E-learning and Face-to-face Classes: a Mixed Approach for Engineering Education on Electromagnetic Compatibility

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Abstract
The knowledge of technology directly impacts the subject under study and, ultimately, the student learning. The students' learning is maximized when technology is tailored to the subject and to the teachers. In this work, we re-designed an engineering course in electromagnetic compatibility to include pedagogical concepts supported by technological tools. We adapted the main ideas from the Technological Pedagogical Content Knowledge framework and designed the web platform based on pedagogical knowledge and technological knowledge. The course in electromagnetic compatibility consists of laboratory activities that cannot be virtualized or digitalized. Moreover, we wanted to keep some of the on-campus classes to increase engagement in the course. Therefore, the final course resulted in a mixed or hybrid education experience. The re-designed course had more positive assessments than previous courses taught with a traditional format.

Keywords: *E-learning, Digital learning technologies, E-lectures, Hybrid education*

1 Introduction
Frontal lectures are the most well-known teaching style, adopted at each stage of education, from elementary classes to university courses. They are cost-effective but, mostly, they are accepted as a standard traditional methodology by teachers and students. Acceptance is the starting point for both teaching and learning [1], and probably the main reason why traditional frontal lectures, with no or minimal interaction between teachers and students, are still considered pillars in education, despite the numerous studies that prove them to be the least effective way of learning.
On the other side, technological tools can come into education when teachers and students agree on their value; or when there is a compelling necessity for them. Urgent needs can force people to re-think well-established habits and patterns. When we turn need into a virtue, innovation happens. The COVID-19 pandemic directly impacted education and teaching methodology, forcing us to quickly re-design a traditionally taught in-class course.
This paper describes how we re-designed a master's engineer course in electromagnetic compatibility (EMC) taught at the Luleå University of Technology (LTU) by putting into practice tools and best practices from Information and communications technology (ICT). The course is not compulsory, and it is usually taken by a mix of national and exchange students. Due to the current circumstances, the course had a limited number of students, only five. However, this helped us experimenting with new technologies and learning strategies. We adopted a mixed or hybrid education approach that combined e-learning techniques, face-to-face classes, and laboratory activities in small groups. In fact, the EMC course cannot be converted into a full-distance course because the mandatory laboratories require specialized, bulky, and expensive equipment, such as an 8 x 5 x 4 m anechoic chamber, an electrostatic discharge (ESD) simulator gun, see Figure 1 andFigure 2, respectively, as well as a transient immunity tester T2000, and a line impedance stabilization network (LISN).

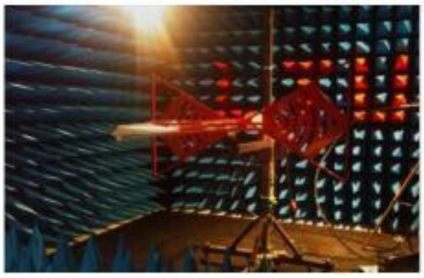

Figure 1 EMC chamber at LTU

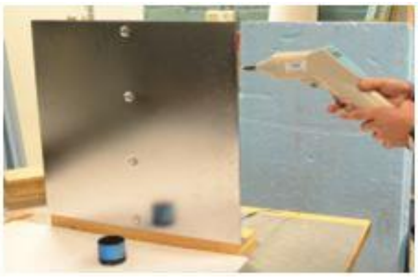

Figure 1 ESD simulator gun

However, we could digitalize the traditional face-to-face classes. We experimented with quizzes, flipped e-lessons, and web-related material to increase the involvement of the students. The lectures on-campus could benefit from the preparation material provided in the web platform used. The recorded lectures followed the flipped classroom approach. In the following, each section provides a brief overview of the technology and pedagogical ideas used and how we interpreted and incorporated them into the course.

2 A non-disruptive technology knowledge

In the re-designed course, we interpreted and personalized several inputs from the Technological Pedagogical Content Knowledge framework (TPACK). The Technological Pedagogical Content Knowledge framework, or TPACK, emerged in 2006 [2] and highlighted the role of knowledge about technology in effective teaching. The TPACK is divided into three main knowledge components that interact with each other and form the TPACK framework. The three major components are technology knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). This section focuses on the TK, which highlights the teacher's education in traditional and new technologies, on the PK, and their intersection, the Technological Pedagogical Knowledge (TPK).

A complete re-design of a course is a time-consuming task. The introduction of digital tools may risk absorbing the teacher's energies, consequently decreasing teaching quality or causing misuse of technologies [2]. For this reason, we interpreted the re-design of the course as a team job, and we kept the student's learning, rather than the technology itself as the primary goal of the course. Four teachers taught the EMC course. Among them, three teachers have a long teaching track record and provided a high CK to the course. The fourth teacher can be called, by using the same terminology in [3], an early career teacher (ECT), with a limited teaching experience, but a knowledge about the technology that LTU offers for distance teaching, gained from pedagogical courses that are offered at the University. The teacher's experience with technology is critical and will impact the course [3]. A recording of a traditional face-to-face lesson, for example, is not a TK because technology is used passively as an application. Conversely, technology should directly impact the subject under study and, ultimately, on student learning by giving new learning possibilities. The teachers first should be "app-enabling" rather than "app-dependent" [4]. The re-design of the course was, for us, the first step towards this direction. The ECT had the main responsibility of re-designing the course with the following goals:

1. give a "fresh new look" to the web platform of the course and use web-relevant material to increase the students' interest in the topic,
2. provide recorded lectures for two of the nine modules, in the form of flipped classrooms, and
3. create interactive quizzes for each module to support on-site lectures.

2.1 The web-platform and the pedagogical knowledge

At LTU, we use Canvas© Learning Management System (LMS) as a platform for courses. The student view is depicted in Figure 3. The course was divided into self-contained modules that consist of 1 or 2 lectures, and laboratory activities. The pedagogical knowledge was crucial for the correct organization of the course. As suggested in [5], each module contained a briefing that guided the student through the preparation material before the lecture.

Figure 2 The Canvas platform used

2.2 Web material to increase the student engagement

We wanted to engage the student in the topic by relating it to real life. The web platform allowed a proper usage of relevant web resources, following similar ideas as in the Technological Pedagogical Content Knowledge – Web (TPCK-W). For example, standard and standardization bodies can be dull and uninteresting for the students. Therefore, we used official YouTube channels from recognized engineering organizations, such as the International Electrotechnical Commission (IEC), or the European Committee for Electrotechnical Standardization (CENELEC), and embedded relevant videos directly in the platform as introduction material. Furthermore, we provided articles and references to well-known EMC online magazines.

2.3 Quizzes

Quizzes are well-proven tools that enhance student learning and performances [6]. Therefore, each module contained quizzes created directly in Canvas. The quizzes were beneficial to steer the students' attention to the most important topics of the course that will also be part of the assessment, and increased the degree of how well the expectations regarding the course material and the assessment matched, in line with the constructive alignment theory. Moreover, the students could benefit from immediate feedback to correct and study again what they have missed. For example, the quiz depicted in Figure was made for the module on Transmission Lines and asked the student which of the pictures is not a transmission line. Feedback also plays a significant role in the activation of the

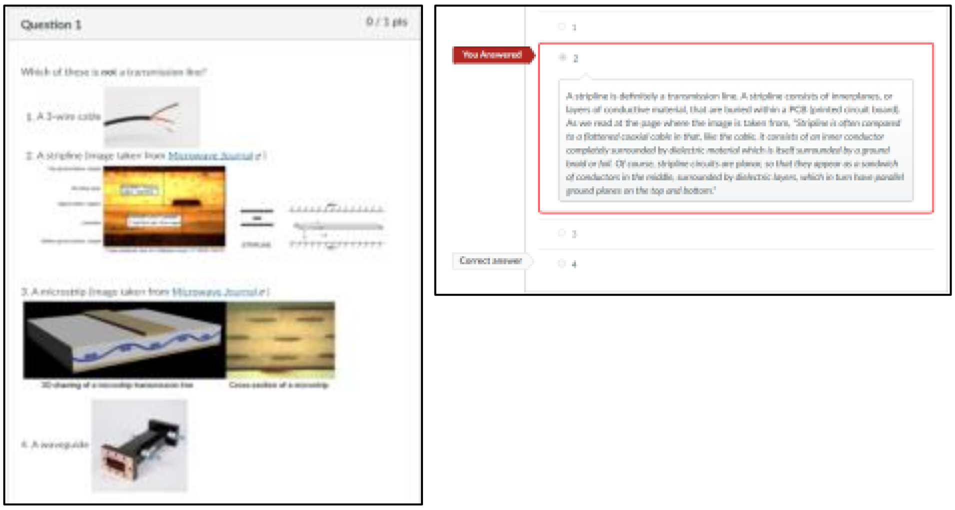

Figure 4 Example of a quiz with the immediate feedback upon submission

student [7]. The feedback in a quiz is a valuable tool that we used to refresh some main theoretical results or redirect the student to the relevant material in the reference book. Therefore, upon submission, the students would get immediate formative feedback as a textbox for the answers. We provided feedback also for the correct answers to strengthen essential concepts.

2.4 Flipped e-lessons

E-lectures are a recognized and nowadays accepted way of teaching. Teachers appreciate that a lecture is recorded once, and it will stay available for the years after, saving time for repeating the same concepts. Students appreciate that they can watch a lesson at their own pace. The drawbacks of e-lectures are the same as for standard frontal lecturers: teachers may risk becoming lazy and not updating the lectures if necessary; a student will not actively listen to the lecture. For these reasons, we incorporated the central concept of flipped lessons into our recorded lecture. Two of the nine modules were replaced by recorded lectures. The recorded lectures were longer than the previous face-to-face lectures to account for the asynchronous communication between students and teachers.

Moreover, they were enriched by simulations and quizzes that would activate the student. The lessons were recorded using Kaltura Capture©, which automatically uploads the video in the University cloud (called LTU play), embedded in the Canvas platform itself under the Media Gallery menu. The video can include the teacher's camera and quizzes, as well as preparation quizzes, as depicted in Figure , where we show three frames taken from a lecture on radiated emissions. As in the standard quiz, we can provide immediate feedback to the students.

Figure 5 Three frames of a recorded lecture with a quiz

3 Students evaluation

We observed that the students performed either better or similar in the partials and lab activities during the course. The course evaluation was in the form of self-report measures, where the students were asked to numerically rate their agreement regarding teaching and the quality of the course. The re-designed course had more positive assessments than previous courses taught with a traditional format, as depicted in Figure 6. The students were more positive about the alignment of the course content to the assessments, probably thanks to the quizzes, flipped e-lectures, and preparation material provided in the web-platform. In the future, we will investigate quality criteria tailored for online education.

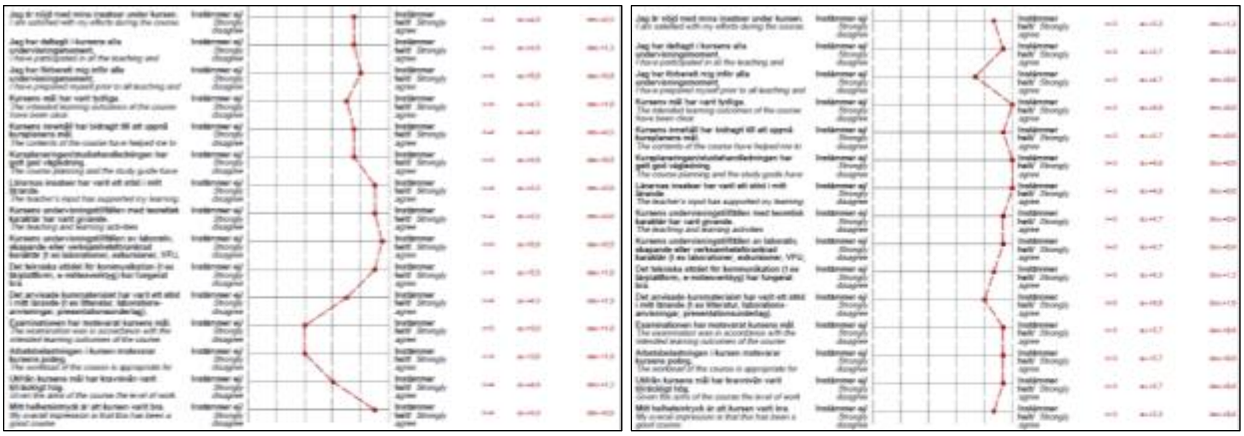

Figure 3 To the left, the self-assessment for the previous course. To the right, the evaluation for the new re-designed course.

4 Conclusions

A key element for the re-design of the course was the team job among the teachers. An early career teacher was responsible for introducing digital tools, while high-experience professors were teaching with the traditional face-to-face approach. However, the web platform supported the students' active learning by providing material and quizzes before the lectures. In this way, the introduction of the technology was not disruptive, and the course kept a high content knowledge.

The web platform for the course followed the main pedagogical knowledge concepts: usage of relevant web material to boost the student interest in the topic and usage of formative feedback. The recorded lectures followed the main ideas of flipped classrooms with embedded quizzes and simulation tutorials.

5 References

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