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A Paradigm Shift in Teaching Aerospace Engineering: From Campus Learners to Professional Learners – a Case Study on Online Courses in Smart Structures and Air Safety Investigation

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In this paper, the transition from teaching on-campus to an online audience consisting of working professionals in an Aerospace Engineering context is described. The differences in the learner's needs and the transition in teaching methods and style that is required from teaching staff is discussed. This is illustrated by two case studies: for Smart Structures and for Air Safety Investigation. Recommendations on how universities can contribute to Life Long Learning are given.

I. Introduction

MOST universities have taught on-campus courses to students, typically in their early twenties, for decades and although many have also provided for professional (and life-long) learners by means of seminars and short courses taught on-campus on set topics. Only a few universities had a set program to offer professional learners dedicated courses based on original on-campus courses.

After the widely-publicized success of the Massive Open Online Course (MOOC) on Artificial Intelligence by Thrun and Nordvic from Stanford in 2011 with over 160,000 learners enrolled, the endless possibilities of online learning started to reach the world of STEM education. The Faculty of Aerospace Engineering of Delft University of Technology in the Netherlands, the largest aerospace faculty in Western Europe, with an enrollment of almost 3,000 BSc, MSc and PhD students, decided to develop its own array of online courses ranging from MOOC to blended campus courses and paid on-line MSc courses [1], [2].

Initially, the paid online MSc courses were intended for working professionals as well as for our own on-campus students, but experience quickly showed that the needs, interest and priorities of a working professional are very different than that of an on-campus learner. A need arose for a new type of online courses: the so-called ProfEd – Professional Education, aimed at working professionals in the field, teaching at academic level, taking into account the specifics of these learners.

This paper outlines how two Aerospace Engineering MSc courses were transformed into two successful ProfEd courses run via the online platform of TU Delft (www.online-learning.tudelft.nl). The courses highlighted as case studies are:

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- Smart Structures, a course on the use of smart structures in aerospace which allows the learner to get introduced to the field and apply their new-found knowledge to real-world aerospace examples and beyond.
- Air Safety Investigation, which aims to decipher the myth behind air safety investigation with the goal to educate anyone who is involved in the chain of air safety incidents and accidents with the way of thinking and working of an air safety investigator.

In this paper, the authors highlight the challenges faced in creating an online course, address the specific needs of an online learner as well as the specific needs of the professionals at which each course is aimed, explain how aerospace engineering content had to converted to an online environment as well as being adapted to the needs of professional learners, share lecturer experiences and analyze the course statistics, and address how to adapt assessment to the world of online and professional education.

II. Traditional On-Campus Learners versus Professional Learners

There are several differences that can be highlighted between the professional online learner and the on-campus learner aside from the latter expected to be present on campus and the former being online-only: they also tend to have different personal objectives and circumstances and therefore different educational needs. Some of the key differences are explained in the next sections.

A. Grade Oriented vs. Knowledge Oriented

Although as lecturers, we would all like to claim that students come to university to learn, we also know the hard reality that most students are here to "get a degree". As a result, on-campus students, as a whole, tend to be very assessment focused and adjust their learning strategies and the way they process the course content to obtain the grade they need to pass or maintain their GPA. As a result, on-campus students have a tendency to look for the most efficient way to process the knowledge and skills on offer as opposed to gaining as much useful knowledge and skills as possible. The objective of the professional learner is the exact opposite. They predominantly are motivated to take a course to obtain new knowledge and skills to suit their professional needs and are often only interested in a certificate of completion, either to meet their annual training requirements or to prove to their sponsor that they have completed the course.

B. Scheduled Classes vs. Anytime, Anyplace, Anywhere

Another difference is the timing of courses and the day-to-day activities of on-campus students and professional learners. When a student enrolls in an on-campus course there is often scheduled face-to-face time, course preparation and homework and a form of final assessment all firmly scheduled. The primary daily focus of an on-campus learner is expected to be that of studying. However, for a professional learner their work is their primary focus, often closely followed by their personal life and the time left over is often when their personal development is scheduled. For them fixed scheduling, mandatory class attendance are all things from a bygone past. They have a much greater need for flexibility within the running period of the course, so that they can tailor their learning around their day-to-day activities.

C. Curriculum Focused vs. Stand-Alone Course

On-Campus courses typically form part of a prescribed curriculum, as a result lecturers know what prior knowledge to expect from their learners as they are familiar with the other courses on offer. For stand-alone courses that are not offered for college credits, but for Continuing Education Units (CEUs), prior knowledge is often only recommended. The prior knowledge of the learners often stems from a large and diverse range of previous educational experiences, meaning it is important for a lecturer in these types of courses to establish a common baseline at the start of the course.

III. Consequences for Course Design

So, what does this mean for the design of an online ProfEd course? First of all, the course must be designed to be clearly structured and modular to allow for required the flexibility. Second of all, the knowledge and skills offered in the course must be well defined and adjusted to the needs of the professional learner. Thirdly, the assessment used shifts from summative to more formative, as course completion and retention of learner's motivation become clearer. This is where the Online Learning Experience (OLE) model comes in. The OLE model was developed by Jorge et al. at Delft University of Technology to assist in course design of online courses [3]. It asks each lecturer to grade their intended course on 8 principles: Supportiveness, Interactivity, Activeness, Contextualization, Innovation, Flexibility, Diversity, and Inclusiveness. The result is a spider plot that outlines where the emphasis of each course

lies. It helps focus the lecturer on the goals they want to achieve and also allows a lecturer to reflect on how their online course differs from their on-campus course.

In the section below we will outline how this development took place for each of the two courses.

A. Case Study I: Smart Structures

This course was based on an on-campus MSc course titled "Introduction into Adaptive Aerostructures", with a study load of 84 hours divided over 6 weeks of teaching and a final assignment. This course was initially converted to an online MSc course that professionals could enroll in for a fee, but was found to be too time-consuming and too focused on campus learning outcomes for working professionals [1], [2]. The lecturer therefore decided to convert the course to a ProfEd, switching focus, from a specific course focusing on selected details of smart structures, to an overview course which covers the whole research area of smart structures in less detail. The basic idea behind this shift of focus is to provide the professionals with an overview of, and coherence within, the field of smart structures. In fact, seeing and understanding this coherence is initially more important than the details because this particular research field has grown unbounded in the past two decades. The presumption is that the professionals, once exposed to the complete overview, can select their topics of choice to go into more depth in other (online) courses. The assessment method was shifted from a large final project, which was used for the on-campus version, to a selection of four smaller assignments that the professionals needed to solve. These assignments were merely an encouragement to follow and apply the material. All four assignments needed to be handed in, in order for students to pass the course.

What you see here is a shift in the level of Bloom's taxonomy used [4]. The MSc course is at higher Bloom's taxonomy level (4-6) and the online course is more at lower taxonomy level (1-3 remembering – understanding – applying). If we then take a look at the OLE model (see figure 1) for both the online ProfEd and the on-campus course you can also some notable differences. In the online course, there is less interactivity. This is due to inability at this stage of the course to do (virtual) experiments with smart structures which are shown in class. The same can be said for the active criterion. As the online course is more basic there are less contextual examples and less diversity in topics due to the difference in expected prior knowledge of the learners between the on-campus and the online course. What can also be seen from the model is the room for innovation in the course, such as the inclusion of virtual labs, for instance.

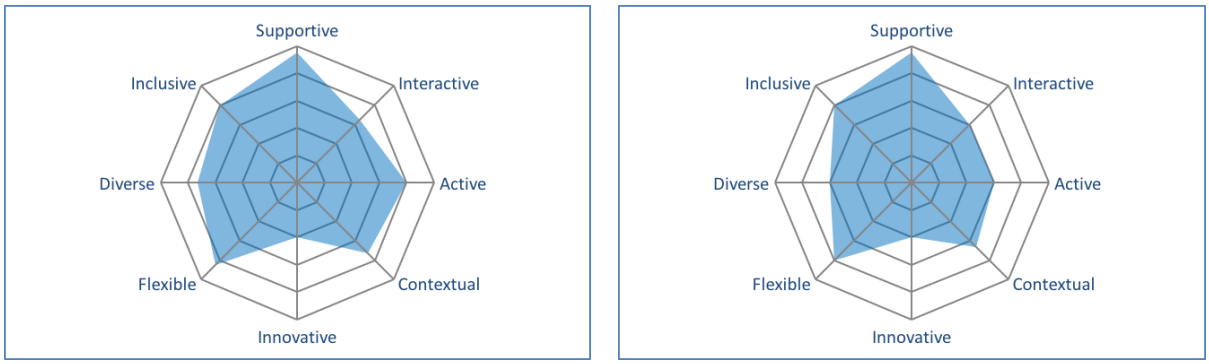

Figure 1: OLE models for the on-campus course in Introduction to Adaptive Aerospace Structures (left) and the online Smart Structures ProfEd course (right)

B. Case Study II: Air Safety Investigation

This course is based on an on-campus course in Air Safety Investigation entitled Forensic Engineering [5]. The on-campus course is characterized by weekly theory with hands-on exercises which are aimed to weekly challenge student's in order to be prepared for "Crash Day", the final exam where students investigate and report on a mock accident. The challenges can range from logical thinking to observation and preconceptions skills. Both the hard skill engineering is combined with the soft skills which include working in groups. The course is taught by an experienced Air Safety Investigator and a Structural Integrity expert. For their adaption to an online ProfEd (Professional Education), they widened the target audience from aerospace engineers to anyone who is interested or involved in aviation safety and related fields. This meant that the course content had to be adapted to ensure that the

course was not only focused on engineering but more on the structure of an investigation, investigation skills and ways of thinking. This meant that certain hands-on exercises needed to be digitized or changed in order to achieve the air safety course objectives.

To give the online students more choice it was decided to have two tracks; a generalist and an expert track. The track choice entails that the online students can do additional work and exercises if they so desire. This choice is believed to be a desired learning path for students and increases the course attractiveness. The generalist track would be given to fulfil the learning objectives on a Bloom's lower levels of learning [4]: 1. remembering – 2. understanding – 3. applying. By using previous air safety investigations as an example skills and procedures are taught to the online students. However, as this was a professional course it was felt that some in-depth exercises would further benefit the course. Thus, an expert track was created to extend the levels of learning to the application and analyzing level (3-4) with some exercises even having students reflect on the course material and write small reports themselves (Bloom's level 4-5-6). The discussion board is used to address issues and give feedback on questions. Also, the discussion board is used as a tool to have students work together on one case study.

Another particular challenge in adapting some of the learning goals of the on-campus course Forensic Engineering (the hands-on part) to the online Air Safety investigation course was to transfer interviewing and accident scene observations to an online format. This was done by creating an online simulation of a three-dimensional digital accident scene that students could visit to test their observation skills.

If we now look at the OLE model for the online ProfEd and the on-campus MSc course as shown side-by-side in figure 2, the differences between the courses can be observed. The on-campus course has been designed to be less interactive as students are expected and more used to working together, something which is much harder to realize in an online course due to the different schedule and pace of each learner. Secondly, the online course is less active than the on-campus course. Again, for this particular course this makes sense: in the on-campus course students handle actual aircraft debris, do real face-to-face interviews etc., course elements that were replaced in the online course with similar but less active activities such as computer simulations. Thirdly, there is slightly less context in the online course. Again, in this case these were some of the choices made due to the online environment as well as the different learner audience. This also accounts for a slightly less diverse course offering. Finally, the online course is much more inclusive, which was a deliberate choice by the lecturers as they did not want to limit the course to aerospace engineers but instead focus on anyone who is interested or involved in aviation safety and related fields. Even if this meant it slightly went at the expense of the context.

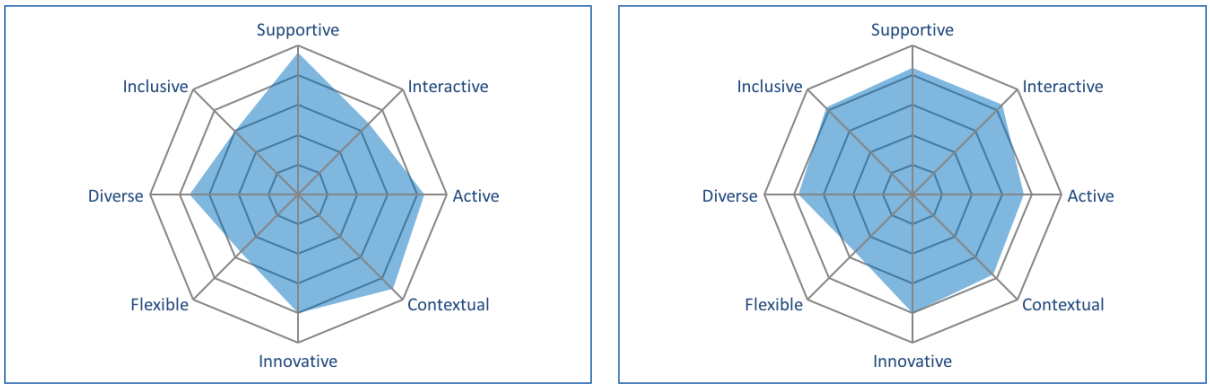

Figure 2: OLE models for the on-campus course in Forensic Engineering (left) and the online Air Safety Investigation ProfEd course (right)

IV. Course Statistics

Both courses have now each ran twice, with the third run in Air Safety Investigation ongoing at the time of writing (Fall 2017). In table 1 the number of participants and the course completion rate have been listed for the completed runs of both online ProdEds. As can be seen the course completion rates are high, which is an indication that the learners are motivated and stay motivated. It may also indicate that the courses are fit for purpose but in order to say more about that we also need to look at course satisfaction which we will discuss later in this section.

Table 1: Overview of number of course participants and course completion

	Smart Structures 2016	Smart Structures 2017	Air Safety Investigation Fall 2016	Air Safety Investigation Spring 2017
# of participants	7	5	17	17
# certificates	6	4	17	15
# expert track certificates	N/A	N/A	12	15

In each online course the participants are strongly encouraged to share their opinion on the course and demographic background information is also collected. Demographics of each of the courses, as listed in table 2, show a spread across the globe in terms of participants. The Smart Structures course attracts a younger audience at the moment on average than the Air Safety Course.

Table 2: Demographics of course participants based on pre-course survey (n = number of responses)

	Smart Structures 2016 (n = 5)	Smart Structures 2017 (n=3)	Air Safety Investigation Fall 2016 (n = 17)	Air Safety Investigation Spring 2017 (n = 11)
Africa	-	-	-	9%
Asia	20%	33,3%	5.9%	9%
Australia & Oceania	-	-	5.9%	-
Europe	60%	33.3%	70.5%	64%
North America	-	33.3%	5.9%	9%
South America	20%	-	11.7%	9%
Average Years working experience	6.4 yrs	13 yrs	20 yrs	18.9 yrs
Average Age	30.2 yrs	33 yrs	41 yrs	39 yrs

Table 3: Average Grade Given by Students to course based on post-course survey (n = number of responses)

	Average grade (out of 10)	Standard Deviation (S.D.)
Smart Structures 2016 (n = 5)	8.4	1.36
Smart Structures 2017 (n = 2)	7.5	0.5
Air Safety Investigation Fall 2016 (n = 11)	8.9	1.38
Air Safety Investigation Spring 2017 (n = 10)	8.3	1.42

If we look at learner satisfaction, the picture is overwhelmingly positive. In table 3 the average grade out of 10 and the corresponding standard deviation are given. The lowest grade given at any point for either of the courses is a 5 out of 10. Analysis of further results from the post-course survey that learners indicated overwhelmingly that the course met or exceeded their expectations (see table 4). The transformation from an on-campus master student oriented course to an online course focused on working professionals seems to have been successful.

Table 4: Extend to which learners indicated that the course met their expectations based on the post-course survey (n = number of responses)

	Smart Structures 2016 (n=5)	Smart Structures 2017 (n=2)	Air Safety Investigation Fall 2016 (n=11)	Air Safety Investigation Spring 2017 (n=12)
Course did not meet my expectations	-	-	-	8.33%
Course was exactly what I expected expectations	40%	50%	27%	66.67%
Course exceeded my expectation	60%	50%	73%	25%

V. Conclusion

From the uptake of the courses it is clear that there is a need for online ProfEd courses in aerospace from universities for working professionals. However, it is not a simple one-on-one conversion from a campus course to an online course. The learners have different objectives and requirements and different ways of working.

Therein also lies the challenge for the lecturers developing the course. They must identify those needs accurately. This is where making use of the OLE model is very insightful. It also requires an ability to have a critical perspective to one's own work and the ability to view a course from the viewpoint of a professional learner. The upside of this endeavor is that the course evaluations show, that if done well, learners are extremely satisfied and have gotten the appetite for more learning. It also adds to the university's reputation, and has the potential in the long run to add a sizeable money stream to the university's income, if managed well. It also contributes to a better understanding by university lecturers of the current state-of-affairs in industry and their needs, and brings new and more industry contacts which also widens the lecturers' horizon.

Although the investment in time is considerable, it is recommended that more of these courses are developed in the aerospace domain. They will go a long way in assisting industry in maintaining their innovative power and further strengthen the links between education and industry essential for delivering better aerospace engineers to face the future and the challenges that lie ahead of us.

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