The digital transformation of Engineering curricula: the categories that preserve Constructive Alignment

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1 Introduction

Scientific publications discussing online learning (or distance learning) have significantly increased throughout the last decade [7]. The COVID-19 pandemic represented an unexpected condition that significantly changed people´s habits and lifestyle along with the education domain boosting even further its digitalization, mostly at higher levels [6]. The digitalization of education is facilitating a pedagogical shift from physical to virtual and distance learning is becoming more popular every day, as it may partially replace on-campus education [8]. In this new digital scenario, the focus on engagement, the instructor's role, and course design concerning the desired outcomes have higher importance [7]. As for the course design, teachers have been challenged to comply with the Constructive Alignment (CA) approach [3]. In this work we assume that Teaching Learning Activities (TLA) and Assessment Tasks (AT) should be adjusted to achieve the same Intended Learning Outcomes (ILO) set before distance learning [9]. In view of the above, this paper assesses two courses selected from the Industrial Engineering study program offered in two prominent European higher education institutions. The CA approach is the baseline of this work and is used to analyse how the TLA and AT of the selected courses are adjusted to maintain alignment with the ILOs defined before the digital transition [9]. The main contribution is defining a set of categories from the evidence collected to guide the digital transaction in engineering and beyond by maintaining the alignment on ILO-TLA-AT.

2 Theoretical background

The CA is a design approach for outcome-based teaching and learning. This approach was proposed by [2] and it is based on two principles:

The constructivist approach to learning: its fundamental assumption is the centrality of the student activities in the learning process. The learner actively constructs their own knowledge [5] "bringing an accumulation of assumptions, motives, intentions, and previous knowledge" [1]. Therefore, the focus is shifted towards what the student does [2]. This has become dominant in the education domain.

The designing of aligned curricula: the learners are provided with a set of clearly specified learning goals, i.e., the ILO. Suitable TLA are designed to engage the students and lead them to achieve the ILO. AT are created to test the learners and give them feedback. The alignment ILO-TLA-AT is realised with "action" verbs embedded in these three elements [2]. These "action" verbs are selected looking at the well-known Bloom taxonomy [4].

3 Methodology

The courses recalled in Table 1 are considered for the analysis. Such antithetical courses with their intrinsic characteristics offer two different perspectives in the industrial engineering field and may be more relevant and bring richer information to the current analysis. As shown in Table 1, the TLA and AT have been re-designed in a distance education environment to ensure alignment to the ILO of both courses. Each instance in Table 1 is analysed to find significant patterns. This allows identifying the sub-categories that are further abstracted to relevant categories, i.e., *Technology, Interaction and Time* (TIT), see Table 2. The TIT categories are the important dimensions that need to be considered during the transition to digital education to ensure the alignment ILO-TLA-TA.

4 Results

Table 2 displays the three emerged categories and the corresponding sub-categories, namely the aspects of the digital TLA and AT observed for each TIT category. The analysis of the antithetical course has led to the same conclusions in all the three categories:

Technology: includes the digital technologies involved in digital TLA and AT. These technologies are introduced to enhance the student learning experience and facilitate the achievement of the ILO.

Time: refers to how the time dedicated to teaching was spent with asynchronous and live activities.

Interaction: considers the engagement of the learners in the online courses. Mainly investigated is the level of interaction between teacher-student or student-student, communication and participation, and community building.

5 Conclusions

The CA introduces a feedback loop between what and how the teacher wants to teach. The resulting course design is more resilient and can successfully overcome

		Scientific methodology	Manufacturing processes
TLA	*Lecture and guest seminar*	The particular features of **video conferencing tool** such as "**screen sharing**" enables **equal visualization** for the students: each student can follow the lecture and what the teacher is displaying from his/her own **screen**. Teachers and students connect to the lecture **right on time**. **Live** lectures are **recorded and published later on**. Use of digital **white board** with the aid of touch screen. **Lack of feedback**, students just speak up to ask questions	Use of **video conferencing** causes **the lack of student's feedback and connection** to the professor that cannot control them easily. Use of **pre-recorded video** allows students to **customize** the learning process and facilitated numerous activities in the use of the pc at home (visualization, hardware, software, charge power, etc.). **Remote virtual laboratory** using a simple **action cam** by the lab technicians allows machining process customized experience "**remote piloting**".
	Homework/ Consultation hours	Use of the **collaborative tools** such as google docs, presentation for **co-creation and sharing**. **Feedback** from peers is given on a slower pace. There is no physical interaction in class for quick update.	Use of **video conferencing tools** trigger the birth of consultation hours. In physical consultation hours logistics and time were the main problems that prevented students from asking **opportunities of discussion together with the professor**
	Class work/ Practical lectures	Use of a specific feature of **video conferencing tools** such as "**breakout rooms**" would split the students in groups and make them discuss. This is a **synchronous** method useful during a lecture to make students reflect in a group about the topic just presented. An "**online discussion**" is set on the **learning management system** as **asynchronous** method where students are asked to provide short reflections on a topic related to the lecture given	**Virtual team** for homework (group) is a practical experience of project management in the context of remote working. It imposes the communication of the members as well as a formal definition of the task and the use of the **collaborative tools** that became a standard in the current set of skills that a "smart worker" should satisfy.
AT	*Remote examination Essay Report Class presentation*	Use of **video conferencing tools** for monitoring the students and creating the **virtual room** for being in the exam. Questions were opening mic and speaking or posted on the **chat**. Use of the **learning management system** to publish the tasks for the exam and to upload essays and reports. Rethink the exam format to avoid cheating: a short initial **quiz** with multiple choice questions is proposed to the students; a series of open book questions are presented as essays.	The high number of participants (100+) and the characteristics of the test prevent the use of open questions and require a **time-framed quiz**. The quiz generation is a quite **time consuming** (but necessary) task to guarantee the AT aligned to the ILOs. The oral examination is divided into two sections: the **Class work presentation** and the theory answer. A final report is uploaded to the **learning management system** aiming at summarizing the project work.

Table 1: The TLA and AT designed during the digital transition to ensure alignment with the ILO of the courses *Scientific methodology* and *Manufacturing processes*, respectively from Production Engineering at KTH The Royal Institute of Technology (Sweden) and Energy and Management/Industrial Engineering at the University of Pisa (Italy). Highlighted in bold are the aspects of the digital TLA and AT that correspond to the sub-categories further abstracted to the *Technology, Interaction and Time* (TIT) categories.

CATEGORIES	SUB-CATEGORIES
Technology	Forum, Action cam, Video conferencing, Cloud-based tools, Digital white board, Video conferencing tools, Learning management system
Interaction	Feedback, Networking, Socialization, Level of student engagement, Level of interaction among peers and teacher-student, Live interaction with chat and with "remote piloting"
Time	Asynchronous and live activities, Time dedicated to teaching, Puncutuality

Table 2: The *Technology, Interaction and Time* (TIT) categories of the digital changeover for the Engineering curricula. This table represents the lesson learned based on the evidence summarized in Table 1.

unpredictable events such as the current COVID-19 pandemic. However, the short notice digitalization of education forced by the above mentioned pandemic has challenged constructively aligned courses. Therefore, educators had to think about new way of performing TLA and AT that would preserve the ILO-TLA-AT alignment established before the digital shift.

This work is based on two practical experiences of digital transition in higher education and proposes the TIT categories as the main relevant dimensions to be considered in the re-design process of TLA and AT. The proposed categories must be considered as guidelines to be followed during the top-down exploration of different domains. The insight from these guidelines will ensure the ILO-TLA-AT alignment by covering all the main aspects in the re-design process.

The abstraction process adopted in the methodology allow to transpose specific engineering instances to a set of general variables that may be considered as a reference point also in different disciplines. However, further research and additional case studies are needed to validate the proposed categories.

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