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Push or Pull Students into Blended Education
A Case Study at Delft University of Technology

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Abstract

Blended education, or “flipping the classroom” is rapidly becoming a mainstream form of teaching within universities. Within Engineering Education, it is popular as it allows more time in-class to focus on hands on activities such as demonstrations and solving complex problems. This paper discusses the effort conducted to re-structure, according to the blended learning principles, the “Propulsion and Power” course of the Aerospace Engineering Bachelor degree programme at Delft University of Technology (TU Delft). The redesigned course was supported by a dedicated online & blended education unit within the university, and is characterized by a very peculiar structure due to the different approach chosen by the two involved lecturers. The first lecturer decided to “pull” the students, by proposing a number of additional videos available in the World Wide Web as a support and complement to the material taught in class. Conversely, the second lecturer opted for a “push” approach, self-recording theory videos to be watched by the students at home and devoting the in-class hours to exercises and applications of the theory. This format resulted in a clear improvement of the average exam grades and pass rates. The student feedback showed enthusiasm about the new blended course, with only a very small minority still preferring the previous, more traditional approach. Although there seems to be a slight preference of students towards the “push” strategy, the “pull” approach has also been widely appreciated. However, the objective to re-attract students to the contact hours in class was only partially achieved, since just a slight improvement in the number of attending students was observed. This paper clearly shows that the efforts to implement a blended teaching strategy has great benefits for both students and staff alike.

Keywords*: blended learning; online education; student engagement; electronic assessment; aerospace engineering.*

1. Introduction

At the Faculty of Aerospace Engineering at Delft University of Technology (TU Delft) there is an active culture of implementing new teaching techniques. The faculty was among the first to use computerized homework and interactive design systems, and to implement project education in its curriculum [1]. Thus, when TU Delft announced its intention to introduce and actively promote online and blended learning for campus education, aerospace engineering immediately joined the initiative. The university formulated a clear mission statement with regards to Open & Online education: *"to educate the world and improve campus education by means of Open & Online education. We aim at opening up our knowledge in engineering, design and science to students all over the world and engage students via new innovative learning experiences"*.

To achieve this mission, the TU Delft Open & Online Education programme was created in 2013. This three-year strategic programme aims at experimenting with online education and focuses both on campus (in blended learning format) and fully online education (MOOCs and accredited courses in online format) [2]. To facilitate this the TU Delft Extension School was founded, a support organization dedicated specifically to this programme. It offers support on pedagogy, marketing, technology and business. Lecturers, staff and the Extension School support team closely collaborate in their efforts to create online courses. The aim is not only to create online education but to also (re)use online materials in campus education, thus creating more blended education on campus [2].

One of the initiatives of the TU Delft Extension School consists of funding and supporting the efforts of teachers willing to introduce new courses, or modify existing ones, based on a blended education approach. In this context, a proposal to modify the "Propulsion and Power" course offered in the 2nd year of the Aerospace Engineering Bachelor degree programme was funded.

This paper is focused on the preparation, execution and outcomes of this effort towards a new blended version of the course. The new course is characterized by a very peculiar structure, due to the different approach chosen by the two lecturers involved in it. While the lecturer of the aircraft propulsion part has decided to "pull" the students, by proposing a number of carefully selected additional videos available in the World Wide Web as a support and complement to the material taught in class, the lecturer of the space propulsion part has opted for a "push" approach: he recorded a number of videos on the theoretical part of the course and asked the students to watch them at home, before coming to the lecture, while the in-class hours were spent on exercises and applications of the theory.

In the paper some quantitative results (course attendance, pass rates and average grades), as well as the feedback received from the students at the end of the course, will be presented and discussed. In this way, we hope to give a valuable contribution to the academic debate on how blended education can be implemented and how it can improve the educational practice in teaching engineering topics, especially to large groups of students for many colleagues facing similar challenges in the world. The paper will also show how different blended education strategies can be implemented without needing an excessive amount of resources.

2. Benefits of Blended Education

Blended Learning has many different definitions. Alan and Seaman [3] define blended education as a form of instruction in which "*30 – 80% of the course content is delivered online*". However, there is also criticism on the use of the term blended education as if it is a new thing. Driscoll already argues to "get beyond the hype" in 2002 [4] and Oliver and Trigwell [5] also object against the use of the term 'blended learning' as from the perspective of the learner it is not a new form of learning but rather a different form of instruction and pedagogy. More appropriate definitions are listed by Graham [6] based on an extensive inventory of definitions: "combining instructional modalities" or "combining instructional methods" and finally "combining online and face-to-face instruction". What remains is that all the elements of the course need to be connected to each other to create a real "blend" between the face-to-face instruction and the online part. For the purpose of this paper the last definition: "combining online and face-to-face instructions", as summarized by Graham [6], is used.

Designing and teaching in a blended education format requires a large amount of organization skill from lecturers involved. But why would one pursue blended learning? Evidence shows that blended learning tends to better promote active learning by the students resulting in higher participation in exams, better pass rates and less drop-our rates [7] and [8]. Blended learning is also attributed to lead to deeper understanding, however closer research of this claim indicates that this deeper understanding is not caused by the blended learning itself but rather by the required rethinking and redesigning the way we as lecturers teach [9].This is illustrated by the notion that a well-designed combination of face-to-face learning and e-learning results in a course set-up that is active, diverse and flexible. The rhythm of online activities combined with face-to-face learning makes students study in a more regular pace during the whole course. A well-designed blended course offers students a more diverse range of contents and activities compared with a traditional course. It is much more than just watching a recorded lecture. The E-learning part offers flexibility in time and space; students can choose (within limitations) when and where to study [10]. According to the meta-analysis of the US Department of Education, blended learning is on average considerably more effective than only face-to-face learning education or only online learning [11]. The full positive effect of blended learning can be achieved, however, only when the courses are carefully (re)designed and taught [12]. There are many different forms of blended education. Most people only think of online videos with in-class exercises as proposed by Bergman and Sams [13], but other possibilities exist, such as the use of e-tools to allow students to work within the learning preferences to improve their skills [14]. Gillet [15] agrees with that and sees in blended and online learning the opportunity for students to have a more personalized learning.

One form of blended learning, which will be the focus of this paper, is flipping the traditional lecture with the homework assignments. This results basically in face-to-face sessions with activities and homework based on watching video-lectures. Many different lecturers over time have experimented with blended learning in this way. A large EU project, BLEND-XL, run from 2005 to 2009 [16], showed different engineering degrees trying out blended learning with their students, indicating in the subsequent evaluations that they enjoyed it tremendously and that they felt in contributed to their learning. This is supported by other studies such as Lou et al. [17], as well as Forcada et al. [18] which both show that blended methods have a positive effect on student creative learning and on their learning attitudes. Students state according to Sams [13] that having videos of the lectures is convenient; students can study when they need and at the pace they like. However, the most important part is freeing up classroom time for a lecturer to work with students when they really need this support. According to Sams: "The time when students really need me to be physically present is when they get stuck and need my individual help" [13].

3. Educational Environment: The Aerospace Engineering Bachelor at Delft University of Technology

The Faculty of Aerospace Engineering of TU Delft has a reputation for excellence in education. With more than 1500 BSc and 1000 MSc students in 2015, it is one of the largest educational institutes in the Western world dedicated to aerospace engineering. Its teaching language is English.

The mission of the Faculty of Aerospace Engineering of TU Delft is *"to be the best aerospace engineering faculty in the world that inspires students, staff and society with modern education and ambitious research of the highest quality for the future of aerospace"* [19]. Such an ambitious mission requires an innovative, modern and efficient study program, which needs to take in due consideration the many multidisciplinary challenges generated by the complexity of the systems produced by this engineering branch. The current curriculum is aimed at educating "Tshaped" graduates [19]. The broad bar of the T-shape is provided in the BSc, by offering a broad academic background in basic engineering sciences as well as a consolidated knowledge of aerospace engineering and technology and the development of academic intellectual and engineering skills and attitudes to analyze, apply, synthesize and design. The stem of the T-shape is provided in the MSc, which teaches in-depth aerospace engineering and science and focuses on detailed knowledge of and experience in one or more sub-disciplines. Its final qualifications are in line with criteria of the three technical universities in the Netherlands for Academic Bachelor's and Master's Curricula [20]. To achieve these final qualifications, the Bachelor Program employs a variety of teaching and learning methods ranging from active lectures and studio-classroom to almost independent self-steering project groups.

The current Bachelor is a 3-year, 6-semester and 180 ECTS (European Credit Transfer System) program, structured to resemble a real design engineering cycle. In this respect, five of the six semesters are dedicated to specific steps of the design cycle: (1) exploration, (2) conceptual design, (3) detailed design, (4) test & simulation, (6) verification & validation. The fifth semester is devoted to a minor program, where students are encouraged to look into another (engineering) field or discipline [19].

The BSc program follows the CDIO™ approach and focuses on aircraft and spacecraft engineering and technology, as well as roles and activities of aerospace engineers [21]. It is characterized by a significant number of courses that focus on specific aspects of aerospace engineering and technology already from the start of the first year of study. In addition, each semester includes one design project of increasing complexity from knowledge to application, synthesis and evaluation ([22], [23]). Besides the vertical thematic structure, the BSc program also has a horizontal structure, running through the entire program and comprising three elements: Aerospace Design (one module per semester which contains one thematic design project and a complementary engineering design course), Aerospace Engineering and Technology (primarily theoretical courses in the aerospace domain each addressing the theme and correlating to each other), and Basic Engineering (courses on mechanics, physics and mathematics) [24].

4. The "Propulsion and Power" Course

The course "Propulsion and Power" is offered in the 3rd quarter of the 2nd year BSc program of Aerospace Engineering (semester 4). The course accounts for 4 ECTS and is given by two different lecturers equally sharing the educational effort: the first lecturer introduces the principles, fundamental equations and engineering practice of air-breathing propulsion, while the second lecturer discusses electric power systems and space (rocket) propulsion.

Given the importance and relevance of the topic, as well as the fact that this is the only course in the whole BSc program specifically devoted to propulsion, the course is among the most popular ones for students and usually attracts a large interest.

In the academic year 2014/2015, a total of 359 students have taken part in one or more of the assessment items of the course. The number of students taking at least one of the bonus assignments spread over the whole course duration (see sections 4.2 and 4.4) was 341, out of which 234 students took all of the bonus assignments. The average attendance to the lectures in class can be estimated in the order of 100-150 students.

4.1. Learning Objectives

The course is based on the following learning objectives. At the end of the course a student is able to:

1. Understand the basic principles of thrust and power producing mechanisms for aerospace vehicles.
2. Perform basic sizing of thrust and electric power generation systems suitable for aerospace vehicles.
3. Describe the various components of a gas turbine engine, their working principle and be able to explain factors that determine their performance.
4. List/describe/explain: the main thrust and electrical power generation options available; the (main) components that make up the propulsion and electrical power generation system and their function; the current limits to thrust/power generation.
5. Apply control volume analysis and integral momentum equation to estimate the thrust produced.
6. Apply physics to predict the electric power generated by solar photo-voltaics, batteries, and electrical generators.
7. Develop system models from schematic system descriptions.
8. Size the electrical power system for a given mission.
9. Select the appropriate propulsion/power system from basic types depending on system requirements.
10. Assess the effect of changes in design/operating parameters on system performance.

4.2. Course Structure (Pre-Existing)

The previous course format was based on a total of 14 “traditional” lectures in class (2 hours per lecture): 2x7 hours on air-breathing propulsion (first lecturer), 2x7 hours on electric power systems and rocket propulsion (second lecturer). A traditional, (in-class) written exam was taken by the students at the end of the course, with one single re-sit offered at the end of the educational period immediately following. The overall maximum grade for the complete course is 10, with 6 being considered a passing grade in the Netherlands. Four bonus assignments were offered to the students during the course, two for each part, granting a maximum of 2 bonus points. These bonus points could be added by the students to their exam grade, but only if the exam grade was sufficient (i.e., it was not possible to change an exam fail into a pass just using the bonus points). Some of these bonus assignments were done as homework and some in class as tutorials. In particular, the last 2-hour lecture of the second part (power systems and rocket propulsion) was devoted to a tutorial, which accounted for 85% of the bonus points allocated to this part of the course. Participation or a sufficient grade in the bonus assignments, however, was not mandatory to pass the course. Lecture slides were the main study material for the course, supported by readers developed by the course staff and by some recommended (but not mandatory) books.

4.3. Reasons for Change

In its pre-existing version, the course was already very popular and well received by students, consistently being among the five best scored courses of the whole BSc program in the quality control system based on student feedback. Average grades and pass rates were also considered good. However, there were several reasons for which this situation was not yet considered to be optimal by the instructors.

In particular, the idea of moving towards a blended version of the course was triggered by two main motivations.

Firstly, for this course, a clear and non-negligible “migration” of students was observed from attending the traditional lectures in class to watching the recorded version in their own time at a moment of their choosing. All the lectures of the course were recorded in the Academic Year 2012-2013 by means of the internal recording system of TU Delft “Collegerama” (collegerama.tudelft.nl) and made available to the students. In their feedback, students repeatedly stated that they appreciated the quality of the recorded lectures, and a large majority of them expressed a clear preference to watch them at home instead of attending the same lectures in class. As a result, the number of students dropped, from a previous average of approximately 150 students per lecture to less than 100, although this lower attendance did not influence the course pass rate (see results for 2013 and 2014 in Table 2).

Secondly, discussions with the students during and after the course showed that a majority of them tended to start studying very late for the exam and usually did not study much during the course itself, while it is well known from literature [25] that a regular study behavior clearly improves study success and course results. The course was typically perceived as difficult, the exam as hard although the pass rates in the order of 75-80% for the regular exam and 70% for the re-sit, as well as the average grades in the order of 5.5 out of 10, were considered to be fine by the faculty's quality control office.

The lecturers strongly felt that the student engagement with the material should be more continuous and consistent during the course and at the same time respecting the students desire to have more freedom on when to engage with the theory of the course. Hence a proposal was made to the TU Delft Extension School for funding and support to change the course format into a blended one, mostly based on the "flipped classroom" concept and complemented by a completely electronic exam and homework to facilitate grading and early feedback.

The proposal aimed at improving the student engagement during the contact hours, increasing the effectiveness of the lectures and their alignment with the learning objectives. In making this change, the main identified challenge was to maintain and eventually improve the already excellent evaluation of the course, avoiding low-quality approaches that would probably have a negative effect. This effort resulted in a new course structure, described in detail in the following section.

4.4. New Course Structure (Blended Approach)

To assist in the design of online and blended courses the TU Delft Extension School has developed its own pedagogical model: the TU Delft Online Learning Model [10]. This model encourages an online learning experience that is diverse, inclusive, supportive, interactive, active, authentic, innovative and flexible at the same time. All its courses (online or blended) are designed with this model in mind allowing the lecturer to design a course that meets the identified needs of the learners.

With that in mind, the blended version of the course offered in the Academic year 2014-2015 was designed with three key elements of the model in mind: (1) introduce more exercises and practical examples (interactive); (2) make a more extensive use of active learning elements (active); (3) to not increase the course complexity and limit as much as possible the instructors effort in preparing and executing the course by using videos. (flexible)

In the resulting structure, the general timetable and the number of contact hours in class remained unchanged (2x14 hours), and the bonus points mechanism remained intact. The following changes were implemented with respect to the previously existing structure:

-) The number of bonus assignments was increased to six, offered almost on a weekly basis to the students during the course. In this way students were challenged to be active right from the start of the course. Five assignments were given as homework, while the sixth one was a group tutorial during the last 2-hour lecture in class. The first four assignments students had to complete using a digital assessment tool (Maple TA) allowing for easy grading and feedback.

-) The final exam was offered (both the regular one and the re-sit) completely electronic, also in this case using Maple TA as the digital assessment tool. TU Delft promotes digital assessment and has sufficient facilities to simultaneously examine large groups of students. All exam questions were accessed electronically by the students, with 75% of the problems answered and graded directly by the electronic system and the other 25% answered on paper and graded by the instructors.

-) The in-class lectures were supported by online contents according to the flipped classroom concept as described by Jackie Gerstein [26] and the Flipped Classroom Field Guide [12]. The two lecturers involved in the course each decided to adopt a completely different approach to this respect, indicated for simplicity as "pull" or "push" and described in detail in the following.

PULL approach (aircraft part)

In this case, the instructor decided to activate the students by proposing available online video material to complement the parts taught in class or to refresh assumed knowledge. A total of 44 videos were proposed to the students, distributed evenly over the aircraft part of the course, on topics such as fundamentals of thermodynamics, combustion and fuels, turbo-machinery, principles of jet engines. The video content offered had a duration of about one hour per week. In some cases, several videos from different sources on the same topic were proposed. Each week, to further increase the interest of students, a "fun video of the week" was suggested to the students as well, on topics such as jet powered bikes, motorcycles, drag racing vehicles. The general idea of this approach was to expose students to different lecturing styles and different ways of teaching the same topics, allowing students the freedom to choose material that best fitted their personal learning style. It was not the increase student workload by offering more material in comparison with the pre-existing version of the course. Although most of the topics treated by the videos were also taught during the regular lectures in class, this approach made it possible to create opportunities for more in-depth explanations, answering questions, in class exercises and experiments, including a few practical demonstrations. This made the lectures more interactive and time-effective.

This structure and its goals were explained to the students during the first lecture, but also by means of the following announcement made available in the Virtual Learning Environment (VLE).

As I told during this week's lecture every week we will make some supporting video material available. This will consist of a series of videos explaining further some of the topics addressed during this week's lectures or refreshing basis concepts of thermodynamics. We will make available approximately 1 hour of videos every week. Almost all of the videos are part of lecture series of courses addressing similar topics elsewhere in the world. The combination is chosen such that they meet the set-up of our specific course. Of course it is recommended to make use of other videos in those lecture series when they are of interest to you. In this way we want to show you the vast resources available on the internet in the area of propulsion and power that can be used for further study now and in the future.

PUSH approach (space part)

For this part of the course, the instructor decided to completely move the theoretical topics to online content, using the contact time in class almost exclusively for exercises and practical applications. The first lecture of the space part was used for an introduction, a description of the course structure and a set of “entry exercises” intended to refresh the background knowledge students were expected to have. Subsequently, prior to the following five lectures, several online videos were provided to the students, addressing the theoretical aspects that in the previous format of the course were taught in class. A summary of the schedule of this part of the course, including the topics of all supporting videos, is provided in Table 1. Although complete freedom was left to the students on how and when to watch the videos, they were ideally expected to do so before the corresponding lecture in class, where a set of exercises and practical applications of the theory were proposed and discussed by the teacher. As an example, after exposing the students to the basics of rocketry and the ideal rocket theory in the videos attached to Lectures 11 and 12, these principles were then applied in class to the study and characterization of two very famous rocket engines: the Space Shuttle Main Engine and the Rocketdyne F1 engine used for the Apollo missions to the Moon. The lecturer recorded a total of 26 videos with a typical duration of 10-15 minutes per video. An average effort of approximately 1-1.5 hours per video was required to the lecturer to prepare, record and post-process them (not including the time previously required to prepare the lecture slides).

Also in this case, the structure and objectives of the space part of the course were explained to the students by means of the following VLE announcement.

During my lecture today, I have explained that the second part of the course (electrical power systems + rocket propulsion) is based on a different structure with respect to the past. *The theory is now left to your self-study at home (by looking at the slides or watching the videos that I have prepared: both are already available for the whole course). It's important that before the lecture in class you get at least an idea of the theory associated to it, because this will make the session in class more useful for you and your overall learning experience more complete.* *In class we will just recall very shortly the theory and then work at exercises (mainly taken from old exams, but also a couple of design cases of real rockets and spacecraft). In most of the cases you will be given a few minutes to work yourself at each exercise, and then we will discuss together the solution. Thus, don't forget to bring with you a calculator and enough writing paper!*

Table 1: Schedule of the lectures and online videos for the second part of the course (power systems and space propulsion).

Lecture 8 Introduction	*No Videos*
Lecture 9 Electric Power Systems	09-1. Introduction and Fundamentals (1)
	09-2. Introduction and Fundamentals (2)
	09-3. Dynamic Generators: Fundamentals and Working Principle
	09-4. Dynamic Generators: Basic Equations
	09-5. Drive Systems, Static Generators
	09-6. Photovoltaic Generators: Working Principle and Characteristic Curve
	09-7. Photovoltaic Generators: Performance and Sizing
Lecture 10 Electric Power Systems	10-1. Batteries: Working Principle and Fundamentals
	10-2. Batteries: Discharge Rate and Sizing
	10-3. Fuel Cells, Capacitors
	10-4. Power Management
	10-5. Power Conversion and Distribution
Lecture 11 Rocket Propulsion	11-1. Introduction (1)
	11-2. Introduction (2)
	11-3. Rocket Propulsion Fundamentals: the Rocket Equation
	11-4. Rocket Propulsion Fundamentals: the Thrust Equation
	11-5. Rocket Propulsion Fundamentals: Specific Impulse and Efficiency
Lecture 12 Rocket Propulsion	12-1. Ideal Rocket Theory: Assumptions and Building Blocks
	12-2. Ideal Rocket Theory: Nozzle Flow and Jet Velocity
	12-3. Ideal Rocket Theory: Mass Flow Rate and Expansion Ratio
	12-4. Ideal Rocket Theory: Characteristic Velocity and Thrust Coefficient
Lecture 13 Rocket Propulsion	13-1. Classification of Rocket Engines
	13-2. Cold Gas Rockets
	13-3. Liquid Mono-Propellant Rockets
	13-4. Liquid Bi-Propellant Rockets
	13-5. Solid Propellant Rockets
Lecture 14 In-Class Tutorial	*No Videos*

If we measure both approaches in terms of the Golden Rules of Flipping from the *Flipped Classroom Field Guide* [12], we see that the PULL approach has fewer activities in-class but otherwise adheres to the rules. The PUSH approach is a 'full flip', making all of lectures into homework and doing mostly activities in the classroom. For reference purposes the Golden Rules of Flipping, as stated in [12], are given:

1. *"The in-class activities involve a significant amount of quizzing, problem solving and other active learning activities, forcing students to retrieve, apply, and/or extend the material learned outside of class. These activities should explicitly use, but not merely repeat, the material in the out-of- class work.*
2. *Students are provided with real-time feedback.*

3. *Completion of work outside class and participation in the in-class activities are worth a small but significant amount of student grades. There are clear expectations for students to complete out-of-class work and attend in-person meetings.*
4. *The in-class learning environments are highly structured and well-planned."*

[source: Flipped Classroom Field Guide [12]]

5. Results

Two quantitative tools have been used to evaluate the effectiveness of the new course structure: the pass rate and the average exam grade. These numbers are shown in Table 2 for three course editions, the 2013 and 2014 ones (with the previous non-blended structure) and the 2015 one (with the new blended structure), for both the regular exam and the re-sit.

The results show a clear improvement of the average grade (for both parts of the course) and the pass rate in the regular exam session 2015. This trend seems to be only partially confirmed by the re-sit session 2015, but this is probably due to the higher number of students passing the first exam and, thus, the lower number of students taking the re-sit. This is confirmed by the clear improvement visible in the global pass rate during each academic year, calculated considering the total number of students attending the regular exam and the re-sit of that year.

The lecturers involved in the exam felt that the level of difficulty of the exam in 2015 was comparable to the previous editions (or even slightly more difficult). This feeling appears to be supported by the statistical analysis of the test. The reliability using Cronbach's alpha and the difficulty (p-value) were calculated for each exam. Due to the software used to assess the multiple choice questions in 2013 and 2014 it is impossible to include the scores for the open questions in the calculation of the reliability and the difficulty but it is expected that the difficulty score would have been lower as the open question were focused on assessing higher Bloom's taxonomy levels [25]. It is impossible to predict what would have been the value of Cronbach's alpha. The results in Table 2 show that all exams have a Cronbach's alpha greater than 0.7 for the 2015 exam indicating a high reliability of the exam and the difficulty of the exams as indicated by the p-value of each exam is either higher than previous exams or does not differ by a large amount taking into account the previous comments on the limitation of the data of 2013 and 2014, and are in any case close to the ideal value of exam difficulty of 0.5 [25]. The improvement can therefore be directly related to the new structure of the course, which seems to help the students to better achieve the learning objectives and prepare for the exam.

According to these results, one of the initial objectives (increase the pass rates and the student scores) seems to have been fully achieved. Another objective (increase the student attendance in class) was apparently only partially achieved: the estimated average number of students attending the lectures is about 100-150, which is a slight improvement with respect to the recent decreasing trend but is still less than 50% of the "active" students participating in the assessment. Finally, and most importantly, the objective to make students active right away from the beginning of the course was also reached. The participation in the weekly bonus tests was high.

Table 2: Average grades and pass rates in the last three editions of the course. Grades range from1 - 10, pass grade is 6 out of 10. All results marked with * pertain to the MC part of the exam only.

Year	*Session*	Average grade aircraft part	Average grade space part	Reliability of exam (Cronbach's alpha)	Difficulty of exam (p-value)	# of students taking exam	Pass Rate (session)	Pass rate (year)
2013	**Regular**	5.36	5.88	0.56*	0.59*	405	75.6%	73.7%
	Re-Sit	5.32	5.87	0.56*	0.58*	200	70%	
2014	**Regular**	5.85	5.84	0.62*	0.71*	282	80.5%	77.4%
	Re-Sit	4.9	5.78	0.56*	0.60*	120	70%	
2015	**Regular**	*6.42*	*6.44*	*0.75*	*0.49*	*314*	*85%*	*82.2%*
	Re-Sit	*5.64*	*5.81*	*0.70*	*0.51*	*85*	*71.8%*	

6. Student Feedback

Another valuable tool to evaluate the new course structure is student feedback. Two different types of feedback were received, both obtained at the end of the course after the regular exam: the official course evaluation carried out by the faculty as a part of the education quality control procedure, and a more specific feedback requested directly by the instructors to the students. Both feedback tools were totally anonymous and the identity of responding students was not traceable.

The official course evaluation is performed by means of a standard evaluation form for all the courses of the BSc program. Students are asked to provide their evaluation on several aspects related to the course material, organization, coherence, difficulty and assessment, using a 5-point Likert scale from 1 (bad) to 5 (good). In addition, they provide a final global evaluation of the course as a whole, in this case using a Likert scale ranging from 1 (poor) to 10 (excellent). Unfortunately, the university's chosen evaluation software does not allow us to evaluate if statistically significant differences in the evaluation scores between the two years exists.

The complete results of this evaluation are presented in Table 3, where the results obtained in 2015 (new blended structure) are compared to the 2014 ones (previous course format). A total of 55 students participated to the evaluation of the 2015 course, while 31 students participated to the 2014 evaluation. This low response rate is due to the fact that all course evaluations are carried out online by a central office and not through the lecturers involved, leading to low motivation and participation from students.

The results in the table show that, although the course was already evaluated as very good in 2014, its appreciation improved further in 2015. Noticeably, a slight increment can be observed in the score given by the students to all sub-criteria. It is particularly interesting to note that the largest increment was obtained in the criterion "difficulty of assessment corresponds to difficulty of the course". This shows that one of the initial concerns which led to the decision of changing the course structure (the course was perceived by the students as difficult) seems to have been removed, even if the level of difficulty of the 2015 exam is judged by the lecturers comparable, if not slightly higher, than the previous ones.

Table 3: Results of the students course evaluation in 2015, compared to the 2014 edition.

		Evaluation 2014 (n=31)	Evaluation 2015 (n=55)
Material	*Use of VLE*	4.26	4.42
	Course material (e.g. reader, book, slides)	4.16	4.27
	Sample questions	4.29	4.45
	Content (e.g. topics)	4.23	4.44
	Sufficient examples related to Aerospace Engineering	4.61	4.75
Organization	*Lectures*	4.03	4.19
	Lecturers	4.29	4.34
	Teaching methods used	4.1	4.16
	Structure of the course	4.16	4.39
	Relevance of the course for my education	4.48	4.69
Coherence	*Coherence of course within the semester*	3.97	4.18
	Coherence of topics/themes within the course	4.13	4.33
	Building on knowledge of prior courses	4.16	4.31
	Attention paid to relationship with other courses within the semester	3.87	4.07
Difficulty	*Study load*	3.94	4.24
	Difficulty of the course (topics, etc.)	3.97	4.15
	Boundary conditions (lecturers, teaching methods, organization, materials, link to prior knowledge etc.)	4.13	4.24
Assessment	*Grading*	3.96	4.02
	Course material is represented in assessment	4.13	4.27
	Difficulty of assessment corresponds to difficulty of the course	3.45	4.18
	Study goals of this course are covered	4.13	4.29
Global evaluation of course (scale 1-10)		**8.07**	**8.35**

The second feedback was based on a set of questions asked to the students in order to evaluate the effectiveness of the new blended course structure and to compare the two different approaches taken by the lecturers of the two parts of the course ("pull" vs. "push"). A total of 82 students took part in the feedback. The questions asked and the answers received from the students are summarized in Table 4. The table clearly shows that students generally appreciated the course structure: only 9% of them did not consider any of the two strategies effective to meet the learning objectives, while about 40% considered both the strategies effective. About 35% of the students indicated that they watched all or most of the videos, and only 23% of them did not watch any of the videos. Overall, although both strategies are definitely appreciated, there seems to be a clear preference for the "push" strategy (space part of the course). Another interesting information provided by the table is that, although the number of students who watched the videos is comparable for the two strategies, for the videos recorded by the teacher (space part) the students tended to watch all of them once started, while only a few students watched all the videos supporting the aircraft part.

Table 4: Summary of the answers received from the students to the feedback questionnaire proposed by the lecturers (n=82).

In your opinion, which one of the two blended education strategies (aircraft part or space part) is more effective to understand the course topics and prepare for the exam?		
Aircraft part		**9.1%**
Space part		**41.6%**
Both of them		**40.3%**
None of them		**9.1%**
Did you watch the videos provided to support the course?		
	Aircraft part	*Space part*
Yes, all of them	**9.9%**	**18.3%**
Yes, most of them	**23.5%**	**18.3%**
Only some of them	**42%**	**41.5%**
None of them	**24.7%**	**22%**
Do you think that the supporting videos helped you to better prepare for the exam?		
	Aircraft part	*Space part*
Yes, definitely	**22.1%**	**38.5%**
Yes, partially	**46.8%**	**41%**
No	**31.2%**	**20.5%**

It is also interesting to look at some of the comments provided by the students together with their feedback. Among the positive ones:

-) I really enjoyed the in class demonstrations! Who doesn’t like watching things explode and burn?

-) The dedication of the lecturer of the space part is very motivating for the course, good job!

-) The videos supporting the aircraft part are from different providers, thus when watching them marathon style, they offer alternation and variety. The videos supporting the space part offer probably a little bit better preparation, because they are stripped from unnecessary extra info. Please keep the fun videos, they offer another perspective on what you learn.

-) The videos supporting the aircraft part are set up very well. They are made by people who are popular and experienced video makers, with the right equipment to make it all look fancy.

-) I very much enjoyed the lively lectures related to the aircraft part. Moreover, I liked the fact that weekly tests were provided, which force you to keep on track with the material as the course progresses.

-) I very much like the fact that the lecturer of the space part spent all the time on practicing exercises instead of going through the pure material. I enjoyed the bonus assignments which really help understand the material and how to apply it.

-) Good lectures and the exam was not too hard, neither too easy.

-) I appreciated the bonus points cause this frequent making of exercises made me understand the course material more.

-) Perhaps the best course I have attended as a BSc Aerospace Engineering student. There was a lot of practice material, the teachers very helpful, always available to help. I think more and more exams should be digital, since the students can know their final grade faster but also because it's easier for professors to grade.

-) The way the space part of the course was set up, was very nice. Making videos of the lectures works very well because that way you can skip certain parts you already understand and re-play others that are quite difficult. Doing the exercises in class really gave a good understanding of how to solve them and, if you couldn't, how the teacher would solve them. All in all, a really nice course.

Conversely, among the less positive remarks:

-) For the space part, I do not have a real preference for live or recorded (video-based) lectures; however, after having watched the videos and done the exercises, attending the live lectures did not lead to significant benefit anymore.

-) I did not really like the interactive space lectures. Too much doing stuff in the lectures. I'd rather prefer the material being taught with every now and then a question in between.

-) I think it's very good that the teachers try to innovate, however, for me personally the setup for the Power & Rocket part was not ideal (i.e. the fact that during the lecture only exercises were discussed instead of theory). Exercises I can do at home; theory is easier to understand when it is explained in class.

Looking at the above comments as a whole, it is very clear that there is no "perfect" teaching strategy that will make all students happy. Some students are very open to this innovation, whilst some others still prefer more traditional ways of teaching. Although it is clear from the feedback results presented in this section that a large majority of the students definitely liked the new blended structure of the course, the only negative remarks received on it were from a few students who still prefer the pure “knowledge-transfer” lecturing style, including a very limited number of activating elements. Reaching a 100% level of satisfaction of students is a very challenging and, probably, almost impossible objective in higher-level education.

7. Conclusions and Recommendations

The initiative taken of turning a traditional face-to-face on-campus engineering course into a blended course seems to have had the desired effect the lectures set out to achieve. The analysis of students’ performance and the outcome of student evaluations clearly show that the implementation of blended education positively affected the pass rate and the average grade without compromising on difficulty and reliability.

Going blended gave lecturers the opportunity to offer more active face-to-face content in class which led to higher student appreciation and involvement. By simultaneously introducing digital assessment the work load of the staff remained balanced.

Attendance in class did not improve as much as the lecturers had hoped for, but it is anticipated that this will increase as students will realize the value of the in-class activities and accept this new form of teaching.

When comparing the two different approaches used to introduce blended learning, students indicated a slight preference for the “push” approach over the “pull” approach. This was to be expected as the “push” approach allows for more tailoring of the material to the learning objectives. However, the “pull” approach has also been proven to be a very worthwhile approach especially if a lecturer does not want venture into the world of editing and recording videos. To assist others in this effort, large parts of the “power and propulsion” course will be made available in the close future on OpenCourseWare, via Ocw.tudelft.nl.

For colleagues who are considering implementing a blended approach both formats form a good solution. The most important gain you get by implementing a blended approach is the (re-) engagement of your students with the material and you as a lecturer in-class. Your choice depends on your personal preference and teaching style, resources available and your confidence in creating your own online video material. A mixed “push”-“pull” approach is of course also a viable option.

As this research shows, supported by other evidence from literature, a well-structured blended approach almost always pays off in terms of higher student and lecturer satisfaction, better learning outcomes and more student engagement which is after all what we do this for.

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References

1. G.N. Saunders-Smits, *Study of Aerospace Alumni*, Delft University of Technology, 2008.

2. TU Delft Online Learning website, https://online-learning.tudelft.nl, Accessed 1 April 2016.

3. I. E. Allen and J. Seaman, Grade Change – Tracking online Education in the United States, Babson Survey Research Group and Quahog Survey Research Group, LLC, 2014.

4. M. Driscoll, Blended Learning: Let’s get beyond the hype, *e-learning,* 54

5. M. Oliver and K. Trigwell, Can blended learning be redeemed?, *E-learning*, volume 2, no 1, 2005.

6. C. Graham, Blended Learning Systems: Definitions, Current trends and Future Directions in *Handbook of blended learning: Global Perspectives, local designs*, Pfeiffer Publishing, 2004.

7. M. Victoria Lopez-Perez, M. Carmen Perez-Lopez, Lazaro Rodriguez-Ariza, Blended learning in Higher Education: Students’ perceptions and their relation to outcomes, *Computers & education*, 56, 818-826, 2011.

8. D. Saparniene, E. Virgailaite-Meckauskaite, G. Saparnis, B. Poskuviene and B. Giesbers, Assessment of Blended Learning and the Use of Constructivist Approach in Management Information System Course, *Proceedings of Student Mobility and ICT: Dimensions of Transition*, University of Amsterdam, 16-17 December 2009.

9. E. Stacey and P. Gerbic, Teaching for blended learning – Research perspectives from on-campus and distance students, *Educational Information Technology*, 12:165-174, 2007.

10. N. Jorge, S. Dopper, W. van Valkenburg, Defining a pedagogical model: The TU Delft online learning experience, *Proceedings of the EDEN Conference*, Barcelona, Spain, 2015.

11. B. Means, Y. Toyama, R. Murphy, M. Bakia, K. Jones, Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies, US Department of Education, 2009.

12. Coursera, Flipped Classroom Fieldguide,

https://docs.google.com/document/d/1arP1QAkSyVcxKYXgTJWCrJf02NdephTVGQltsw-S1fQ/pub#id.suagqb7wve21, Accessed 4 August 2015.

13. J. Bergmann, A. Sams, Remixing Chemistry Class, *Learning & Leading with Technology*, 36(4), 22–27, 2008.

14. D.T. Tempelaar, B. Rienties, & B. Gisbers, Student Learning Preferences in a Blended Learning Environment: what Students opt for what type of tools?, *Proceedings of Student Mobility and ICT: Dimensions of Transition*, University of Amsterdam, 16-17 December 2009

15. D. Gillet, Tackling Engineering Education Research Challenges: Web 2.0 Social Software for Personal Learning, *International Journal of Engineering Education*, Vol. 26-5, pp. 1134-1143, 2010

16. Delft University of Technology with RWTH Aachen University, University of Zilina, Academy of Humanities and Economics Lodz, Northumbria University, Blended XL, Finding a balance in blended learning with extra large student groups, Progress report On EU Project, http://www.blend-xl.eu/files/publications/blend-xl%20progress%20report.pdf, Last accessed 26 April 2016.

17. S. Lou, C. Chung, R. Shih, H. Tsai, K. Tseng, Design & Verification of an Instructional Model for Blended TRIZ creative Learning, *International Journal of Engineering Education*, Vol. 29-1, pp. 1-14, 2013

18. N. Forcada, M. Casals, X. Roca, M. Gangolells, Student's Perceptions and performance with Traditional vs. Blended Learning Methods in an Industrial Plants Course, *International Journal of Engineering Education*, Vol. 23-6, pp. 1199-1209, 2007

19. A. Kamp, Delft Aerospace Engineering Integrated Curriculum, *Proceedings of the 7th International CDIO Conference*, Copenhagen, Denmark, 2011.

20. A. Kamp, Self-Assessment Report, Bachelor of Science, Aerospace Engineering, Delft University of Technology, 2013.

21. A. Kamp, The Trail of Six Design Projects in the Delft Bachelor Aerospace Engineering, *Proceedings of the 8th International CDIO Conference*, Brisbane, Australia, 2012.

22. G. N. Saunders-Smits, P. Roling, V. Brugemann, N. Timmer, J. A. Melkert, Using the Engineering Design Cycle to Develop Integrated Project Based Learning in Aerospace Engineering, *International Conference on Innovation, Practice and Research in Engineering Education*, Coventry, United Kingdom, 2012.

23. J. A. Melkert, A. Gibson, S. J. Hulshoff, 2003, An International Design-Synthesis Exercise in Aerospace Engineering, *Global Journal of Engineering Education*, 7(1), 2003.

24. Delft University of Technology, Study Guide, http://www.studyguide.tudelft.nl, Accessed 1 April 2016.

25. J. Biggs, *Teaching for Quality Learning at University*, 2nd edition, Open University Press, McGraw – Hill Education, 2003

26. J. Gerstein blog, https://usergeneratededucation.wordpress.com/2011/06/13/the-flipped-classroom-model-a-full-picture, Accessed 26 October 2015.

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