# Flexible Learning during Educational Disruption: A Case Study of Teaching Integrated Circuits Design

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***Abstract*—To date, there has been little written that explains how engineering-related tuition can be rapidly and effectively moved online. Furthermore, there is sparse literature written that focuses on how students can adapt to such technologies in a relatively short space of time. Finally, it is both necessary and prudent to increase discourse on the effective online teaching of technical design subjects. This paper evaluates the effectiveness of online tools such as interactive live lectures, slide annotation, and electronic whiteboard, for engaging students in electrical and electronic engineering education. The paper advances those debates by providing an evaluative analysis from the perspective of students taking an Integrated Circuits design module that was delivered during the 2020 COVID-19 crisis. The major research question is: to what extent do electrical engineering students perceive online learning tools to be useful in enhancing their sudden learning change? Responses were collected using an online questionnaire that was offered to 23 students who enrolled in the module, and a 70% completion rate was received. The findings showed that students engaged well with the technologies, and they found them easy to use and beneficial for their learning.**

***Keywords—Flexible engineering education, online learning, interactive teaching.***

## I. INTRODUCTION

In this paper, a case study of an online approach used in engineering education is presented in the context of a requirement for moving rapidly from regular face-to-face teaching to online processes.

There has been little published on how the use of technology has assisted the educational community during the sudden crises [1], though some work has now been undertaken as the crisis has deepened [2]. The aim of the research presented in this paper is to add to this body of knowledge by investigating students' engagement with – and perceptions of – the online tools used in the delivery of an engineering module. The paper outlines what was done, why, and gives some indications around students' reactions to the actions taken.

It begins with an overview on the general e-learning approach at the institutional level, discusses some enhancements to that approach and then provides a case study of synchronous online teaching of the integrated circuits and systems module. The present work was undertaken in order to investigate students' preferences around various interactive pedagogic tools used in an online setting hence the paper presents findings into such questions and concludes with some thoughts looking forward.

## II. UNIVERSITY GENERAL APPROACH IN RESPONSE TO COVID-19

The Coronavirus outbreak, later known as COVID-19, became a serious issue in China around the Chinese Spring Festival in 2020 [3]. Strict measures were immediately implemented by the Chinese government, leading to major challenges for teaching institutions worldwide. International institutions in China struggled to educate students both in China and overseas; particularly, after international students were restricted from returning to the mainland. Such restrictions were also applied to international academic members of staff. [4]. This meant that from January 2020, e-learning became a mandatory requirement in many institutions [5-7].

As a result, significant achievements were made in e-learning, despite the implementation challenges that have endured since 1990 [8-9]. In an attempt to overcome the challenges posed by COVID-19, the university's general approach was to request that, as a minimum, educators should upload some form of lecture slides with audio commentary, either using Panopto or by adding voice notes to existing materials such as *PowerPoint* (PPT) slides. Thus, recorded lectures became the fundamental element of an e-learning approach [10-14]. The recorded videos together with the lecture notes were uploaded to the official Learning Management System (Moodle).

Within the Faculty of Science and Engineering (FoSE) at UNNC, there were two additional challenges for programmes: 1) the requirement for accreditation and 2) the nuanced nature of engineering education, which typically requires interactive learning [15-16]. This approach facilitated legitimate concerns regarding student-faculty interaction (crucial for learning design methods) and around student engagement; specifically, would students refuse to engage with the materials in spite of the of the advantages brought by a higher degree of flexibility and autonomy?

The faculty response was to use additional learning facilities for electronic teaching delivery at UNNC, as listed below:

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- Moodle, a *learning management system* (LMS), that enables the distribution of lecture notes, online videos, fora, online example sheets, amongst others.
- MS-Teams together with Moodle for providing instant interaction with students and allowing the integration of additional *MS-Office* tools such as (*SharePoint*, *Outlook* and *Forms*) as well as multiple applications including *Zoom* and *Panopto*.
- The online video meeting application, Zoom, to provide live tutorials but not lectures. Features including screen sharing, public and private chat, polls and breakout rooms, provide opportunities for possibly increasing student interaction and attention.
- Panopto and MS-PowerPoint can be used together with Zoom for the purposes of delivering and capturing lectures. Lecture videos can be split into several MP4 files, each of a reasonable size, to overcome variations in network speed and network quality.

## III. Online teaching adjustments in an engineering module

### A. *Module Details*

The effectiveness of the described flexible approach to e-learning, during Covid-19, can be examined through a final year electrical and electronic engineering module, entitled 'Integrated Circuits and Systems'. It was offered to students from two different programmes within the EEE department, BEng in Electrical Engineering and BEng in Mechatronics Engineering and was taken by 23 students. The module contributed 20 credits out of a total of 120 credits students needed to obtain in the final year.

This module was taught in the spring semester and included 3 components, one of which was '*digital very large scale integrated'* (VLSI) circuit design, and this was the major component of the module, corresponding to 50% of the module content. The module content included both theoretical and practical aspects, and involved numerous equations and drawings; many of them precise coloured layout drawings. One quarter of the module assessment comprised of coursework, which required students to analyse, design and simulate different levels of the circuits.

### B. *Standard Module Delivery*

According to the module specifications, the VLSI module content required a weekly lecture and seminar. In teaching the subject, the instructor needed to explain the relationship between the circuits at various levels, including architectural, transistor and layout – and this requires interactive teaching illustrated by annotations. To perform the coursework, the students have previously used a freeware tool, which could be run on lab computers or the students' own PCs. Office hours would be announced to students and would normally be conducted through a face-to-face appointment. The timetable of the course is arranged and announced before the semester starts.

### C. *Module Delivery under Covid-19*

Flexible methods of delivery were implemented within the VLSI content, which covered a digital integrated circuit analysis and design at the architectural, circuit and coloured layout levels. A synchronous e-learning approach was used in order to improve the effectiveness of the delivery [17-18]. This approach included the annotation of teaching material, live lectures, and one-to-one tutorials [19-21]. Three further items were added:

- A tablet (MS-Surface) was used to deliver live webinars on Zoom. Synchronous teaching was used when delivering both lectures and seminars. Digital ink helped to use the digital whiteboard smoothly and replaced the physical classroom whiteboard.
- In planning for an interactive online teaching approach, the module convenor decided to maintain the contact hours of teaching sessions as per the original timetable, though online rather than in a physical classroom.
- Informal opportunities for students to discuss modular issues ('Office hours') were arranged upon request, either through chatting by text, or using audio/video short sessions for further interactive discussion. Discussions between the module convenor and students took place privately on MS-Teams platform to enhance students' engagement and as a way of providing pastoral care.

### D. *Lecture preparation during the outbreak*

Before the module teaching started, a page on Moodle was created for uploading the teaching material. For this particular semester, a Team specific to the module was created by the module convenor on MS-Teams. All students were enrolled in the team and the invitation was confirmed by email. All module announcements were published through both Moodle and MS-Teams, but there was more interaction on the MS-Teams platform where it was observed that students would share the announcements, comment on them and mention the module convenor and each other.

An interactive approach was deemed to be the best approach in teaching the VLSI subject. 26% of the students who attended the module were international students from 5 countries and time-zones other than that of Mainland China. Fortunately, these were all Asian countries and the time difference was no more than 2 hours. The remaining students who enrolled in the module were domestic students from across different provinces. In the first teaching week, a student rep was nominated by students to facilitate the communication among the students and the convenor. PowerPoint lecture capture was used for lecture video recording and it was found to be of a reasonable resolution because the generated video file size was not excessively large for online uploading and viewing when compared with other lecture capture software. Each lecture was split into smaller sub-files because the quality of the offsite network facilities might vary where students were located, both domestically and abroad. Each file was 10-15 minutes long and no larger than 30 MB.

The videos of each lecture together with the lecture notes were uploaded to Moodle at least one week in advance to help students prepare for the lecture. The students used their own devices and internet connections to access the teaching material and engage in the live classes. All students confirmed that they were able to watch the uploaded videos smoothly. The virtual classroom was booked on Zoom and the invitation was sent to all students through announcements on both Moodle and MS-Teams, and a meeting invitation was sent through the MS-Exchange calendar.

### E. Online lecture delivery

The timetable that was announced before the COVID-19 outbreak was followed when conducting all of the teaching sessions of the spring semester. The weekly two hour lecture was maintained, with the lecture time adjusted to start one hour later than originally planned to accommodate students in all time zones. The live lecture was conducted through Zoom, benefitting from its various features such as, group and private chat, whiteboard, polls, raising hands and other features. To mitigate some internet speed issues experienced by students, the streaming was deactivated from the students' side while lecturing. Students were asked whether they had questions or comments after each topic. They were also encouraged to interrupt the lecturer when they had urgent questions. The lecture slides were annotated during the lecture using electronic ink, thus replacing the physical smartboard as shown in Fig. 1. After the lecture, the annotated slides were shared with the students to help them remember the discussion during the class. The electronic whiteboard was used in each session to further illustrate some of the design issues.

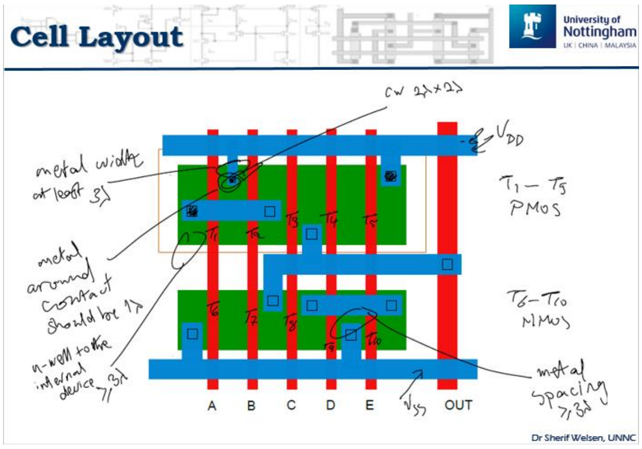


Fig. 1 An example of slide annotation during the online live lecture

### F. Tutorials and problem solving

The pre-planned timetable was also followed for delivering tutorial sessions. In addition to the official group tutorial, one-to-one tutorials were used when necessary and were deemed particularly important after the lecture sessions. Usually, few students requested the private tutorial, which was not noticeably different from face-to-face teaching. Synchronous sessions through Zoom were used for conducting tutorials in a manner similar to lectures, as opposed to using the electronic whiteboard. The tutorials were focused upon problem solving and answering questions from students. In order to increase students' engagement, problem sheets were issued as weekly quizzes that followed each lecture. Students were asked to submit the answer through MS-Teams, then during the tutorial the whole set of problems were solved in detail. After each quiz, the whiteboard view was saved and shared with students. A purposeful space was left blank on the right to give students the freedom to make their annotations, as shown in Fig. 2.

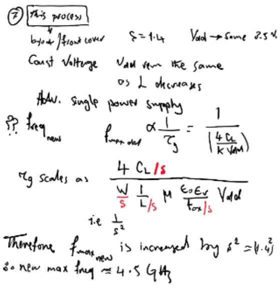

Fig. 2 Problem solving through the electronic white board

One-to-one tutorials were also conducted through MS-Teams and these were usually initiated by a request from students after annotating the teaching material, or even double annotating the annotated slides. Such close contact with the students seemed to be a great way of growing students' confidence because they used the tutorial not simply to ask about topics they didn't understand, but on many occasions, to emphasise what they had learnt. An example of a personal tutorial discussion topic is shown in Fig. 3.

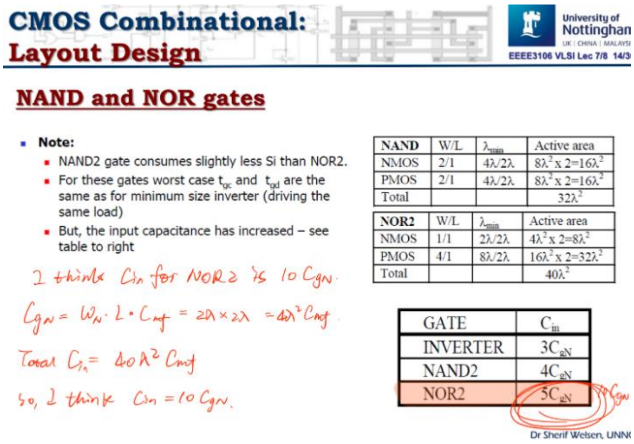


Fig.3 Students' annotation of teaching material during the online one-to-one tutorial

## IV. METHODOLOGY

The current study is attempting to determine the extent to which electrical engineering students perceive various online learning tools to be useful in enhancing their sudden learning change. In this study, a questionnaire was given to all 23 students who enrolled in the module and it was completed by 16 participants. Students answered questions regarding the helpfulness of the method of teaching, the helpfulness of the teaching method and technology, student engagement and student preferences.

The invitation to participate in the survey was sent to all students as an announcement on MS-Teams, with a follow up reminder. Whilst 78% of the students who enrolled in the module responded to some of the survey questions, 69% completed the full questionnaire. The responses were analysed using simple statistics together with the responses from the open question fields to derive meaning from the results.

## V. FINDINGS

The survey questionnaire responses are described in the following paragraphs.

During an intervention such as this, the investigators were interested to know if their intervention was successful. To this end students were asked:

Did you find it easy to use the online technology?

Did the online, live lectures used in this subject help you learn effectively?

The response to these questions are presented in Fig. 4. Overall, students felt that they found the technology easy to use and that they perceived that the online live lectures were useful to them. When asked whether they felt this module was better or worse than other modules taken online, 8 out of the 9 gave praise for the module and students recognised the effort their lecturers used when teaching them.

This is commensurate with previous research demonstrating that students show improved engagement when they realise that their teachers have an interest in their learning [22]. Furthermore, some students offered some insight into how the method of delivery motivated them; four cited the live lectures as the reason they perceived that the current module was more effective than other online modules and gave the following comments:

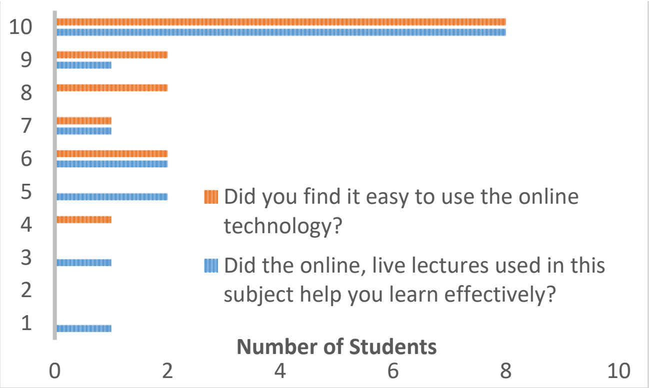


Fig. 4 Evaluation of the Success of Online Technology and Lectures.

*I think this module is the best as it is the only module that has live online lectures.*

*Only this module has live lectures which motives [me to] study.*

*It has better motivation compared with other video-recorded modules.*

This useful insight perhaps offers understanding on why students become demotivated when attempting to engage with online courses and MOOCs. It is clear that the students found the real-time live lectures motivating and this is a potential avenue of investigation in future research studies on the motivation of students studying via online arrangements.

In an intervention where existing utilities were used to overcome teaching challenges, it is also interesting to investigate student perceptions of the technology that was used, so that future educators will know which resources are best to draw upon when adapting to unforeseen situations. To this end, students were asked if the annotations and whiteboard were useful, alongside asking if live lectures were better than pre-recorded lectures. The results are presented in Fig. 5, which demonstrates that the teacher annotations were considered the most useful intervention in their learning. This reinforces the previous point that students felt better motivated and had improved engagement because of the live lectures. Perhaps, this behavioural trait can be explained by other work [23] which discusses the volitional nature of student learning. It is understandable that students will engage with methods that satisfy their needs and that they find useful. Furthermore, it is interesting to see that the annotations were more highly rated in this question than the comparison of live lectures with pre-recorded lectures. This suggests that simply delivering webinars will not yield the best motivational gains. It would appear that the ability for educators to annotate their slides whilst delivering online teaching is essential.

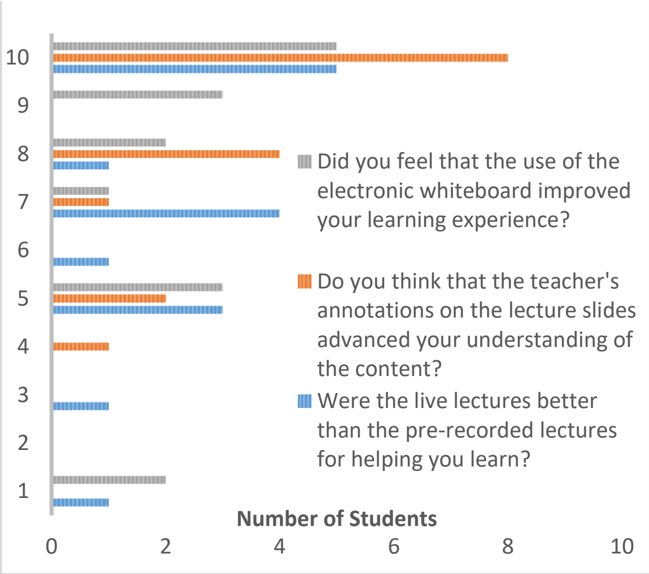


Fig. 5 The Percieved Effectiveness of Technological Adjustments

It can also be seen that students were appreciative of the adjustments that they considered useful and they applauded the online videos and the flexibility that those afforded them. This is evidenced by the answers to the question ‘I recorded at least 1 live lecture on my device’ which was indicated by 12 out of 16 students and had been reviewed by 10 out of those 12. This is unusually high, but not commensurate with previous research indicating that pre-recorded lectures typically have low viewing rates [24].

Finally, students were asked if they would prefer to continue with online lectures as opposed to classroom lectures and if they were distracted when learning online. The responses to this question are presented in Fig. 6. It can be seen that whilst students were divided on the issue of distraction, they were happy to replace face-to-face lectures with online lectures.

In conclusion, it has been seen that students are capable of making their own choices whilst learning and won’t spend mental resources on activities that they perceive as wasteful. They are receptive of personalised efforts to teach them, but equally critical of one to one sessions that they perceived as low efficacy. They are receptive of efforts to increase the flexibility of their learning such as placing webinars online, but equally critical if those webinars are used as a replacement for real-time teaching. It is apparent that student perception of their needs is a critical factor in teaching and this might answer many questions concerning engagement in online education.

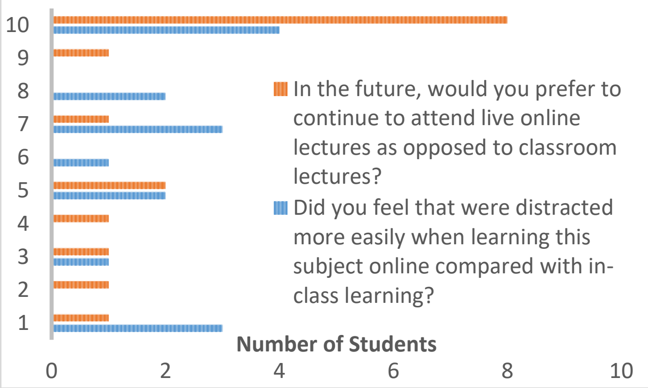


Fig.6. Student Preferences and Distractions

## VI. Conclusion

The paper has outlined the learning that has come about from a series of sudden changes brought about by unpredicted circumstances. A number of tools were implemented and then evaluated in order to investigate how students have engaged with different learning situations, and the findings have suggested that students engaged well with the technologies, finding them easy to use and beneficial for their learning. In particular, slide annotations and recorded lectures appeared to be powerful tools. It certainly seems that the approach taken by the lecturers on this module has been effective and received well by the students. The findings have suggested that some technologies were more useful than others across the sample, but also that there were some differences between students regarding their preferences for the use of particular tools.

For the authors of this current work, the task of investigating why some tools and pedagogies appear to work better than others is a task that will continue: some may believe that there is some novelty value in such tools and that students' appreciation of those tools will decrease over time. Others may believe that students were sympathetic and gave inaccurately high evaluations because of the suddenness of the change and that perceptions may change over the longer term.

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