods, according to the results of a student survey.

Students' performance and feedback have demonstrated that well-designed online teaching can be as effective as traditional teaching (Radha et al. 2020). Although some aspects of education, such as learning in the same physical environment with peers, and the role modelling and mentoring that typically occurs in the physical environment, virtual learning can't replace. Although virtual learning has a variety of benefits for students, such as comfort, adaptability, and improved interaction through chat capabilities (Alqahtani and Rajkhan, 2020; Chung, Subramaniam and Dass, 2020; Torda, 2020; Wahid et al. 2020; Alvarez, 2021). Virtual learning, however, cannot replace clinical rotations and the experience gained from working in real clinical settings (Mseleku, 2020).

Despite the limitations of virtual learning, the COVID19 crisis has forced us to quickly adjust and

change education. This situation, however, provided the opportunity for long-term education improvement, as faculty members were required to learn new skills and teaching strategies (Ratten, 2020). Students have participated in virtual learning and used various assessment strategies. All of these changes occurred during the educational process, resulting in educators' skills being improved by taking risks, testing new exercises, and re-energizing their teaching (Chen et al. 2020; Goh and Sandars, 2020; Tesar, 2020).

These modifications in the educational process may be useful for future E-learning system implementations, as preparation for E-learning implementation remains the most important factor in enhancing the educational process (Alqahtani and Rajkhan, 2020). Specifically, both students and faculty members felt the virtual learning experience to be beneficial, and most faculty members want to continue utilizing the virtual learning teaching technique in the future.

Limitations:

Because this study was conducted on undergraduate MLT students, the recommendations and conclusions cannot be generalized. As a result, it may not apply to students from various disciplines or levels that have very different learning objectives and outcomes (e.g.: humanitarian and art students or postgraduate students). Another limitation is the small number of students who participated in this study.

CONCLUSION

ERL was successful in achieving learning outcomes in the knowledge and cognitive domains. However, laboratory skills and psychomotor domain require hands-on laboratories and face-to-face interaction, in addition to the clinical rotation, which is required to learn a variety of social and personal attributes. Furthermore, the experience gained by students and educators during the COVID-19 crisis should be beneficial in the future. Furthermore, to ensure the adequacy of virtual learning for students, the standards of online learning strategies and learning outcomes must be thoroughly revised and assessed regularly.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

The proposed idea was created by HZ and MA. IA and MA developed the theory and performed the computations. The analytical procedures were validated by IA and HA.

The manuscript was written by HG with assistance from MW and AZ. The findings were considered by all writers, and they all contributed to the final publication.

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