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Sustainable Engineering higher education in Oman-lessons learned from the pandemic (COVID-19), improvements, and suggestions in the teaching, learning and administrative framework.

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Abstract: This research study has investigated the challenges faced due to the pandemic (COVID-19). This paper further provides recommendations that can be adopted by academics, learners, and administrators to make the education system more robust and sustainable. The impact of the COVID-19 pandemic can be felt in various fields across the world including higher education. The closure of face-to-face (FtF) learning in educational institutions worldwide has impacted over 95% of the world's student population. Therefore, in wake of this, many institutions have quickly adopted to offer complete online teaching and learning in a very short period. However, such a quick transition has raised several challenges. 1) What are the challenges encountered by academics and their readiness to adapt to the rapid remote learning transition? 2) What are the challenges encountered by learners (students), and their readiness to adapt to the rapid remote learning transition? 3) What are the recommendations for strategic planners or high-level administrators in institutions to tackle such pandemic risks effectively in the future? To address research questions mixed methods are used. A qualitative questionnaire survey is framed by an extensive literature review to understand the perceptions of academics and learners. A total of (n=525) academician samples and (n= 1460) student samples have been collected. The academic and learner's perceptions are analyzed by estimating the Pearson correlation coefficients. The mean and SD values based on academic rank stood at 3.01±0.96, and by experience stood at 2.96±0.98. Similarly, learner's perceptions stood at 2.67±0.95. Keywords: FtF (Face to Face); problem-oriented and project-based learning (POPBL); LMS (Learning management system); emergency remote teaching (ERT); emergency risk (COVID-19): Standard deviation (SD).

Declarations: NA

1. Introduction:

Observing the current global crisis turned on due to the pandemic (COVID-19 virus) situation seen around the world has enforced various industries to adopt different methods of work styles to keep pace with the regular life course. The number of COVID-19 affected cases globally has reached near to nineteen million (as of today) [1] and still seems to be increasing exponentially in some countries like the USA, Brazil, India, and most of the European countries including the UK. Although there are concerns that the COVID-19 data by some countries is not accurate never the less the effect is seen to be

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predominant. Therefore, the current increasing trend shows that the governments are likely to continue to lock down and could ask their respective citizens to follow social distancing, wearing protective masks, and other necessary precautions until some better updates are seen such as vaccine development or any substantial treatment for the COVID-19 virus. The impact of the COVID-19 virus on the commercial market is seen to be enormous and its correct estimate is still yet to be known which may take few more months to analyze if the COVID-19 virus and death rate gets controlled. It is predicted that some countries may take months to recover from the ongoing economic crisis and return to the regular life course. The Education sector is also not an exception to escape from the ongoing pandemic. However, It could have been a hotspot for the spread of the disease if no action would have taken at the right time affecting the millions of innocent students and the associative staff. Most of the universities globally have to suspend face-to-face (FtF) studies as an immediate interim to contribute to avoiding the fast spread of the COVID-19 virus. As a result, many challenges are continuously raising in providing continuing education along with the best learning experience.

Engineering studies are indispensable education in society. Intellectual skills and knowledge learned through these studies play a very vital role in building and transforming our society either it be in infrastructure, power, environment, and technology almost every discipline, engineers are required. Generally, any education system including engineering involves two major complementary processes to define the overall objective of the education system. 1) the learning process and 2) the teaching process. Both processes require good synchronization to achieve the learning outcomes of the enrolled engineering program studies. [Mobarak, H.M, 2016] However, it is often observed that there exist's mismatches between these two processes resulting in the poor performance or loss of the potential excellent engineers for our society. Further, Engineering studies also require good hands-on practice by performing experimentation, analysis of the experimental data, research, and innovation. Several innovative and teaching methodology solutions are proposed globally by various academicians to increase the effective learning of engineering students. [Wilson-Lopez, et.al, 2020] studies described the significance of adopting argumentation-based pedagogies in engineering education and how it impacts and improves the student learning experience and engagement. [Lehmann, M, et.al, 2008] research studies have considered both problem-oriented and project-based learning (POPBL) as the best methods in developing sustainable engineering education. [Karabulut-Ilgu, et.al, 2018] review studies have revealed that flipped classroom (or) blended teaching methodologies have been gaining popularity in both learning and teaching methods since 2012 in the engineering pedagogy. Further, recent research conducted by [Alomari, M, et.al, 2020] has investigated the effect of human factors on the effectiveness of the learning management system which is based on blended teaching methods. This study has developed an updated framework to enhance the learning user experience in blended teaching methods.

The engineering discipline consists of a wide range of topics covering the broad education spectrum in almost, all the fields of science and technology. Despite its vast education spectrum, the fundamental teaching methods used in course content creation will contribute to the six principles of the engineering education objectives as defined by Bloom's Taxonomy of Educational Objectives [Felder, R.M, et.al, 2004]: 1) Knowledge 2) Comprehension 3) Application 4) Analysis 5) Synthesis and 6) Evaluation. The regular approach or methods used in achieving these objectives is currently becoming questionable due to the current COVID-19 pandemic. Most of the universities across the globe have started to use effectively their respective E-learning systems to keep students engaged or seem to consider remote learning as the only viable temporary option to sustain in the education industry. Nevertheless, unpreparedness to predict such risks could occur in the educational system or inability to handle such risks effectively upon occurrence needs to be thoroughly analyzed. So far, the priority risk factor in an education institution considering the student perspective is based on student learning experience, student retention, and student success factor. Almost none of the educational institutions might have considered the readiness in tackling such risks upon occurrence. Therefore, an updated rigid educational deliverance methodology needs to be investigated that can not only handle such emergency risks but also improves and make the model robust.

In engineering higher education the teaching methodology mainly comprises an outcome-based instructor-centered approach, a practical hands-on approach, a problem-based, and a project-based approach. Although usage of E-learning platform tools such as learning management systems (Blackboard and moodle), online lecture conference tools or video recording seems to be an alternative option to compensate for the outcome-based instructor-centered approach, (POPBL) approach. But there arise several challenges that are being prevailed in the deliverance of the practical hands-on experience. As most of the engineering courses have a lab component that provides the students with co-relating the theoretical concepts taught during the class, implementing and testing the design process, evaluating and finding solutions, troubleshooting skills, innovation skills which are the core parts of the program learning outcomes. Although there exists literature on online engineering education, to the best of our insight there has been no comprehensive analysis conducted on the challenges faced by academics and learners who were primarily dependent on face-to-face (FtF) teaching and learning before the pandemic. Furthermore, depending on the obtained survey results few recommendations are suggested to administrators that can improve overall teaching and learning experience and also can sustain to pandemics. [Syauqi, K., et.al, 2020] research study discusses the learner's perceptions only due to pandemic. [Opriș, I., et.al, 2020] research study discusses the pandemic challenges and opportunities focusing mainly on particular engineer discipline. Another research study [Revilla-Cuesta, V., et.al, 2021] discusses the teacher's perceptions only due to pandemic. More importantly, little to no literature exists so far documenting the teaching and learning practices adopted in the sultanate of Oman. This paper can be extremely helpful in contributing to the world engineering education practices database. Therefore, to address the above-raised gaps the following research questions are considered:

RQ1: What are the challenges encountered by academics and their readiness to adapt to the rapid remote learning transition?

RQ2: What are the challenges encountered by learners (students), and their readiness to adapt to the rapid remote learning transition?

RQ3: What are the recommendations for strategic planners or high-level administrators in institutions to tackle such pandemic risks effectively in the future?

To investigate the above-presented research questions a survey is conducted in technical colleges and universities of oman specifically focusing on engineering academics and students. The outcomes of this research are not only addressing the engineering discipline but can also be considered in general and even the entire education system as a whole. COVID-19 emergency risk is considered to be a global pandemic by the united nations. Further, providing quality education is one of the seventeen sustainable goals developed by the united nations which seems to be at risk due to the current ongoing health crisis [www.undp.org, 2020]. Therefore, the current education system needs upgrades to tackle such emergency risks effectively in the future and thus contributing to UN sustainable development goals.

2. Literature review and methodology

2.1. Literature review

The popularity of the remote learning approach has seen tremendous growth by the availability of various MOOCs (massive online open courses) platforms such as edX, Coursera and Udacity, etc. specifically from the developing and under-developing countries where the accessibility to quality education and resources are limited [Ch, S.K. and Popuri, S., 2013]. The second prime factor witnessed for gaining popularity is flexibility, expediency for learners, and usage of technology for auto-grading, where the enrolled students can instantly observe their performance and take necessary feedback for continuous improvements. The third factor is getting certified for an already qualified person showing continuous learning, commitment in their respective core areas which are welcoming attributes for an employer. On the other hand, E-learning challenges particularly focusing academics perspectives are attributed to five subcategories and they are 1) Learning Style and Cultural Challenges 2) Pedagogical E-learning Challenges 3) Technological Challenges 4) Technical Training challenges and 5) Time Management Challenges [Islam, N. et.al, 2015]. Considering both sides of a coin, the transition to a remote learning approach is seen inevitable during emergency risk circumstances such as COVID-19 and also can be a guiding experience for future potential risks (if any) in higher education institutions. Various challenges have been raised at the higher educational institutions during the transition of teaching from an Outcome-based instructor-centered /blended teaching approach to a complete remote learning approach. Specifically highlighted concerns are related to faculty readiness in using online teaching tools, necessary infrastructure availability at both ends (academicians and students), assessment methods to fairly meet the course learning outcomes, and challenges prevailing in delivering lab courses/sessions [Sahu, P., 2020].

A mixed approach (qualitative and quantitative) is used in developing the survey questions and analysis of survey data to conclude. Table 1 lists the articles reviewed to developing the qualitative survey upon which the academics would majorly relate the quick transition experience. And Table 2 is in perspective with the learner's readiness and expectations.

Table 1: Academics survey questions using the qualitative approach.

Articles reviewed	Major findings summary	Construct and the statement question used in the survey
[Albrahim, F.A., 2020], [Adnan, M., 2018], [McGee, P., Windes, D. and Torres, M., 2017], [Rhode, J. et.al, 2017], [Salehi, N. e t.al, 2017], [Kenzig, M.J., 2015].	The technological skills (professional development) of the faculty play an important role in content development in teaching online.	Faculty competency Readiness in the use of technology (Item no: 1) Q1: I have competent technical skills to deliver an online course.
[Hsiao, C.C. , et.al, 2019], [Schophuizen, M , et.al, 2018], [Gul, S., et.al, 2017],	1) Assessment methods are different from face-to-face (FtF)/ flipped classrooms in contrast to online teaching. 2) a thorough knowledge o f the mapping of the learning outcomes is required.	Awareness of assessment methods and mapping learning outcomes (item no:2) Q2: I have a complete awareness of various assessments suitable to deliver my course online. Q3: I have competent knowledge of mapping course learning outcomes suitable for onlin e teaching.
[Kebritchi, M., et.al, 2017], [Zayas, N.L., 2011], [Worley, W.L, et.al, 2009],	Timing constraints; it is hypothetically believed that online teaching takes more time and effort than regular Face to Face teaching (FtF)	Time management (Item no: 3) Q4: I have enough time to transit my courses from face-to-face (FtF)/flipped method to completely online.
[Brinthaupt, T.M, et.al, 2011], [Grant, M.R., 2011], [May, G.L, et.al, 2003],	Teaching styles; the regular teaching methods used during face-to-face (FtF) teaching do not work effectively in online teaching.	Teaching Styles (Item no: 4) Q5: I have competent knowledge of different teaching style practices used in online teaching mode. Q6: I have supported community and resources to learn the best online teaching styles.
[Altalbe, A., 2018], [Potkonjak, V, et.al, 2016], [Valdez, M.T. , et.al, 2015], [Valdez, M.T , et.al, 2013], [Valdez, M.T, et.al, 2011]	Delivery of remote lab courses in engineering is possible by Virtual labs and associated software packages.	Remote labs (Item no: 5) Q7: I have virtual labs for my courses where applicable. Q8: I have simulation packages to support my courses. Q9: I have a proportionate student number to conduc t remote labs effectively

Table 2: Learner's survey questions using the qualitative approach.

Articles reviewed	Major findings summary	Construct and the statement question used in the survey
[Cole, A.W., et.al, 2019], [Kebritchi, M. , et.al, 2017], [Dray, B.J., et.al, 2011]	Learner's (students) readiness is a large contributing factor in the success of online teaching and learning. 1. Students must have minimum technical skills and resources. 2. identifying and adopting new learning styles suitable for online learning.	Learner's readiness (item no: 1) Q1: I have IT resources to engage in online study. Q2: I have received the necessary training or support at my institution to engage in online study. Q3: Instructors used different learning styles to increase my motivation and analytical thinking.
[Murphy, C.A., Stewart, J.C., 2017], [Jaggars, S.S., Xu, D., 2016], [Bawa, P., 2016].	It is very important to have an effective course content design in online teaching and learning to meet the course learning outcomes.	Effective c ourse content design (Item no: 2) Q4: instructors have designed the course content which is easy to interpret, understand, and apply effectively. Q5: Instructors have used effective assessment methods to validate my learning.
[Song, D , et.al, 2019], [Kim, M.K. and Ketenci, T., 2019], [Correia, A.P. and Jaramillo, N., 2016].	Learner's active participat ion is another contributing factor to the success factor of online learning.	Learner's active participation (item no: 3) Q6: Instructors have provided various online forums for discussion, thinking, talking, observing, and feeling.

2.2 Methodology

2.2.1 Research method:

This research is attempting to investigate the impact of COVID-19 on engineering studies in the sultanate of Oman. A literature review (qualitative approach) is performed to construct the questionnaire survey that helps to understand the academics and learner's perceptions during this rapid remote transition teaching and learning occurred due to pandemic. Academics questionnaire survey consists of five items which hold nine questions. The first item question is framed on technology skills (professional development). The second item questions targets online assessments skills and learning outcome mapping skills through remote learning. The third item question is on time management, the fourth item questions are based on various teaching styles, and the fifth item questions are based on remote lab facilities. On the other hand, the learner's questionnaire survey consists of three items that hold six questions. The first item questions are constructed to understand the learner's readiness in terms of resources and IT skills. The second item questions are on effective course content design for the easy and enhanced learning experience. The third item question is constructed on active participation. All item questions for both academics and learners are constructed on a five-point Likert scale system. Where rating 1 corresponds to strongly disagree and rating 5 corresponds to strongly agree. Before the dissemination of the survey questionnaire, it is thoroughly checked by various expert questionnaire researchers in terms of wording, content, and appropriateness to the current pandemic outbreak as perceived by the researchers. All the questions are constructed on google forms and are distributed by emails links to all the engineering colleges and universities in Oman.

2.2.2. Data collection and analysis methodology:

The respondent's data is imported into SPSS software. The first step is filtering the raw data, identifying the outlier, and coding into a specific number format to be able to perform the correlation analysis. For instance, if any one of the respondents has not answered any item questions they are treated are outliers in our analysis and have omitted from the further process. Pearson's correlation analysis is the method adopted in our study rather than the traditional descriptive analysis. It helps to identify the gaps and difficulties faced both by the academics and learners at different levels. For example, junior faculty members might be more sensitive towards the understanding and application of the latest technological skills than the senior faculty members. Pearson coefficient "r" value helps to determine the relationship strength and direction between two variables (bivariate). For example, faculties based on academic rank categorized into different number datasets are treated as variable V1 and their recorded responses for a particular survey question as variable V2. Then performing a Pearson correlation analysis using these two datasets helps to understand the agreement strength and direction towards the asked question based on academic rank, experience, etc. Before performing Pearson correlation analysis, Pearson's hypothesis "r" testing is conducted to identify the limit of "r" values for the collected data and also see whether the correlation exists and is valid. The null hypothesis is defined as as H_0;P=0, and Alternative hypothesis is defined as H_a;P≠0, where 'P' stands for sample population considered of the actual population. Because considering the actual population is almost practically impossible and thus not obtainable. Alpha in our study is 0.001 and degrees of freedom (df) is 523 (df = N-2) (where N stands for the sample size of the population) for Academics and 1458 for learners. The decision rule for the "r" value is determined by the Pearson's r standard table [pearson's "r" value, Illinois education resources, 2021]. From the standard table, one can observe that for df values ≥ 100 and Alpha = 0.001 the r-value should lie between -0.254 to +0.254. therefore, if the analyzed Pearson r-values lie in the above range then the null hypothesis is rejected which means the strength and relationship of the obtained results are valid and acceptable. The algorithm for estimating the r-values in SPSS is shown in the figure. 1, The analysis is carried out in four steps. Step 1 is to filter the raw data, assign the coded values as per the below-set table 3.

Table 3: Coding of the filtered raw data into SPSS based on Academic rank, experience, and study level for learners.

Academic rank	Coded data value into SPSS	Experience in years	Coded data value into SPSS	Learner's perception based on the study level	Coded data value into SPSS
Lecturer	1	2-5	1	1st year	1
Assistant professor	2	5-10	2	2nd year	2
Associate professor	3	10-15	3	3rd year	3
Professor	4	15-20	4	Final year	4
		-	5	Postgraduate	5

Step 2 is to perform the Pearson's tests for different surveyed questions to understand the academic and learner's perceptions. Step 3 is to validate the obtained r-values and finally step 4 is to understand the strength and direction of the relationship between the two considered bivariate variables.

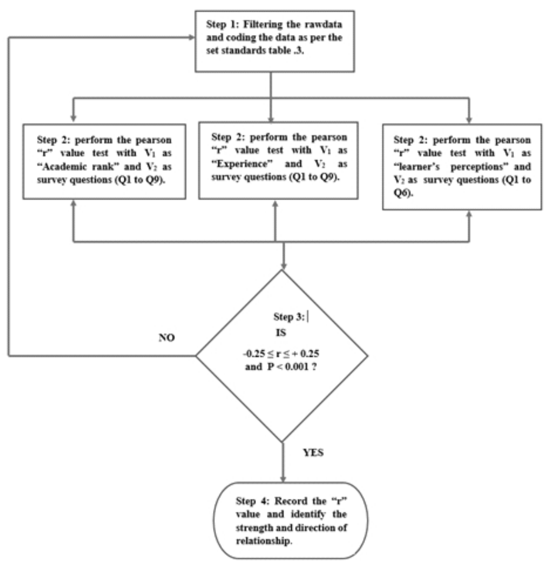

Fig. 1: Pearson's correlation algorithm adopted in our study.

3. Participants and results:

3.1 Demographic information of the participants:

Sultanate of Oman, a member of the Gulf Cooperation Council (GCC) countries hosts a total population of around 4.7 million among which 2 million people are expatriates [ncsi.gov.om, 2020]. Expatriates have remained a major source and choice of labor workforce in building the national economy. On the other hand, high wages, low or no taxation, and a high standard of living are the major reasons for the expatriates to pursue a career in the GCC countries. However, considering the growing population of Oman every year and the demand to meet the citizen's basic needs is also growing continuously. As a result, new governance rules, policies are being introduced into the employment system favoring the local nationals as the main priority in employment both in the public and private sectors. Therefore, various jobs are being replaced with the local nationals. On the other hand, the associated job skill sets required to perform both technical and non-technical jobs are observed to be lacking in the local nationals. These lead to the vision and establishment of a strong educational system in Oman to facilitate the local nationals and empowerment of the society. Currently, the Sultanate of Oman hosts sixty higher educational institutions among which thirty-one are public higher educational institutions (1 university, 29 colleges, and 1 institute) and twenty-nine private higher educational institutions (8 universities and 21 colleges) [Al'Abri, K., 2019,]. All these educational universities, technical institutions, and colleges provide various degrees in the field of science, engineering, technology, and administrative skills to empower the local nationals. The current total number of enrolled students in the country into various degrees (both undergraduate and postgraduate studies) is around 0.2 million. The teaching methodology in most of these institutions is the Outcome-based instructor/lecturer-centered method. The learners are highly dependent on the teacher in terms of subject matters. To contain the COVID-19 pandemic, the ministry of higher education and other associated ministries in the education sector has suspended all face-to-face studies until further notice. Such a sudden decision has left both the students and the academic staff in a state of uncertainty whether to suspend the studies for a while and reschedule the academic calendar accordingly. or adopt the E-learning completely for some of the courses. However, due to uncertainty (exact time) in return to the normal state, E-learning is seen to be a viable solution to continue engaging the students in their studies.

There are thirty colleges in the sultanate of Oman providing various engineering courses in the different engineering disciplines. Among the thirty colleges, 12 colleges are run by the public institution authorities and only one college is from the only public university available in Oman. The percentage of the adopted teaching approaches taught in these public universities and the technical colleges are shown in below table 4. Similarly, there are seventeen colleges from the private domain, among which eight colleges are from the universities and the rest are from the individual colleges. Overall, the majority (around 96.5%) teaching method that is adopted in these universities and colleges is an Outcome-based instructor-centric approach. Authors highly anticipate that the dependence on the instructor-centric approach can be reduced to 75% of the total engineering courses and increase the student-centric learning approach to 25%. As some of the courses in most of the engineering disciplines are constructed to teach some fundamental laws and principles whose value remains constant. For instance, electrical circuit laws such as Kirchoff current law, Kirchoff Voltage, Ohms law are standard rules that are taught to students to understand the analysis and behavior of the circuit. According to the data available from the ministry of higher education in Oman [moheri.gov.om, 2021], there are about 46000 students enrolled in various engineering programs. Figure .2 shows the total distribution of the student enrolled in various study programs. Authors anticipate that the increase in the student-centric approach for some of the courses in various engineering programs can benefit instructors, students, and administration. The instructor here can develop online resources that can be in the form of video lectures, Assignments, daily or weekly activities where students can follow the teaching material virtually and discuss the ideas, problem-solving methods using various social platforms such as Microsoft teams, zoom, etc. For instance, a study [Chen, C.H. and Tsai, C.C., 2021] conducted in Taiwan have presented the high opportunities of using enhanced mobile technology learning to facilitate and design better student-centered learning activities. On the other hand, administrators always enjoy listening to positive feedback from the students in terms of their learning experience, satisfaction, flexibility and overall improving the quality of studies.

Table 4: percentage of teaching approaches adopted in Oman

Public Sector Engineering colleges in Oman	Number (no.)	Outcome-based instructor-centric approach	Student centric-approach
University	1	96%	4%
Technical and Applied science colleges	12	95%	5%
Private Sector Engineering Colleges in Oman			
Universities	8	98%	2%
Technical colleges	9	97%	3%
Total & Average	30	96.5% (Average)	3.5%(Average)

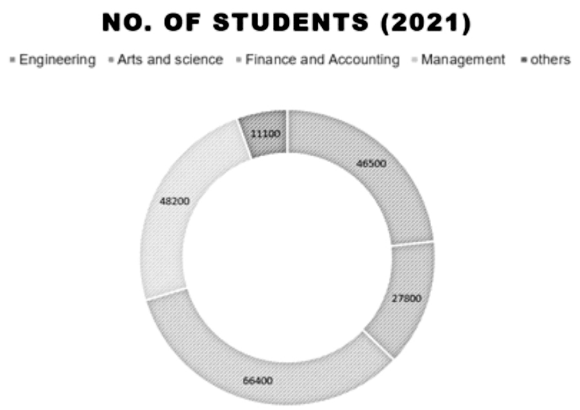

Fig. 2:Total no. of students enrolled in various study programs.

The data collected and analyzed (academics perspective) in this research study have been summarized in table 4. These participants belong to 12 higher educational institutions in oman (6 universities and 6 technical colleges) who are involved in teaching various courses related to various engineering disciplines.

Table 4: Information of the Academics participants in the survey

	Lecturer	Assistant professor	Associate Professor	Professor	Total (percentage)	Mean ± SD
Samples (n=525)	240 (45.7%)	160 (30.4%)	96 (18.2%)	29 (5.5%)	**525 (100%)**	---
By Major						
Civil	58	48	24	8	138 (26.2%)	
Electrical	52	36	26	5	119 (22.6%)	
Mechanical	42	21	14	4	81 (15.4%)	
Instrumentation	34	15	13	2	64 (12.1%)	
Electronics and communication	25	10	8	2	45 (8.5%)	
Aeronautical	11	9	4	3	27 (5.1%)	
others	18	21	7	5	51 (9.7%)	
Total					**525 (100%)**	
Experience (in years)	3-15	2-10	10-18	≥ 20		10.24±4.21
Ethnicity						
Indian	150	55	26	5	236(44.9%)	---
GCC & middle east nationals	75	68	58	11	212(40.3%)	---
European, Canada & American nationals	15	37	12	13	77 (14.6%)	---
Total					**525 (100%)**	

Table 5. Shows the learner's participation samples based on the year of the study in various engineering courses.

Table 5: Information of the learner's (student) participants in the survey

	1st year	2nd year	3rd year	Final year	Masters (MSc)	**Total (percentage)**
Samples (n= 1460)	380 (26.02%)	520 (35.61%)	365 (25%)	145 (9.9%)	50 (3.42%)	1460 (100%)
By major						
Civil	115	121	94	39	18	387 (26.5%)
Electrical	82	211	105	26	14	438 (30%)
Mechanical	50	88	25	21	8	192 (13.1%)
Instrumentation	35	40	66	16	4	161 (11.6%)
Electronics and communication	26	25	35	19	6	111(7.6%)
Aeronautical	22	15	30	8	--	75(5.1%)
others	50	20	10	16	--	96(6.5%)
SEX						
Male	196	412	255	98	42	1003(68.6%)
Female	184	108	110	47	8	457 (31.3%)

3.2 Results:

A quantitative analysis strand is used to analyze the responses received from both the participant groups. The items represented in Tables 1 and 2 are measured on a five-point anchored numeric scale, where 1 = 'strongly disagree' and 5 = "Strongly agree". In addition to that, a thematic comment section was also made available in the survey. However, it is restricted to the three numeric scales 1 (strongly disagree), 3 (neither agree nor disagree), and 5 (strongly agree) to know the reasons and also to gain deeper insight into the participant's reasoning behind their logical choices. Further, the academic participants based on their academic rank are anchored to a numerical scale where 1 = "lecturer" and 4 = "professor" to enable to perform correlation analysis, similarly, based on experience in academics, a five-point numerical scale is developed where 1 = "experience between 2-5 years", 5 = "experience more than 20 years" to gain a deeper insight of the academic perceptions towards the quick transition from FtF to online delivery of their courses. Another advantage would be in correlating their experience with the different constructs of the survey. SPSS 23.0 software is used to perform the correlation analysis. Pearson correlation coefficient is determined for each item in the survey and is presented in Table 6. On the other hand, learners based on their year of study have mapped to a five-point numerical scale where 1 = "1st-year student in bachelor program" and 5 = "Master student in MSc program" to enable to perform the correlation analysis. The student perceptions during the quick transition from face-to-face (FtF) to complete online learning is presented in table 7.

Table 6: Pearson correlation coefficient (r) values to identify the academic perceptions due to the quick transition from FtF teaching mode to complete online mode.

Construct	(item no: 1)	(item no:2)		(Item no: 3)	(Item no: 4)		(item no:5)			Mean ± SD
Questions	1	2	3	4	5	6	7	8	9	
Academic rank (r)	-0.76	0.27*	0.29*	0.53*	0.45*	0.47*	0.31*	0.74*	0.45*	3.01±0.96
Experience (r)	-0.56	0.57*	0.53*	0.33*	0.26*	0.29*	0.26*	0.75*	0.65*	2.96±0.98

Note: *p <0.001; and 95% of the Confidence interval (CI) has remained between the values 0.16 to 0.89 for all the items analyzed in the survey.

Table 7: Pearson correlation coefficient (r) values to identify the learner's (student) perceptions due to the quick transition from FtF teaching mode to complete online mode.

Construct	(item no: 1)			(Item no: 2)		(item no:3)	Mean ± SD
Questions	1	2	3	4	5	6	
Learner's perceptions (r)	0.26*	0.28*	0.56*	0.52*	0.39*	0.62*	2.67±0.95

Note: *p <0.001; and 95% of the Confidence interval (CI) has remained between the values 0.14 to 0.90 for all the items analyzed in the survey. *p

4. Discussions and Recommendations:

4.1 Academic perceptions:

The Pearson correlation coefficient (r) values range from -1 tp +1, where -1 indicates a strong negative correlation ship and +1 indicates a strong positive correlation ship between the chosen variables. Further either it is a positive or negative correlation based on the range of r values they are subdivided into three categories. The Pearson coefficient values (r) present between 1 -0.7 are considered as strong positive correlation, 0.7-0.5 are considered as moderate, 0.5-0.3 fall under the weak category, and less than 0.3 falls under the very weak category [Moore, D.S., et.al, 2015]. A similar approach is followed in the negative Pearson correlation coefficient values (r). In this study, All the item numbers in the academic perceptions have indicated a weak, moderate, and strong positive correlation except item no 1. Where Surprisingly strong negative correlation perceptions are seen to the academic rank and a moderate negative correlation ship is observed concerning the experience. The lower academic ranks such as lecturers have shown more confidence in their technical skills in contrast to the higher academic ranks. Upon analyzing the qualitative thematic responses of the higher academic ranks it has been observed that the rapid transition from an FtF to complete online has been stressful for them due to the limited time and availability of the on-campus support personals. A recent study [Hodges, C., et.al, 2020] has comprehensively discussed the difference between emergency remote teaching (ERT) and online learning. Both are different aspects and cannot be compared with each other. However, the possible requirement for ERT should become a part of the faculty member's skill set, and also in their professional development program and also in the risk register of the academic institutions.

The r-values of construct 2 (Awareness in assessment methods and mapping of learning outcomes) concerning academic rank is a very weak positive correlation. This indicates most of the junior and few mid-career faculty members are facing a lack of knowledge in adopting various assessment methods suitable for online teaching and learning. Engineering courses have a wide variety of learning outcomes to achieve in terms of design aspects, understanding and remembering, applying, evaluating, and innovation. Using the Same traditional assessment methods during the face to face learning is not effective in online learning. For instance, conducting an assignment that involves developing a new model or design right after posting the content discussed with few examples into the LMS (learning management system) is not an effective way of assessing the students [Kenzig, M.J., 2015]. Regular instructor active interaction (online forum discussions, online conferences, etc) with the students must be there to allow the students to practice on the development of the new model or design in pieces along with the instructor's feedback. On the other hand, the r-value concerning experience-based has shown a moderate positive correlation. Although a few faculty members despite having high academic experience in years are still under the first stage of the academic ranking tree(lecturers) due to the qualification limitations. However, they have demonstrated high confidence in knowing the suitable assessment methods adopted online as a result showing a moderate positive co-relationship with construct 2.

The r-values of Construct 3 (time management) concerning academic rank is a moderate positive correlation. The academic professionals having ranks Associate professor and full professor have shown positiveness in terms of availability of time to transit while the academic professionals with ranks Assistant professor and lecturers have shown lower positiveness. Analyzing the thematic responses of the survey participants has led us to conclude that this is mainly due to the higher teaching workloads for the ranks lecturer and assistant professor. [McCaslin, S. and Brown, F., 2015] study reports citing various references that the time required to teach a regular FtF course into a completely online format is almost double. Therefore academic professionals having a higher teaching load is a strong matter of concern that needs to be considered especially during emergency risk circumstances. Since some of the major advantages considered in FtF learning are better faculty interaction, student engagement, and collaborative learning [Paulsen, J. and McCormick, A.C., 2020]. Achieving the same advantages in online learning mode will remain as a challenge if the instructors are facing time management challenges.

The r-values of Construct 4 (teaching styles) concerning both academic rank and experience is a weak positive correlation. The thematic analysis of the survey participants has shown that this is due to the lack of professional development activities and the advanced infrastructure related to this area. Effective teaching styles play a very crucial role in the successful teaching and learning of online courses. Some effective strategies include dynamic presentations, lab tutorials, simulations, virtual labs, conceptual discussions, active interaction, and collaboration with the learners to support their knowledge developments and activities [Torrent, M., 2020], [Lager, I.E., et.al, 2020].

The r-values of construct 5 (remote labs and associated software packages) concerning both academic rank and experience are further categorized into three sub-categories 1) the presence of virtual labs 2) usage of simulation tools and 3) proportionate student number. The r-values for virtual labs concerning both academic ranks and experience fall under the weak to very weak category. Thematic analysis of the survey respondents has shown that no significant move has been taken towards establishing the virtual laboratories. [Sarac, V.J., et.al, 2020] study has reported the use of two virtual laboratories in the field of electrical circuits and electrical machines. This research study has demonstrated that students can achieve the same set of experimental skills as physical laboratories with easy access anywhere and anytime. They also reported that virtual laboratories are cost-efficient for those who are facing financial hindrances. However, lack of real-life delays (measurement errors) and skills to troubleshoot the real faulty equipment are still drawbacks in virtual labs. Questions 8 and 9 are framed based on understanding the reasons laid out by the semi-structured interview of the 6 faculty members belonging to various engineering disciplines. The interview lasted for ten minutes, mainly focusing on the methods adopted by them to conduct the engineering labs. the synchronous approach is observed from all the respondents where remote access has been provided to the institution lab computers, further assistance is provided by the lab technicians to facilitate student questions. However, student numbers have seen a bit of concern, because the labs with higher student numbers have seen a risk of long waiting times for their turn to run the simulation experiment. This is because of variation in the workload levels of the different academic ranks and is also evident from the r-values where a moderate positive correlation is observed concerning academic rank. However, a strong positive relationship is observed based on experience which is obvious that the high experience is likely to be higher academic ranks thus having lower workloads. On the other hand, the availability of the simulation tools has been observed with a strong positive correlation concerning both academic ranks and experience.

4.2 Learner's perceptions:

The r-values of construct 1 (Learner's readiness) for three questions have shown very weak to weak co-relationships. Thematic analysis of the survey data has resulted in learner's issues in three areas 1) access to the internet and IT devices (laptop) 2) complete knowledge/skills on LMS 3) language barriers. [Swart, A.J., 2015] study has highlighted the significance of having access to the internet, and complete technological skills in LMS, are the factors that contribute to the effective learning of the students. Language barriers also contribute to the process of effective learning as the student's weak English skills may prohibit them to ask more questions in online interaction sessions and thus causing the poor performance of the student. [Crawford-Ferre, H.G., 2012] study noted that language barriers are also another factor in poor performance and engagement during the online mode of study in contrast to the regular support they would receive during normal FtF studies. All students have different backgrounds with a different atmosphere to study from their living places, for instance, some students live in very remote locations where accessing to internet and other IT infrastructure is very challenging for some students, and it may not for other students. Similarly, financial support to afford the internet data packages, IT infrastructure may also be very challenging for some students. When students study on-campus they have equal opportunities towards the infrastructure and other challenges that might be very difficult to achieve when they study from their living places. Therefore, supporting students with extra data packages, and minimum IT infrastructure could be a good strategic plan by the government to provide equal opportunities to all the students irrespective of their backgrounds.

The r-values of construct 2 (Effective content design) have shown moderate to weak relationships. Proper attention is needed during the transition of an FtF course to online teaching. [Koehler, M.J., 2004] study has noted that the same FtF content cannot be copied and used in online mode. Applying course redesign strategies and integrating technology tools enhances online learning. Further, it also helps in the reduction of costs and increases retention rates of the students [Abernathy, Dixie F. et.al, 2020]. The instructors are encouraged to take into consideration the technology, pedagogy, and appropriate content when designing online courses. usage of multimedia tools such as animations, videos, simulations, and design practices are all the contributing factors in enhancing learning in engineering courses [Hoic-Bozic, et.al, 2008]. The r-values of construct 3 (active participation) have shown moderate co-relationship. Nonetheless, few strategies and recommendations (such as active collaboration, student-faculty interaction, rich educational experience, and supportive off-campus environment) have been presented to instructors and high-level administrators to keep up the student engagement [Meyer, K.A., 2014]. Learners must be continuously engaged and made sure that their individual learning experience is made more fun, innovative, and analytically thinkable to the problems they observe around them. Most of the time traditional FtF learning style may not be effective in achieving them, some learners enjoy learning by simulations and experiment (i.e. test and observe) for the practical part and some by animations, video for theoretical form, and also discussion plays a very crucial role in improving the learner's satisfaction. Therefore adopting various evolving ICT technologies where possible and continuously modifying the teaching methods and collecting feedback from the students all contribute to improving the overall learners learning experience, motivation to learn, and most importantly student satisfaction.

4.3 Role of administrators:

A research study [Lemoine, P.A., and Richardson, M.D., 2020] highlights the significance and need for appropriate planning by administrators that have been missing in the traditional higher education institutions to tackle the pandemic risks. It also highlights that traditional higher educational institutions have to offer something more than online education institutions because if students would have just opted for online education, they wouldn't be enrolled in traditional institutions. Another research study [Bokolo Jr, A., et.al, 2020] has proposed a strategy and framework on how to diffuse the blended learning education slowly into the institutions after surveying about 223 administrators working in different higher educational institutions. The faculty and students are not only the ones to make successful online education and learning. Even, Administrators or high-level managers of the institutions have also a very crucial role in adding success to it. There are some roles where administrators can only satisfy. Such as funding faculty development, maintaining the quality of the online education, deploying and supporting the required infrastructure to deliver the online courses effectively, help the students in their concerns causing the hindrances in their learning whether be it in social, technological, or economics matters. Based on the results obtained in this research study, the role of administrators can play a very positive correlation to handle the difficulties, improving the gaps identified during the remote teaching and learning. The correlation results for each item question rated by the respondents are given in table 8. In the academics section, item no: 5 (virtual labs) has been obtained very weak to weak positive correlation. This means most of the respondents have disagreed with the virtual lab facilities available in their corresponding institutions and thus this item no was given high priority i.e. rank 1 and the respective recommendation which administrators can help in improving this identified gap. Similarly Item no: 3 (Time management) has obtained a moderate positive correlation, which means most of the respondents have agreed that they had enough time to make transition and thus ranked IV. On the other hand, in learner's perceptions item no: 1 (learner's readiness) has observed with very weak correlation and thus ranked 1. This somehow reflects that the support or training needed to understand the technology was missing in their respective institutions. Therefore, training sessions must be conducted at a regular pace for the students to understand the technology systems that are available in their respective institutions.

Table 8: Recommendation to administrators based on the correlation results observed in this study.

Questionnaire construct item no:	Correlation results	Priority Rank	Recommendation mapping below:
Academics			
Item no: 1	Academic rank: strong negative	Rank V	1
	Experience: moderate negative		
Item no: 2	Academic rank: weak positive	Rank III	4
	Experience: moderate positive		
Item no: 3	Academic rank: moderate positive	Rank IV	5
	Experience: moderate positive		
Item no: 4	Academic rank: weak positive	Rank II	6
	Experience: weak positive		
Item no: 5	Academic rank: very weak to weak positive	Rank I	2
	Experience: very weak to weak positive		
Learner's			
Item no: 1	Learner's perceptions: very weak to weak positive	Rank I	3
Item no: 2	Learner's perceptions: weak to moderate positive	Rank II	6
Item no: 3	Learner's perceptions: moderate positive	Rank III	2

4.4 Recommendations:

1) Effective online teaching skills, Assessment methods, teaching styles, content creation, and mapping learning outcomes. Faculty members sometimes get dependent on the support of the administrators to acquire them. For instance, providing subscription access to high-quality journals and magazines where the latest and best practices are documented. Conducting workshops on-campus by inviting experts or encouraging faculty to attend such workshops where they occur. These all should be part of the faculty annual CPD's (Continuous Professional Development) program.

2) Building and maintaining necessary Infrastructure, provide training of technical skills for both faculty and students. Successful online education and learning need a supportive technical infrastructure in place. This includes a learning management system (LMS), IT infrastructure, virtual labs, content or media creation tools, etc. on the other hand, technical skills in using these resources effectively also play a major role in the success of online teaching and learning.

3) Establishing a Student Support Center. Effective student engagement is another KPI (Key performance indicator) to measure the quality and success of online education and learning. Generally, students face various issues where faculty may not be able to address all of them, such as economic issues, social problems, technological and language barriers, etc. Having dedicated personals in the support center to address the

student grievances or appointing the volunteers or generally termed as peers per course are all good practices to enhance online teaching and learning.

4) Funding research in online education and the environment. Administrators should consider funding research projects (even if small budget) in the area of online education and learning. Generally, faculty provide merits to research and also learn from it. It is not just faculty, even other audiences such as various administrative departments in the institutions, and even students can benefit from the findings of the research conducted and thus might be helpful in overall improvements in the quality.

5) Effective workload allocation and time management. Both principles play a very crucial role in maintaining and improving online teaching and learning quality. It is evident from many online instructors that the amount of time required to construct, teach an online course is higher than the FtF courses. Therefore, effective policies need to be developed, deployed, and improvised regularly to balance the concerns reported by the students and faculty members.

6) rewarding incentives for innovations in online teaching and learning. Recognize and awarding the individuals (either it is for faculty, volunteers, or peers, high performing students) for their exceptional efforts made in the online teaching and learning process. For instance, promotion decisions for the faculty in their annual appraisal. Financial discounts to the high-performance students or even certificates of appreciation for the volunteers will all add a positive encouraging boost in the performance of their respective roles and thus contributing to the effective online teaching and learning process.

4.5 Comparisons and a Way forward

In general, the teaching and learning practices in engineering colleges differs from region to region and institute to institute based on its establishment, funds availability, research performance, and the type of students. For instance, a research study [Dziuban, C., et.al, 2018] conducted in the USA has shown that blended education in various courses has shown better results in overall performance (grades) of the students, student retention rates, and strong desire to take such courses rather than taking courses which are completely following Ftf approach and only online modes. Another interesting study [Wu, T.T. and Wu, Y.T., 2020] showcased how project-based learning has improved creativity and critical thinking in high-creativity learners and low-creativity learners. The current teaching and learning practices in the sultanate of Oman majorly constitute the FtF approach combined with the usage of learning management systems (LMS) technology. However, since the outbreak of the pandemic, it is evident that the existing teaching and learning methods were not sufficient to handle the occurred risk effectively. Lacking continuous innovation in teaching and learning methods, lacking continuous professional development for both faculty and students, and failing to adopt the evolution in the new technologies are seen to be the major problem for the low confidence shown during pandemic risk. A case study [Ożadowicz, A., 2020] presented how modifying the blended education system in engineering higher education has been very effective in tackling the pandemic risk effectively. The authors recommend adopting the blending education system by utilizing the latest information and communication technologies (ICT) for content creation (videos), online discussions platforms, self-learning, virtual lab infrastructure possibilities, assessments (tests and quizzes) where possible to at least some of the courses as a starting point. Regular Innovation and modifying the course teaching and learning methods can help to build a rigid engineering higher educational system that can not only handle the pandemic risk effectively if occur in the future but also helps in improving the overall standards, quality of educational experience as a whole.

5. Conclusions:

This study has used mixed methods to address the challenges faced due to emergency risk (COVID-19) in engineering education. One of the main challenges is the rapid transition to complete online teaching and learning modes from blended/asynchronous online teaching and learning modes. Academics have observed challenges in terms of technological skills, teaching styles, time management, virtual labs infrastructure availability, and Assessments skills. Learners have seen difficulties in access to online resources such as the internet and IT devices, lack of training support in using technological skills effectively, and suitable assessment methods. Further recommendations to the high-level administrators are also discussed to improve online education quality.

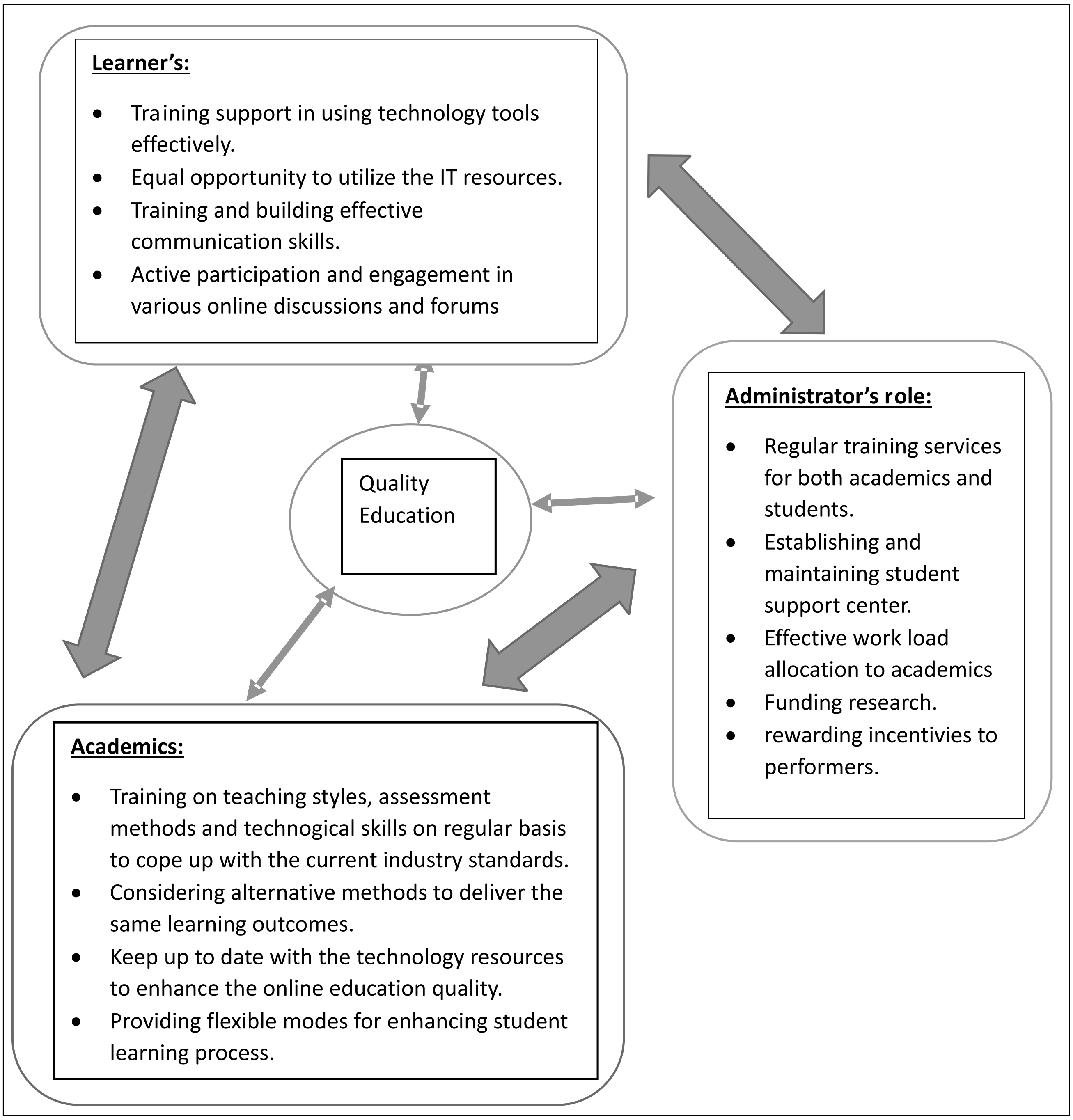

Fig. 3: Factors that need to consider in tackling emergency risks effectively in three major categories and also contribute to achieving quality education

The other important aspect of this research study is also to identify the factors that need to be incorporated into engineering education in regular such that any future emergency risks can be handled in confidence. Those factors are aligned with cooper's framework and are presented in figure 3. Therefore, the recommended factors are hoped to be adopted by the education institutions as a part of CPD for all three major categories and thus become robust to handle any kind of emergency risks if occur in the future and also to improve the overall quality of the education.

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