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A Roadmap to overcoming the Challenges of Cyber Security and Forensics Education in the age of distance learning and the COVID-19 pandemic

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Abstract—This paper focuses on developing a pedagogic roadmap to overcoming the challenges of delivering cyber security and forensics education in colleges and universities through distance learning during the COVID-19 pandemic. The research in this paper identifies the challenges associated with distance learning, teaching and assessment in the Sultan of Oman. The research evidence was gathered through educational practice at the Global College of Engineering and Technology (GCET), in the Sultanate Oman; and this research and pedagogic reflection acts as a case study for developing the pedagogic roadmap. The validation of evidence for the strategies suggested, and outcomes revealed and used at GCET, is through student feedback and questionnaires and satisfaction surveys. The adopted strategies enabled students to continue their learning during the pandemic. The strategies are validated with student satisfaction survey results, independently conducted by the college, which cover teaching and learning methods, assessment strategies, and overall satisfaction.

Keywords—Cyber Security and Forensics Education, Online Teaching, Online Learning Platforms, Virtual labs

I. Introduction

The World Health Organisation (WHO) declared COVID-19 a pandemic on 12th March 2020 [1]. As we all know across the World, the pandemic seriously affected the life of individuals and provided a seismic shock to higher education. On 15 March 2020, the Sultanate of Oman announced a two-week lockdown and postponed all activities in the country; and later enforced a lockdown extended for another two weeks from 29 March 2020 which was further extended. All campus based educational activities were banned until august 2021 [2]. This was a drastic shock and shift in stability for many of higher educational institutions in the Sultanate of Oman, particularly, as 90% of the higher educational institutions in the Sultanate were not prepared for this transition. The majority of institutions were not previously allowed to deliver distance learning. Hence, students were adversely affected in the early stages of the pandemic until the higher education institutions found some time, stability, and confidence to deliver 100% online learning and teaching. The Ministry of Higher Education Research and Innovation (MoHERI) announced that all classes for the academic year 2019-2020 would be conducted online and all campus-based teaching and learning activities moved to online learning and teaching which was further extended to academic year 2020-2021.

Globally, all countries were badly affected by the pandemic. Consider the United Kingdom where the pandemic led to a dreadful impact with UK universities estimated to lose about £790 million in income as universities were unable to make the revenues from accommodation, catering services and conferences [3]. Similarly, in the United States of America in 2018-2019 the revenue generated from the halls of residence, summer camps, and bookstores, was $44.6 billion which decreased to half about $25.3 billion during the first year of the pandemic [4]. Most higher education institutions were struggling to find the resources to pay their staff and to fund research programmes. Moreover, in the next few years, the economic recession will likely limit thousands of students to enroll in higher education. About 20 million people are thought to have lost their jobs in United States of America (USA) in April 2020 [5]. A similar situation happened in the Sultanate of Oman, according to the National Centre for Statistical and Information where 215,000 expat workers left the country from March 2020 to March 2021. The expat workforce numbers fell from 53,332 to 49,898 in the government sector and 1,608,781, to 1,403,287 in the private sector, which directly affected the international student population in the country [6].

II. GCET and Cyber Security Education

The Global College of Engineering and Technology (GCET) is the pioneer in the Sultanate of Oman offering BSc (Hons) Computer Security and Forensics with the partnership of the University of the West of England Bristol, in the United Kingdom. As cyber security is a highly technical programme that combines a mixture of teaching methods, and student engagement activities, starting from formal lectures, practical classes, tutorial sessions, workshops and student led sessions. GCET also encourages students to engage in peer-to-peer review to provide formative feedback on each other's work. Before the COVID-19 pandemic,

GCET was delivering programmes from offices and classrooms on campus; and students were able to attend the live sessions from home as well using the Learning Management System (Blackboard) to access learning material and recordings of lectures. Due to the nature of the program the learning and teaching of BSc (Hons) Computer Security and Forensics is a mixture of theoretical and practical knowledge of cyber security and digital forensics; with the aim of producing ready-for-work graduates. COVID-19 affected the BSc (Hons) Computer Security and Forensics delivery in a number of aspects with respect to teaching practices, assessment strategies, and student learning opportunities.

III. Teaching Practices, Assessments Strategies and Challenges

As per MoHERI restrictions, students were not permitted to access or attend the campus for learning and teaching which limited their access to computer security and forensics labs. This forced the College to make significant changes in assessment strategies, and teaching and learning practices, to overcome the challenges which were:

1) Moving from campus based practical sessions to online practical sessions which forced students to upgrade and install sophisticated software to perform practical sessions.
2) However, in the case of theory sessions, there was a smooth transition as the college has been using Blackboard for live sessions since 2017; and all the sessions are recorded which enables students to have access to lectures at their own convenience.
3) The BSc (Hons) Computer Security and Forensics program consisted of different types of assessments and due to the practical nature of the program, one of the key challenges was how to manage the student's practical coursework which they normally perform in the computer security and forensics labs.
4) Another main challenge was to conduct assessments of different types, such as, in class tests of 1-2 hours to perform a practical task, or group work, which includes a report with demonstration, court visits, along with follow up reports and controlled-condition examinations.
5) Working in groups became another main challenge for students to perform their group/pair coursework, due to restrictions in the Sultanate with social media applications, such as, WhatsApp. One of the key challenges was how to provide support to students so they could work in groups remotely.

IV. Infrastructure and Technical Challenges

The delivery of Cyber security education heavily depends on the infrastructure of the college. Students normally perform their work in laboratories. Due to the nature of the security and forensics program, all laboratories supporting such programs are normally, and technically, isolated from the rest of the laboratories in the institution. So, students can perform practical exercises without harming other systems and laboratories in the institution. In the case of GCET, before COVID-19 students had physical access to their laboratories which allowed them to use sophisticated software, such as, 'Encase' that enables students to work on operating system images to perform the forensics investigation. Encase was accessible only from the campus, but it became a challenge to how students would be able to access these laboratories and software applications remotely. This transition to fully online delivery on the BSc (Hons) Computer Security and Forensics program presented technical challenges with many students asking for heavy support to enable home-based software installation so they could perform practical sessions at home.

V. GCET Strategies for All Engineering and Technologies Programs

Based on the guidelines issued by the Ministry of Higher Education Research and Innovation (MoHERI) decision to suspend all the campus-based activities at all higher educational institutions in the Sultanate, the college management conducted an urgent meeting with all academic Heads of Department to implement a contingency plan. It was decided that GCET would move to fully online delivery with immediate effect; and all the sessions (lectures and laboratory) were to be recorded. The Department of Computing and IT (CIT) adopted the contingency plan to support BSc (Hons) Computer Security and Forensics staff and students. The strategies were divided into learning type, usage of LMS, assessment methods, student engagement, conducting presentations, and group coursework.

A. Learning to Type

All the learning and teaching sessions were online, and recording was able to take place without any interruption using Blackboard. It was decided that all the classes would be conducted as per the timetable schedule without combining classes for a smooth transition. GCET provided the necessary infrastructure to staff to support them to smoothly deliver modules from their home without any hurdles; by making sure that students could access live and recorded sessions using Blackboard.

B. Learning Management System

GCET at the time was using Blackboard as its Learning Management System (LMS) which enabled staff to use 'Blackboard Collaborate Ultra' to conduct live sessions with access to some unique features, such as, group discussion and meeting; with lecture recordings shared with students after the class using the students Blackboard account [7].

C. Group Coursework and Demonstrations

Group coursework and demonstrations were one of the key challenges faced by GCET and all higher educational institutions in the world. GCET was able to provide a Blackboard Collaborate Ultra dedicated link to each group which they used to conduct the online meetings to perform group activities. Since 20-25% of the population in the Sultanate has slow internet connection issues which can affect the students' performance during demonstrations, It

was decided that recording of individual or group demonstrations could be done using Blackboard Ultra, giving the presenter access to students; along with usage of Kaltura which was used to capture the presentation and suitable to individual presentation. Blackboard Collaborative Ultra was most suitable for group based coursework presentations and demonstration [7].

D. Assessments Strategies

There was a need to make the necessary changes in assessment style and approach in the first semester during the pandemic. The Head of Department conducted meetings with the module leaders to come up with the necessary changes in assessment practice, resulting in 24-hours take home examinations. It was decided that examinations would start at 10:00 AM and end at 10:00 AM (24 hours later) which allowed students to download the examination paper and solve questions within defined time intervals. The results were then uploaded to Blackboard via a secure submission link. Similarly, in class tests, these were moved to online tests. Students used Blackboard to perform the online tests in a specific time-period.

E. Students' Engagement

Shifting to online learning and teaching in a short time forced the department to deal with the challenge of student engagement. Keeping in mind the fact that online learning and teaching can affect student engagement (especially first year students), GCET used innovative tools such as 'Mentimeter' and 'Kahoot' to ensure student engagement during the live sessions [8-9]. Considering the cultural aspect, some of the students appeared shy in asking questions during the live sessions. But, with the help of these tools, it was possible for students to ask questions during the sessions by typing the questions and lecturers were then able to answer questions privately during the class which boosted the student's engagement levels while studying online.

VI. Strategies to Delivery Security and Forensics Programme

The Department of Computing and IT (CIT) adopted all the GCET strategies along with some extra steps to support the smooth delivery of the BSc (Hons) Computer Security and Forensics program by providing additional laboratories and the software's access to student homes.

A. Assessments Strategies

Meetings were conducted by module leaders on the program to ensure the necessary changes were effective to enable all assessments to be scrutinized before they were conducted online. Table I shows a comparative analysis of assessment strategies on the program, pre-pandemic and during the pandemic.

TABLE I. BSc (Hons) Computer Security and Forensics Assessment Strategies During Pandemic

Module Code	**Module Name**	**Pre-pandemic assessments**	**During pandemic assessments**
UFCEXX-30-0	Program Design and Implementation	• Portfolio of Programming Exercises • Control Condition exam 1 and 2 (CC1 and CC2)	• No Changes • Online exams
UFCF93-30-1	Computer and Network Systems	• Library Exercise • Programming Assignments (1 and 2) • Control Condition exam 1 and 2 (CC1 and CC2)	• No Changes • No Changes • CC1 and CC2 were changed to online, and type of assessment was modified from completely MCQ's based exam to essay and intellectual thinking type questions with 20% weight of MCQ's
UFCFP4-30-1	Computer Crime and Digital Evidence	• Technical report. • Portfolio	• No Changes • No Changes
UFCFW5-30-2	Mobile and Embedded Devices	• Group assignment 1 and 2. • Control Condition exam 1 and 2 (CC1 and CC2).	• No Changes • Online exams
UFCFJ6-30-2	Security and Forensics tools	• Individual written report on a forensic case study. • Pre-recorded presentation of the analysis, evaluation and demonstration of a security based tool. • Series of in-class exercises.	• No Changes • No Changes • In-class exercises were conducted using on line LMS.

B. Practical Sessions

One of the biggest challenges in the delivery of the BSc (Hons) Computer Security and Forensics modules was to conduct the practical sessions online with surety that all students have equal access to the required infrastructure and software. Providing security and forensics laboratories from the campus-based isolation to student homes was one of the main challenges. But it was essential to enable students to perform their lab work during their designated timetable period without any hurdle. The Department took the necessary steps to provide safe and secure access of these labs remotely; and the necessary actions were taken to make sure that students could have access to the required software to install on their own computers.

C. Technical Support to CIT Students

The Department of CIT ensured that all students could get the free software applications, and support for their modules, such as, Encase and X-Ways security. Forensic tools access was limited to campus-based activities; and the necessary actions were taken to ensure that students could have access from home; and could run applications from their computers and laptops at home. A dedicated helpline was arranged by the Department to provide technical support to students from 8:30 AM to 4:30:PM each day, which enabled students to have labs and software access and advice.

D. Support Sessions

The Department of Computing and IT decided that extra support sessions would be conducted for students who were facing issues related to poor-connections, or not adjusting culturally to fully online delivery. Module leaders of each module in the department dedicated 3 hours per week to provide question and answer sessions for students. These support sessions were very helpful, and students were able to clarify their doubts which helped students maintain their engagement in their studies.

E. Programming Modules

Programming is an integral part of the computer science suite of programs. All the computing programmes, including cyber security and forensics, consist of programming modules. However, programming modules on generalist computing programs were less challenging in online delivery as compared to security and forensics practical modules. Module teams were using different online programming tools such as C++ Shell, Cppinsights and Codiva.io [9-10]. As these compilers do not require any special environment, it was a very smooth transition to have online lab sessions for all programming modules.

VII. GCET Cyber Security Education and Student Satisfaction

During the first week of moving to 100% online teaching and learning, a survey was conducted by the college Quality Assurance and Compliance Office (QAQO) regarding the student satisfaction with online education. The results indicated a satisfaction rate of 59%, which was disappointing, given the high level of student support provided during the pandemic. The reasons for this low score were that students considered that they were not ready for fully online learning and teaching. It was too much of an immediate shock. Based on student feedback, and factors which were affecting student performance, the college came up with strategies to help students better engage with their program. This helped to increase later student satisfaction with online delivery to 88% within a few months.

Table II shows the BSc (Hons) Computer Security and Forensics modules student satisfaction rates for the academic year 2020-2021 with respect to teaching, learning, assessment, and overall satisfaction.

TABLE II. BSc (Hons) Computer Security and Forensics Modules Student Satisfaction Rates

Module Name	Teaching Methodology	Learning Methodology	Assessments	Overall Satisfaction
Program Design and Implementation	89%	79%	76%	85%
Computer and Network Systems	95%	77%	95%	90%
Computer Crimes and Digital Evidence	88%	88%	77%	85%
Mobile and Embedded Devices	80%	77%	80%	80%
Security and Forensics tools	92%	100%	75%	77%
Average Satisfaction	89%	84%	81%	88%

The student satisfaction survey shows that the college and department strategies helped students to achieve the same level of quality and delivery during the pandemic as pre-pandemic. The survey showed that 89% of students in the Department were happy with the online learning and teaching methodology (after adjustments were made to pedagogic practice), 84% satisfaction was noticed in student learning methods, 81% students were happy with the assessments. While overall satisfaction increased to 88%. This was a remarkable achievement, justifying the effort and work put into supporting students during the pandemic by the academic department.

VIII. Conclusion and Recommendations

This paper provided an experiential roadmap to overcoming the challenges of delivering cyber security and forensics higher education, in the Sultanate of Oman. The study investigated the challenges associated with online cyber security education, delivery, and implementation, by Department of Computing and IT at the Global College of Engineering and Technology (GCET), in the Sultanate of Oman during the COVID-19 pandemic.

The first and foremost recommendation is that governments should take the necessary actions to provide the stable internet infrastructure throughout so rural populations, such as those in the Sultanate, can have the same equality of internet connection and access as urban students are getting. This would enable students to study without the adverse effects of poor connectivity.

Secondly, to deliver online programs, particularly cyber security and forensics education, the students offer unique perspectives regarding the switching to 100% online/distance learning delivery. It is possible that the Sultanate of Oman and other countries should think about the scope of online and blended education and allow higher educational institutions to run all academic programs using a variety of blended and distance modes of study. This would broaden the academic landscape of higher education in the Sultanate of Oman, and other countries, providing higher levels of equality, particularly enabling international students to join programs at their convenience [11].

Thirdly, moving to online learning and teaching raises some infrastructure issues for the college and department. Higher education institutions sometimes have limited ICT resources, and the pandemic has put additional pressure on these resources. During the pandemic period many higher education institutions are investing and making efforts to upgrade the ICT infrastructure, but there is a potential need to put significant attention to upgrade infrastructure which can ideally consider supporting online learning and teaching on a sustainable basis. There is a need to have regular and curriculum embedded virtual labs for cyber security and forensics education as part of the variety of approaches to cyber and forensics education.

The research from student feedback in this paper regarding online learning and teaching suggests that the Sultanate of Oman higher education system may need to re-focus on supporting and promoting online learning and teaching which include, improving technical skills, and developing the training programmes to help lecturers and instructors re-model and adopt modern and researched online learning and teaching styles.

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