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Employing the use of tablet PCs in instruction and partly automatizing the assessment process of online university courses during the COVID era

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Abstract
In this paper, we present distance-learning and assessment methods for engineering courses. The primary content of engineering courses involves mathematical equations, but there is an increasing need for drawing figures and tables on the spot, as well as demonstrating theory-in-practice using multimedia. In the present design, synchronous handwriting with a digital pen on pre-prepared slides presented on tablet-PCs was utilized in lectures via a videoconference platform in real-time, attempting to simulate the use of a blackboard while teaching in a physical classroom. The lectures are video-recorded and delivered to students, along with the annotated slides, for further study. Furthermore, a substantial delay in textbook delivery was introduced due to the pandemic that lead the authors to compile personal notes in PDF form to assist students in their study. Regarding course assessment, open book examination is adopted, with internet access allowed to all participants, while the assessment is invigilated via a videoconference platform. In addition, an automatic procedure is developed so that each student electronically receives a unique exam sheet, thus addressing the issue of academic dishonesty in online assessment pertaining wide student audiences. This is achieved by (a) randomizing the order of the exam questions using specific software, (b) including student serial number into the numerical data of each exam sheet, and (c) introducing a small variation in some of the exam questions. Advantages and disadvantages of the present distance-learning approach are discussed and statistics collected via online questionnaires are presented, suggesting that students show strong preference to the current course design over others, even over teaching in the physical classroom.

Keywords: online learning, distance learning technologies, learning assessment, engineering courses, tablet PCs

1. Introduction

Due to the COVID-19 pandemic higher education institutions around the globe had to suddenly shift from face-to-face instruction to online course delivery and assessment. This transformation proved quite challenging as numerous considerations had to be addressed, among which insufficient technological knowledge and skills on the part of both learners and educators, connectivity issues, lack of training in distance learning for educators, modifying materials and methods to ensure learning and engagement, and remodeling assessment to safeguard academic integrity (e.g., Gamage, Silva, & Gunawardhana, N., 2020; Golladay, Prybutok & Huff, 2000; Neuwirth, Jović, Mukherji, 2020; Paudel, 2021; U.S. Department of Education, 2010). Although online education had been around for decades, the "emergency" remote teaching (Hodges, Moore, Lockee & Bond 2020) that had to be adopted impromptu by the majority of institutions due to the pandemic has been documented as "disruptive, aggressive, disastruous and unwelcome" (Iglesias-Pradas et al. 2021, Watermeyer et al. 2021, Wyatt-Smith et al. 2021 as cited in Rapanta, Botturi, Goodyear, Guardia & Koole, 2021, p. 717). Challenges were even greater when lecturing online for large audiences, that is classes with more than 60 students (Elison-Bowers, Sand, Barlow & Wing, 2011), as learner retention rate is bound to drop due to lack of interaction and less personalised communication (Bawa, 2016).

Engineering courses, with a lot of mathematical content that needs to be explained, are predominately delivered via lecturing (Apkarian, Henderson, Stains, Raker, Johnson & Dancy, 2021), either using the blackboard or through presentation slides. Although the blackboard is ideal for the gradual and paced presentation of complex concepts, it does not allow for the presentation of intricate images that are often required in such courses, while the opposite stands for slide presentation (Bauer, 2019). Assessment is vital in monitoring student performance and ensuring that learning objectives have been achieved. In engineering courses summative assessment is very often implemented, and feedback, if any, provided to students is not deemed satisfactory (Subheesh & Sethy, 2018). Incorporating a formative component with constructive feedback comments has been suggested in order to improve assessment practice (McDowell, White & Davis, 2004). However, final examination still carries a lot of weight in most engineering courses and protection of academic honesty during online exams has been a major concern in institutions world-wide (Brown, 2018; Harper, Bretag, & Rundle, 2021). In Greece, this lead to the postponement of final examinations in many institutions (Kiouvrekis, Kokkinaki & Andrikopoulos, 2021).

In this paper we present a teaching and assessment practice followed in three engineering courses, namely *Physics for Engineers*, *Signals & Systems*, and *Digital Signal Processing,* at the Department of Computer Science, University of Crete, Greece, during the pandemic. This practice is a fusion of methods already established for these courses in the pre-Covid19 era, and of new approaches that complement or enhance student-instructor interaction and student engagement, while trying to guarantee academic integrity in examinations during the pandemic. All courses adopt (i) a lecturing and (ii) an assessment scheme appropriately conformed to distance learning. The former employs the use of prepared PPT slides enhanced by real-time handwriting on a stylus-equipped tablet PC, while the lecture is recorded live and delivered to students. The latter is a three-fold procedure consisting of (a) in-class assessments that strengthen student engagement, (b) weekly or bi-weekly assignment sheets that test students' engineering knowledge while improving student confidence by practising self-correction skills, and (c) midterm and final examinations that are designed to deter cheating behaviour via an automatic procedure producing unique exam sheets.

The present paper is organized as follows: Section 2 presents the teaching and assessment of engineering courses before and during the pandemic, highlighting similarities and differences. Section 3 presents the course delivery and assessment methods during the pandemic with greater detail, Section 4 evinces the effectiveness of the proposed methods using student evaluations and finally, Section 5 concludes the paper discussing limitations and future steps.

2. Teaching and Assessment of Engineering Courses before and during the COVID-19 pandemic

For the authors, the utilization of stylus-equipped tablet PCs during lecturing did not emanate from the pandemic. The second author introduced this teaching practice in 2007, for two courses (Signals & Systems, Digital Signal Processing), and adopted by the first author (for Physics for Engineers) in 2015. This means that the pandemic did not significantly change the delivery method of the three courses. However, the lack of physical interaction with the audience led to a series of steps that were taken to further support and enhance distance learning. First, the number of remote assisting lectures provided by teaching assistants (TAs) was increased during the pandemic, as students might have more questions compared to in-person teaching and learning. An assisting lecture – delivered using the same stylus-equipped tablets – was fixed once per week for the whole semester and the content of the lecture was also recorded and uploaded on the course webpage. Second, remote office hours were increased both in length and in frequency to support personal interaction. Although a teleconference platform was used for communication, all students were strongly encouraged to turn their cameras on, relax, and ask any question without hesitation. Third, an in-class assessment named Grading Opportunity (GOP) was introduced to encourage student attendance and participation. GOPs are given to students whenever they (orally) answer correctly non-trivial, in-classs questions. A GOP corresponds to an extra 0.05 on the student's overall course grade – no more than 10 GOPs are allowed per student. In general, GOPs should be low enough to discourage grade-grubbing but also high enough to motivate students to put some thinking into the non-trivial questions posed by the instructors and participate in class discussions. Finally, a set of detailed lecture notes in digital form for each course was compiled (more than 250 pages each) to deal with COVID-related belated delivery of preselected textbooks.

For the assessment, the authors strived to maintain a pre-Covid19 strategy consisting of (a) frequent assignment sheets, (b) a midterm examination, and (c) a final examination, in an attempt to employ formative assessment. An assignment sheet consisted of several theoretical and practical problems, each with its own correct answer given as a hint. This way students could check their own results and rationale and reformulate a solution, attaining a higher level of confidence as the need of self-correction appeared less and less often. Answer sheets were submitted electronically via dedicated software. Moreover, in engineering, knowing formulas by heart is not crucial in problem solving. Thus, exams, either midterm or final, followed an open book policy while internet access was sometimes allowed, well before the appearance of SARS-Cov2. Undoubtedly, systematic invigilation is required to ensure academic integrity with the former being remotely applied using teleconference platforms. In an attempt to keep this assessment structure, significant modifications had to be made to the exam sheets to further reduce or even minimize academic cheating. We chose to adopt a specific open-source Latex-based software called MUCH (Kolountzakis, 2006) to create randomized, different, but with

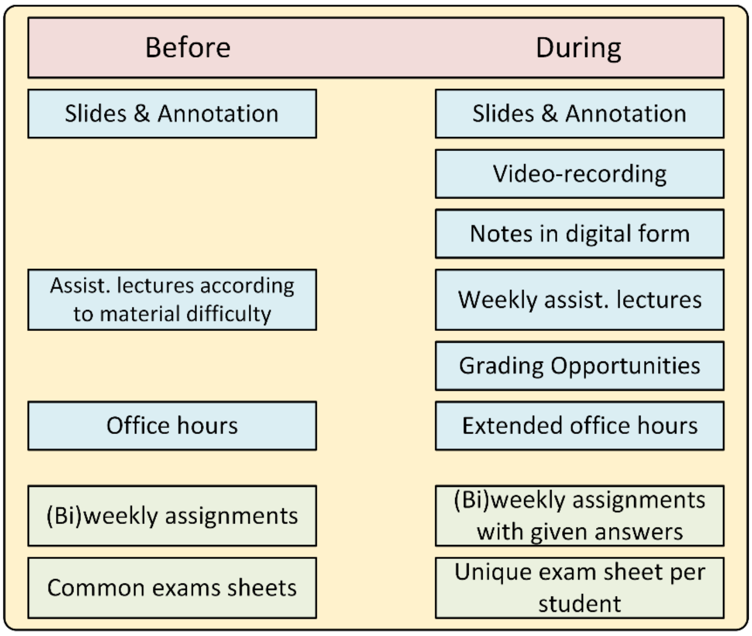

Figure 1: Teaching (in blue font) and assessment (in green font) practice before and during the pandemic.

equal difficulty, exam sheets. The software supports both multiple-choice and essay questions. Figure 1 shows the teaching and assessment practice before and after the pandemic. In what follows, we describe the basic parts of these practices in greater detail.

3. Proposed Teaching and Assessment Practice

3.1 Teaching: Using Tablet-PCs during lecturing

Utilisation of prepared slides in engineering courses is a common practice in both virtual and in-class learning (Bauer, 2019). Advantages of such an approach, among others, include

a) providing students a concrete, error-free, up-to-date material for each lecture,
b) saving valuable instructional time by having figures, schematics, or diagrams drawn beforehand
c) increasing time for questions and discussion over writing on the board or note keeping,
d) adding multimedia (videos, images, audio) to assist explanation of hard-to-grasp concepts or to demonstrate practical applications of theory, and
e) maintaining eye-contact, thus promoting communication with large audiences, since slide content can easily change with a press of a button.

However, several disadvantages have been reported, such as (a) cognitive fatigue due to passive reading and listening, (b) limited information present on slides to keep slide content short, and (c) insufficient description of complex concepts in the form of listed items or a series of bullets rather than as a concrete thought process. It would be beneficial to keep most of the advantages and minimize or eliminate the disadvantages of prepared slide-based material.

Figure 2: Common tablet PCs (older model on the left, modern model on the right).

To this direction, we propose using stylus-equipped tablet PCs for assisting material delivering. Compared to other similar technologies (such as USB-based digitizers), the instructor can actually write on the tablet's screen and can see, correct, and enhance his/her handwriting. Moreover, since a tablet PC has all the benefits of a laptop computer, the instructor can record and share the material, can stream it over the internet, can access webpages and fora, can directly use a keyboard or a mouse if needed, can connect to a variety of external devices (such as projectors, loudspeakers, and laser pointers) with ease, and can use other software in conjunction to improve the delivery of the material. Handwriting on slides alleviates cognitive fatigue, since students can engage into learning, problem solving, or into detailed handwritten explanations. In addition, prepared slide information can be kept minimal while details can be written down during the lecture, and finally, complex concepts can be analytically explained, thus helping students comprehend the underlying thought process. Screen and audio recording helps students reproduce in-class environment any time, ask for clarifications via e-mails, and strengthen material comprehension over multiple replays of the content. It should be noted that tablet PCs are far more expensive compared to their digitizer counterparts but also significantly more convenient to use. Refurbished or second-hand hardware that significantly reduce costs can also be used. In Figure 2, two common stylus-equipped tablet PCs are shown (a second-hand, cheaper, and older model on the left and a modern model on the right) and in Figure 3 we present an

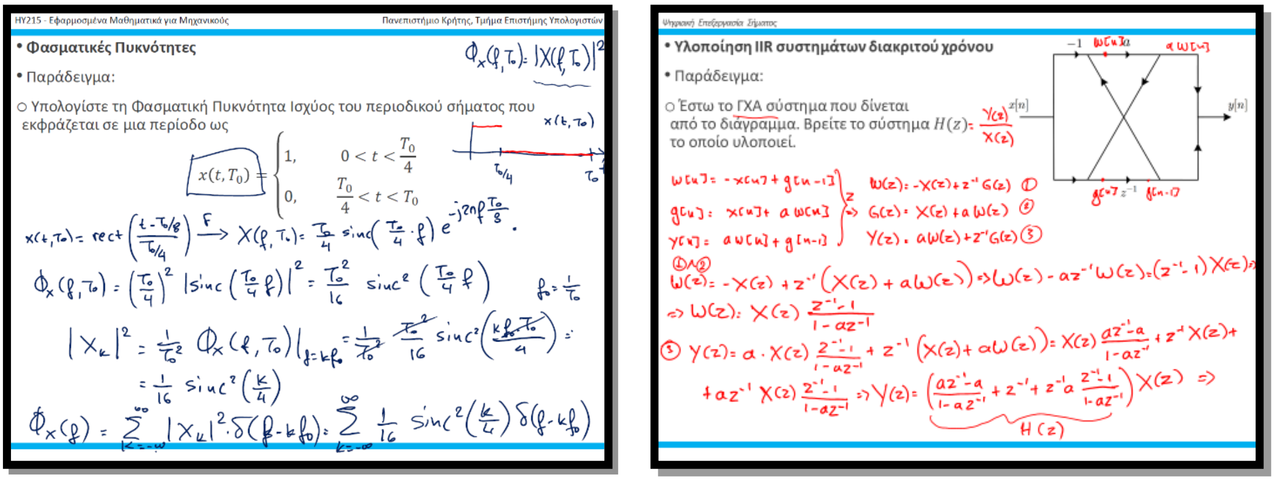

Figure 3: An example of two slides with their handwritten notes.

example of two slides (in Greek) with their handwritten notes.

3.2 Assessment: Modifying midterm and final examinations

In engineering courses, it is important for students to present their thought process in problem solving. Pre-COVID course assessment was based on assignment and exam sheets containing a mixture of standard and novel engineering problems. We deemed that the assignment sheets did not require any modifications during the pandemic; hence only midterm and final examination amendments are discussed here. One way for the instructor to check the student's thought process is to perform an oral examination immediately after a written or an online exam. However, in courses with a very large audience (more than 300 enrolled students), this is not feasible. Furthermore, distance learning platforms offer online examination options in the form of multiple choice questions, code writing or completion, or text input. This could be a convenient way of assessment in a variety of university courses but in engineering courses, a significant amount of mathematics is required to efficiently describe a pathway to problem solution. Unfortunately, math typing in a computer requires some experience – which most undergraduate students do not have – and is time consuming, while at the same time it is not fully supported by most online learning platforms.

For these reasons, we decided to adopt a remote examination scheme as similar as possible to a pre-COVID examination, adjusted to maximize academic integrity. In such previous examinations, all three courses had an open book exam policy, that is, anything that could be written or printed on paper was allowed during the exam (books, notes, and slides). Moreover, when the number of students attending the exam was small (which is the case for the *Digital Signal Processing* course), laptops and internet access were also allowed but communication between students or third parties was strictly forbidden and moderated via invigilators.

For remote examination, students are obliged to connect to a videoconference platform using their personal computers, turn on their microphones and cameras, enter a specified virtual room, and adjust their desk in a specific layout to optimize invigilation. Then, each student electronically receives a unique copy of his/her exam sheet at the specified date and time of the examination. To ensure examination transparency, the following measures are applied on the exam sheets:

a) the exam questions are randomized using specific software,
b) student institutional serial number is included into the numerical data of each exam sheet, and
c) a small variation in some of the exam questions is introduced.

More specifically, we use an open-source software named MUCH (Kolountzakis, 2006) to create unique exam sheets for each student. MUCH was originally designed to generate and automatically grade any number of randomized, *multiple choice* examination sheets. However, its use can be extended to any type of question. The sheets are randomly generated according to some specifications from a database of questions. These questions should be provided by the instructor in TeX format. MUCH creates a file in TeX which – when compiled – contains all exam sheets in a single PDF file that can be successively split into individual sheets.

Randomizing the order of exam questions in an inherent property of MUCH and requires no effort from the instructor – however, a significant amount of time and effort is required to create the database of questions. In order to both reduce time and maximize inviolability, we decided to include the digits of the students' serial number into the numerical data of each exam sheet. This way, not only each question is in a different place in almost every pair of exam sheets, but also the numerical data of similar questions can be vastly different – and the same applies to their answers. Finally, variation is introduced in a small number of questions via a change of sign in an equation, a different operator (e.g. a square instead of a square root), or a different order of operations.

Figure 4 illustrates two different exam sheets for the core course *Signals & Systems*, as provided by MUCH. In

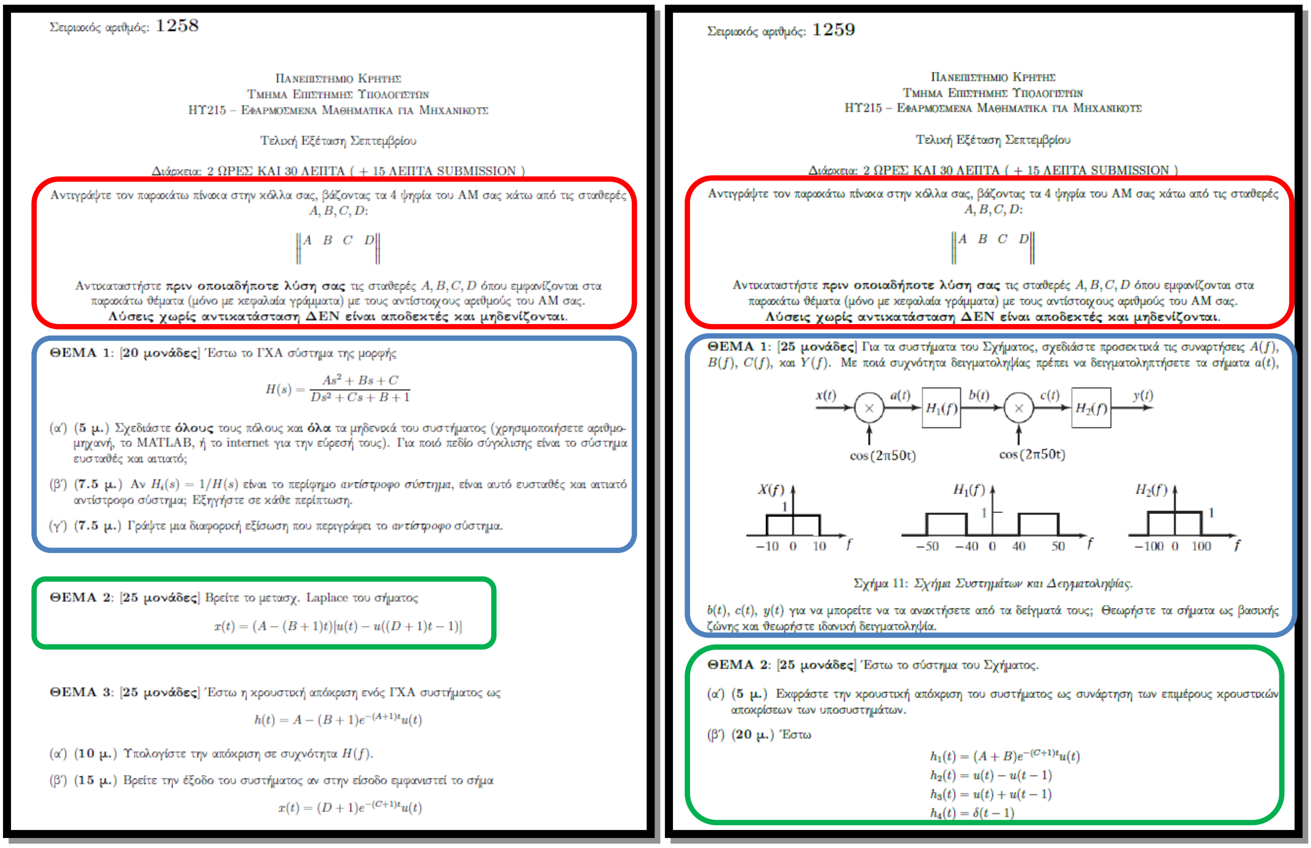

Figure 2: Two different exam sheets as provided by MUCH software.

red boxes, students are asked to copy a small numeric table (A, B, C, D) with their institutional serial number in every page of their answer sheet. This is a common piece of information in all exam sheets. In blue boxes, we highlight Question 1. It can be observed that it is different for both sheets and randomly selected by MUCH. Finally, in green boxes, we highlight Question 2 which is, again, different in both sheets and it contains data that depend on the digits, A, B, C, and D, of each student's institutional serial number.

After receiving their copy, students have time to write their answers in a template answer sheet. Teaching assistants (TAs) invigilate students (one TA per 10-15 students, at most) via their cameras and take notes of anything that might seem to be a violation of the exam policy. The students are explicitly asked to explain and write down their thought process as clearly as possible, and then submit their answer sheet in any common format (PDF, PNG, JPG, or DOC) either by e-mail or by uploading it to a dedicated server. Submission time is usually ten to fifteen minutes and is added to the scheduled examination time.

It should be stressed that despite the benefits of such an online examination scheme, there are certain disadvantages. First, as already mentioned, a considerable amount of time and effort is necessary to create the database of questions, although including student-specific information in each question can significantly alleviate the situation. Second, a large number of invigilators is required for courses with high attendance. Third, the instructor has to grade N different papers, one for each of N students. This leads to a remarkably increased workload compared to a common exam sheet for all students and probably is the major disadvantage of the proposed method. Finally, MUCH is a command-line-based software, without a graphical user interface (GUI), and requires some level of experience and some working knowledge of TeX.

4. Student Evaluations

At the end of each semester, students are asked to evaluate all courses via an online, anonymous questionnaire compiled by the Quality Assurance Unit (MO.DI.P) of the University of Crete. Filling in the questionnaire is non mandatory but students are strongly encouraged by both the department and the instructors to submit an evaluation. However, the questionnaires are sent in the third quarter of each semester and the platform closes about three to four weeks before the exam period, thus students are not given the opportunity to evaluate course assessment via remote examination. Furthermore, official questionnaires are often too generic and do not deal with the details and peculiarities of each and every course. As instructors, we wish to receive student feedback that covers all aspects of each course curriculum, including final examination.

To achieve the above objective, we have compiled custom questionnaires for each course using Google Forms. Anonymity is guaranteed via Google's platform and students are requested to i) answer multiple choice questions, allowing justification for their selections, and ii) provide their opinions and thoughts in free text. The latter is considered to be the most important part of the evaluation. In this paper we present statistical outputs from both questionnaires, with the official one containing feedback for the teaching part only and the customized one providing valuable information for the entire course (teaching and assessment). Since the courses we teach usually have different audiences both in size and in background as well as different placement in the department's curriculum, student feedback is presented per course in the following subsections. We present statistics on four questions regarding course assessment and teaching approach. The first question refers to the evaluation of assessment and the next three questions to the teaching:

a) What is your opinion of the course assessment?
b) How would you evaluate the teaching approach (use of tablet PC)?
c) Would you prefer tablet-based or whiteboard-based teaching?
d) How would you evaluate the quality of the material (slides + handwriting)?

In total, more than 300 students participated in the official and customized questionnaires.

4.1. Physics for Engineers

Physics for Engineers is a 1st year elective course that accounts for 8 ECTS. However, the department strongly suggests first-year undergraduates to attend this course over others. Hence, its audience ranges from 300 to

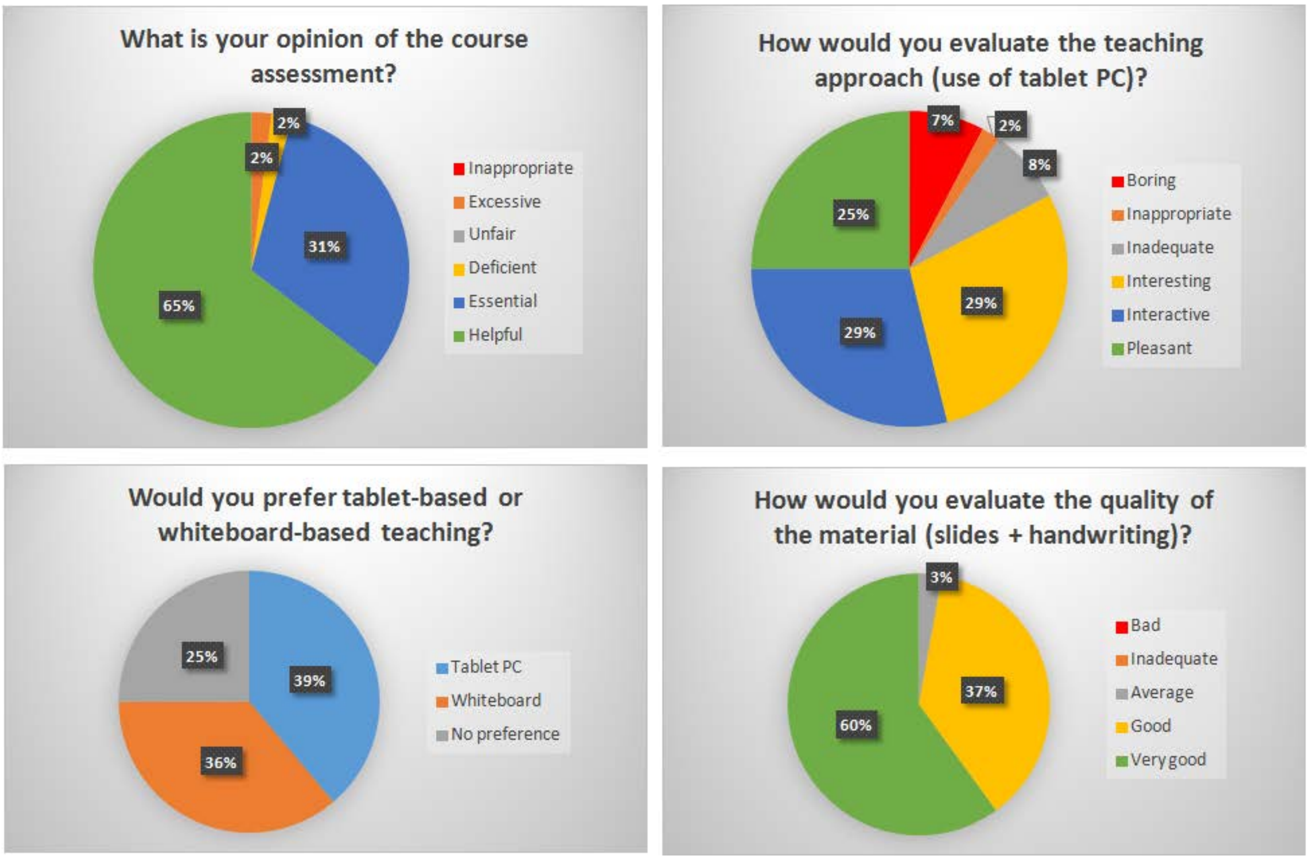

Figure 3: Student feedback for Physics for Engineers.

450 enrolled students per semester. This course has been remotely taught only once, in winter semester 2020-2021 with an audience of 430 enrolled students. Figure 5 presents the students' opinion on teaching and course assessment.

The following observations can be made: 96% of the students consider that course assessment is “essential” or “helpful”. Similarly, 83% of students think very positively about the use of the tablet PC, suggesting that this approach is “interesting”, “interactive”, or “pleasant”. However, it is interesting to note that only 39% prefer tablet-based teaching over 36% of whiteboard teaching. This may be justified by the fact that 1st year undergraduates come from high schools that promote whiteboard teaching of Physics instead of a more technologically-driven approach. Finally, 97% of the audience thinks that the annotated material quality is either “good” or “very good”.

4.2. Signals & Systems

Signals & Systems is a 2nd year core course that accounts for 8 ECTS. Hence, its audience ranges from 200 to 400 enrolled students per semester. This course has been remotely taught twice, in spring semester, 2019-2020 and in winter semester, 2020-2021. Figure 6 depicts student feedback from both semesters.

It is interesting to note the differences and similarities compared to first-year undergraduates that attended Physics for Engineers. Again, students view course assessment as "essential" or "helpful" at a rate of 90%. Similarly, they regard our tablet-based teaching approach as "interesting", "interactive", or "pleasant" at a rate of 96%. However, their preference to tablet-based over whiteboard-based teaching is 74% in favor of the former. This stronger preference relative to 39% noted in Physics for Engineers can be explained by student acclimatizing since most courses in the department promote slides as a means of delivery. Finally, 85% of students think that the annotated slides are of either "good" or "very good" quality.

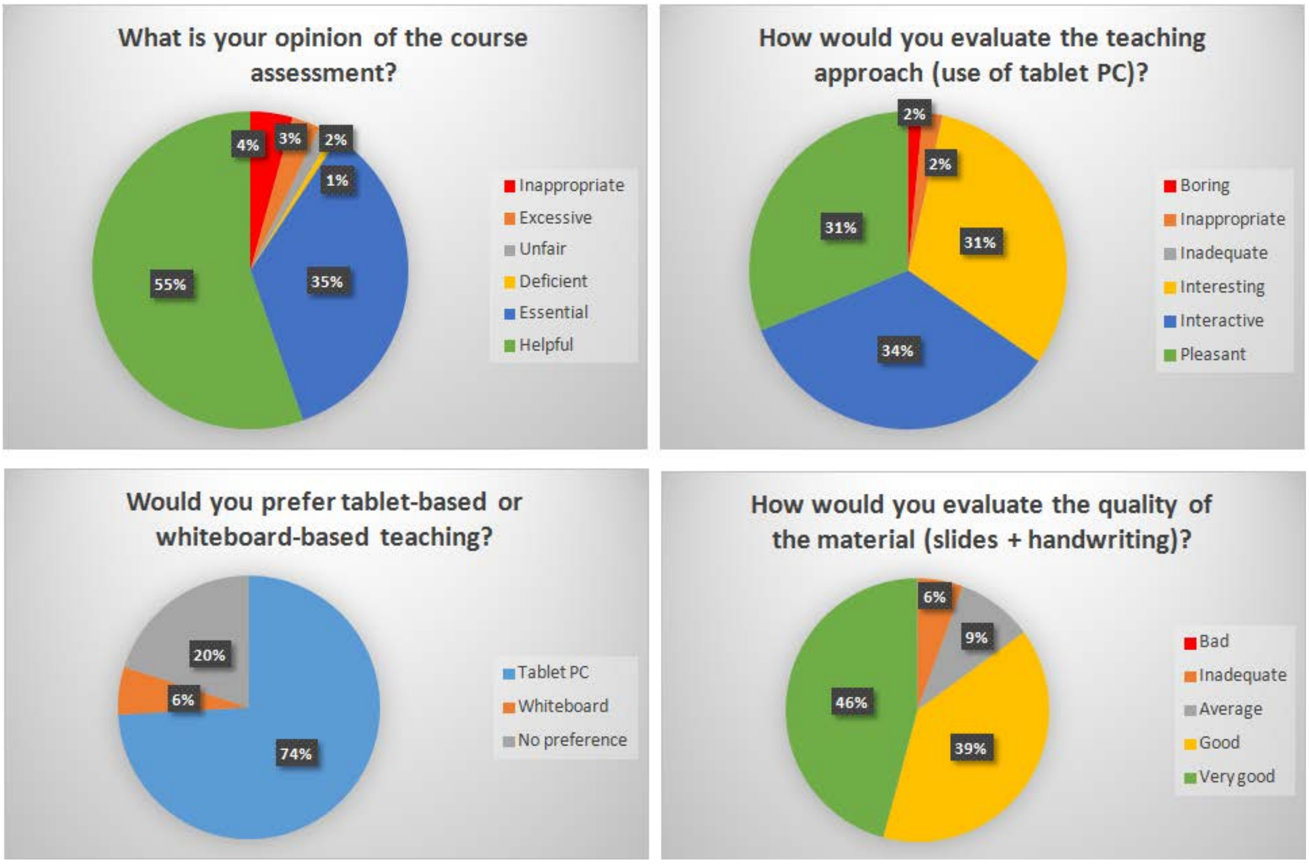

Figure 4: Student feedback for Signals & Systems.

4.3. Digital Signal Processing

Digital Signal Processing is a 3rd year elective course that accounts for 6 ECTS. Its audience ranges from 20 to 50 enrolled students per semester. This course has been remotely taught only once, in spring semester 2020-2021. Signals & Systems is a prerequisite course for Digital Signal Processing. This means that the audience of this course has already been exposed to our teaching and assessment methods in previous semesters. Figure 7 shows student replies to the aforementioned four questions.

From their feedback, it is evident that students are quite familiar with the teaching and assessment approach from previous similar courses and feel very comfortable with the proposed method of delivery. 89% of students consider that course assessment is "helpful" for students. Tablet-PC based teaching is considered "interesting", "pleasant", or "interactive" by all students (100%) while it is preferred over traditional whiteboard-based teaching by 76% of the audience – it is worth noting that no student explicitly preferred whiteboard-based delivery. Finally, the material provided to students is thought to be of "very good" or "good" quality by all students (100%).

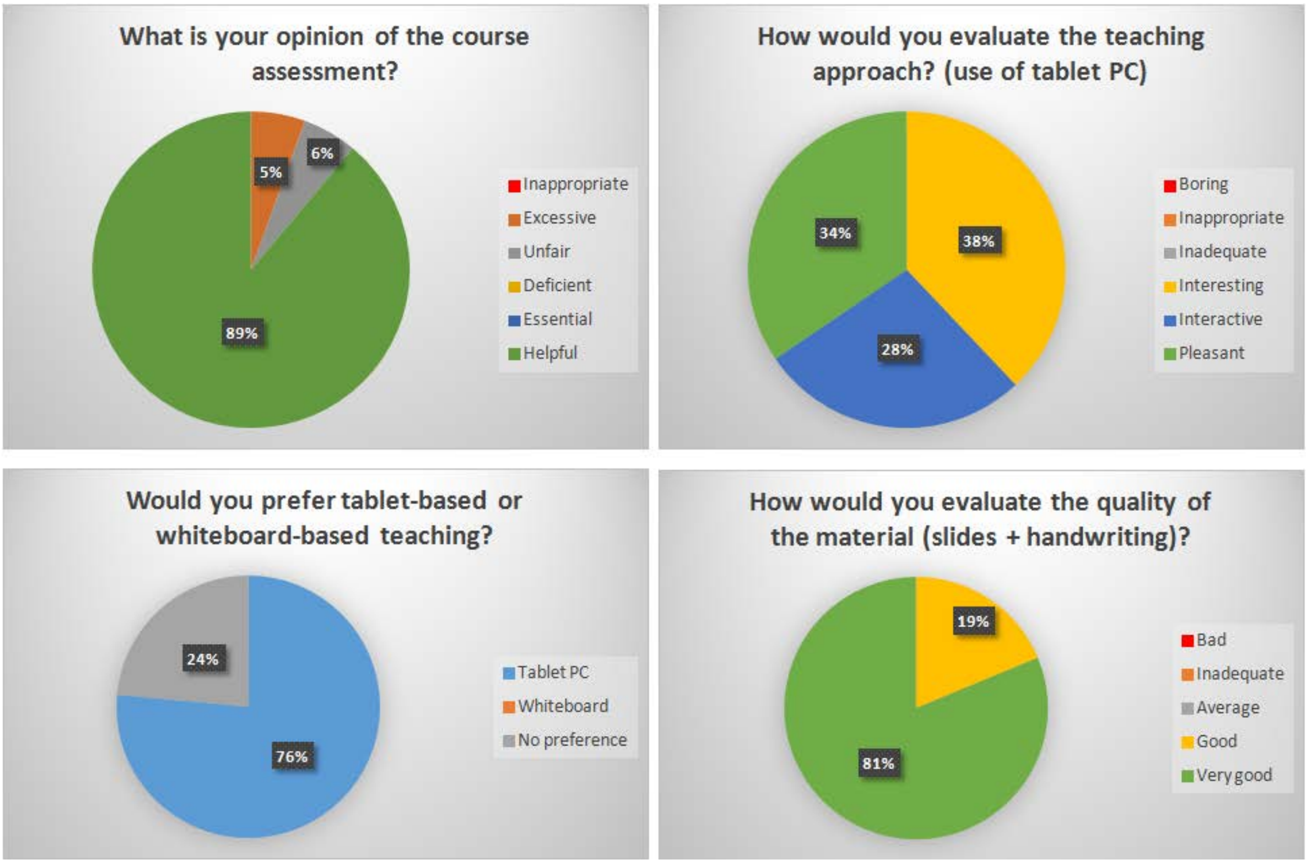

Figure 5: Student feedback for Digital Signal Processing.

5. Discussion

The COVID-19 pandemic caused a radical shift in both academic teaching and assessment. Digital learning platforms, online collaboration and teleconference applications became very popular and constituted the mainstream delivery method for the vast majority of university courses. While these methods can be well combined with lecture slides and instructor narration, they do not promote student engagement, they increase cognitive fatigue, and, as a result, slide content is oversimplified for the sake of time and effort. The situation becomes worse in courses that require a non-negligible amount of mathematical notation and/or a series of complex mathematical equations to model and solve real-world problems. We propose the alleviation of the aforementioned disadvantages by incorporating hand-written slide annotation via stylus-equipped tablet PCs during live online instruction which is video-recorded and made available to students offline. Application of this teaching method in three different, math-heavy courses was very much welcome by students according to their answers to both official and customized questionnaires, stating that this method is “interesting”, “interactive”, or “pleasant”. Actually, the majority of students prefer this method of delivery over traditional blackboard-based methods. Regarding assessment, course examinations can be extremely taxing if oral examination is selected in large audiences. Additionally, multiple choice exam sheets or math-free platforms cannot help instructors assess student comprehension. To this direction, we adopted an open-source software called MUCH, which can automatically generate a series of randomized exam sheets based on a database of questions. Combined with teleconference applications that allow invigilation, one can render a pre-COVID, open book examination environment feasible. Academic dishonesty is deterred by involving the students’ institutional serial numbers in the exam questions and by introducing small variability in specific questions. Students found this kind of assessment “helpful” and “essential”.

It is important to note that year of study seems to play a role in the degree of student satisfaction regarding live handwritten annotation on slides during remote instruction. This observation is further supported by student comments provided in open text format. A number of first-year undergraduates that attended Physics for Engineers noted that using slides and handwritten annotation “is very promising but it’s something new, and *that* creates some difficulties”, while others mentioned that “physical presence in class could be more beneficial”. Furthermore, some students thought that “this technology is efficient but it is still very tiring to attend class”. On the other hand, second- and third-year undergraduates that attended Signals & Systems and Digital Signal Processing correspondingly, seem to have a more positive opinion. Some of them noted that “solving problems in real time using the tablet is very smart and convenient”, others said that “this is the perfect way to teach during this pandemic”, and a few others stated that this teaching method is “exemplary”. Hence, the need for face-to-face instruction and for a period of familiarization with this type of delivery seems more pronounced in first-year student evaluations. Regarding course assessment, almost all students acknowledged the instructors’ efforts to ensure the integrity of the exam process. Few students noted that this assessment is “better by far compared to other courses which prefer multiple choice questions or short oral exams”. High overall student satisfaction and integrity assurance regarding remote examinations conducted by the Hellenic Open University has also been reported in a large scale study (Liapis, Vorvilas, Korovesis, Aggelopoulou, Karousos & Efstathopoulos, 2021). In that study students comment that remote examination is less stressful due to environment familiarity and that their anxiety results mainly from fear of technical problems and limited exam time. Some of our students also highlight in their comments increased stress levels due to “knowing that someone is constantly watching through the camera”, which also raises privacy issues (Chrysanthos, 2020; Bilen & Matros, 2021).

6. Limitations and Future Steps

In this paper, we discussed about teaching and assessment practices implemented in engineering courses of the Department of Computer Science at the University of Crete before and during the COVID-19 pandemic. Live handwritten slide annotation and lecture video-recording accessible to students is a practice we employed long before the pandemic, and which proved especially useful during the emergency remote teaching. Having already adopted this type of course material delivery, we felt better prepared to adapt to large audience online teaching and learning when the crisis broke out. Second- and third-year students were already familiar with the digital tools employed in lectures before the pandemic and welcomed them during the emergency remote teaching. Similarly, positive student attitudes towards the switching to remote teaching have been documented at the University of Patras; the authors note that the institution was “digitally-prepared” before the lockdown (Kamarianos, Adamopoulou, Lambropoulos & Stamelos, 2020). Of course, the use of digital tools alone is not sufficient to guarantee effective online learning. Transition to e-learning has to be based on the careful redesigning of the curriculum so as to ensure active learning (Rapanta et al., 2021). Active learning is key in STEM (science, technology, engineering and mathematics) courses at any level, including higher education (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt & Wenderoth, 2014). Active learning in STEM courses usually involves learning through activities, discussion in class and group work as opposed to a continuous exposition by the lecturer (Freeman et al., 2014). Socializing, communicating and cooperating were reported as elements mostly missing in online education of Greek universities (Raikou, Kaltsidis, Kedraka & Karalis, 2020), but also worldwide (Paudel, 2021). It must be underlined that the practice presented here refers to the exposition part of the lesson and other parts of course instruction such as activities and group work are not dealt with. Based on the experience gained by the instructors and the student teaching evaluations, we believe that the employment of the proposed tools -that is, live handwritten annotations on slides with the use of tablet PCs and video recordings of the lecture audio and annotated slides, can help promote student learning and engagement in both face-to-face and online delivery of engineering course material. However, next steps should involve redesigning engineering course curricula to promote interactive e-learning. The questionnaire revealed a very high level of student satisfaction regarding online assessment. It is important that the majority of students felt that the assessment was fair and helpful. Also, automatically producing unique exam sheets for every student contributed to a certain extent to the safeguarding of academic integrity during final examination. To further improve assessment practice, feedback should play a more central role in formative assessment (Subheesh & Sethy, 2018), thus providing essential guidance and enhancing student learning.

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