



# Teaching Innovation of University Grade in Automotive Engineering

**Francesc Pérez-Ràfols\*, Maria Niubó, José Juan de Felipe Blanch**

Department of Mining, Industrial & ICT Engineering (Industrial Technologies). E.P.S.E. Manresa,  
Universitat Politècnica de Catalunya (UPC), Manresa

## Abstract

In this work, we present the implementation of a flipped classroom methodology in two engineering courses, both with a heavy weight given to problem solution. In class, the students are first evaluated by a test, in order to encourage them to see the videos. In one course the test is gamified, while not in the other, so that the different level of encouragement can be assessed. Then conceptual problems are proposed to help the students think and discuss about the theoretical background. Finally, the problem sessions are approached seeking an active involvement by the students. The aim of this methodology is to facilitate a deeper learning of the needed theoretical background, an issue in which students struggled due to lack of motivation and the student's ability to access information during their study. The results of the methodology are evaluated by using standard questioners passed to the students. Answers were obtained from 31 students, which corresponds to 40 % of all involved students. The results obtained showcase an improvement of student motivation and learning. Key aspects identified leading to the success are a good organization of the curse, the adaptation of all activities to form a coherent course and the active and approachable attitude showcased by the teachers.

**Keywords:** Active learning, creativity skills, flipped classroom, transversal skills, critical thinking

## 1. Introduction

The teaching experience discussed in this paper focuses on two subjects of the University Degree in Automotive Engineering. These subjects are: Fluid Mechanics and Thermal Design. The subject of Fluid Mechanics is a mandatory 4.5 ETCS subject located in the 3rd semester, while Thermal Design is a 3 ECTS credits subject from the 7<sup>th</sup> semester. In both cases, the enrolment is relatively constant, varying between 35 and 50 students per semester. From the teaching point of view, both are organized similarly. They both have one hour per week in large groups (all students at the same time), traditionally dedicated to theory. Then, the subject Fluid mechanics offers two hours of problem solving per week in smaller groups (half of the students

on each group). Similarly, Thermal Design offers one hour per week of problem solving and lab sessions.

In both of these subjects, a lack of enthusiasm has been detected, particularly when it comes to theoretical concepts. This results in an absence of autonomous learning and a marked disregard for the complementary material. This impedes achieving a deep understanding, hence limiting their knowledge acquisition to the lower levels of Bloom's taxonomy (Anderson & Krathwohl, 2001).

Through informal discussions with the students, as well as through questionnaires, a more precise picture arose: the students are actually motivated to learn, but only when it comes to very applied knowledge. However, they do not see the need to understand the theoretical concepts required to sustain such applications. Hence, the lack of motivation does not concern the whole course. However, it results in a much more shallow understanding of the applied knowledge they are interested in.

Hence, the aim of the changes in the teaching methodology is to improve the motivation and implication of the students, so that they reach a better autonomy and responsibility in their learning. If this is achieved, a deeper learning is expected. The core idea is to free in-class space to reflect on the need for the theoretical concepts and how these can be applied to solve applied problems. To achieve this, a flipped classroom approach is followed, in which a significant part of the theoretical concepts is distributed through recorded videos.

## **2. Teaching Methodology**

The proposed teaching innovation fits within the strategic line of combined learning. In general terms, the project seeks to implement a flipped class methodology in order to transmit the theoretical concepts more efficiently. As Tucker (Tucker, 2012) indicates, however, the entire subject must be adapted in order to achieve the maximum positive impact.

The main teaching change will take place in the large group sessions, where the flipped class methodology will be implemented. In this sense, the theoretical concepts will be provided in small format videos, short documents and examples that students will have to watch and read prior to the lesson. According to Herreid and Schiller (Herreid & Schiller, 2013), videos are the preferred way for students to be introduced to the subject. Moreover, the videos are designed to be short and focused on a specific concept, rather than encompassing a full lecture. This has the double advantage of keeping the students engaged and allowing them to use the videos as material to consult. Of course, several videos are then prescribed for each session.

The aim of the large group classes will therefore be to contextualize the theoretical concepts. As noted by Bishop and Verleger (Bishop & Verleger, 2013), it is necessary to encourage the student to be the protagonist of their learning and to be able to prepare at their own pace and in depth on the subject. For this reason, active methodologies will be used with the double objective of familiarizing the students with the already studied theoretical concepts and forcing them to reflect on the applicability of these concepts to problem-solving.

Several methodologies will be used, as Barkley (Barkley, 2010) indicates that the use of several methodologies in the same subject avoids boredom and promotes greater enthusiasm in students. On the one hand, they have been asked conceptual questions that force them to reflect on fundamental theoretical concepts. Being small in scope, these questions allow a first phase of reflection on the part of the students and a subsequent discussion between them and with the teacher. Methodologies such as Aronson's puzzles (Lázaro-Carrascosa et al., 2021) or the preparation of small Pecha-Kucha type presentations (Carroll et al., 2016) have also been used to promote an active reflection on theoretical concepts.

According to O'Flaherty and Phillips (O'Flaherty & Phillips, 2015), one of the most important risks in the implementation of flipped classes is that, if interaction is not promoted, student involvement in pre-lesson activities may fail. In order to ensure that students adequately prepare for the lessons, a series of evaluable online tests (with very little weight) will be prepared to be done in the first minutes of the large group class (Kahoot or Quizt type).

In small group classes, wide-ranging problems will be proposed, related to real cases that motivate them. These problems must be broad enough so that students can see their applicability in their field, thus increasing their motivation. These problems should be used to practice the application of the previously learned concepts. Of these problems, some will be solved by the teacher and others will be proposed to the students to solve in class. When solving problems in class, knowledge is acquired organically in groups and the teacher can act as a guide. These facts favour an active learning of the students (learn-by-doing) (Bishop & Verleger, 2013). For these problems to be effective, these must be chosen carefully. In this case, the following criteria have been used to select them: (1) the problem must challenge the students, so that they need to put their full attention and thinking into it, (2) the students must realistically be able to solve the problem with the knowledge they have at each stage of the course, (3), the problem should be focused on the targeted learning objective, which should be known by the students, (4) the problem should be novel to the students, so that they cannot copy the solution strategy from an earlier one, and (5) the problem must provide for relevant context in the field of automotive engineering to enhance student motivation.

Apart from active learning, this methodology allows for individualized and continuous feedback during the course. It should be noted that, according to Hattie and Timperley (Hattie & Timperley, 2007), feedback has proven to be one of the most effective tools in ensuring that all students achieve the objectives of the subject. In addition, in the process of giving this feedback, the teacher can diagnose the students' shortcomings and adapt the lessons.

Finally, students will be provided with solved problems so that they have extra material to practice their problem-solving skills.

Communication outside the classroom with students, as well as the transmission of documents and the evaluation process, will be done through the university's virtual campus. This allows a centralized point of communications and thus facilitates information transfer and avoids misunderstandings. In addition, it allows students to visualize the entire course from the start and therefore have clear expectations about what is expected of them. It should be noted that, according to O'Flaherty and Phillips (O'Flaherty & Phillips, 2015), this is a key aspect to ensure the success of the flipped classroom methodology.

### **3. Data Gathering for the Evaluation of the Proposed Methodology**

In order to understand the performance of the proposed methodology, questionnaires will be passed to the students. The main tool in this regard is the Student's Evaluations of Educational Quality (SEEQ) (Zabaleta, 2007). This questionnaire, developed by Hebert Marsh in the late seventies, has proven to be comprehensive and reliable. In total, it contains 36 closed questions and 6 open ones. Due to its amplitude, this questionnaire allows evaluating different aspects of the course with great detail and specificity. In particular, it focuses on nine topics: Learning, Enthusiasm, Organization, Personal attitude, Content, Exams, Course Work, and Workload and Difficulty. This questionnaire hence, offers a very valuable information to evaluate the effectiveness and acceptance of a teaching methodology, and provides for guidance to identify and correct its shortcomings.

In order to ease the comparison, the results of each question have been aggregated by transforming the responses from a scale ranging from Strongly disagree to Strongly agree to a scale ranging from 0,2 to 1. Then averages have been taken. In the presentation, however, we keep the original scale for clarity.

Besides the SEEQ questionnaire, questionnaires of the kind Knowledge and Prior Study Inventory (KPSI) has also been used to obtain the subjective perception of the students concerning their learning. This questionnaire includes 5 questions concerning the specific content of each course, and asks the students to rate their level of knowledge. The questionnaire is passed before and after the course to obtain a picture of their learning. To get a general picture, the results of all questions are averaged.

Finally, the method is also evaluated subjectively by the teachers, both paying attention to the atmosphere in class and discussing informally with the students.

## **4. Results**

In this section, the results of the different questionnaires are presented and discussed to evaluate the success of the proposed teaching methodology. The results correspond to 10 answers of 33 students in the Thermal Design course and 21 answers of 43 students in Fluid Mechanics. When structuring this presentation, the questions have been sub-divided according interest topics, following the structure of the SEEQ questionnaire. Nonetheless, the grouping has been slightly changed and some questions have been left aside. This has been done with the intent to focus to those aspects touched upon by the teaching methodology. For instance, questions related to the examination have not been considered, as this has not been modified.

### **4.1. Enthusiasm**

Improving the enthusiasm and motivation of the students was one of the key aspects that motivated the change in teaching methodology. From a subjective point of view, it can be affirmed that the new teaching methodology has worked in both subjects. To validate this perception with quantitative results, the results from the SEEQ questionnaire have been used. The aggregate responses to the relevant questions are presented in Figure 1.

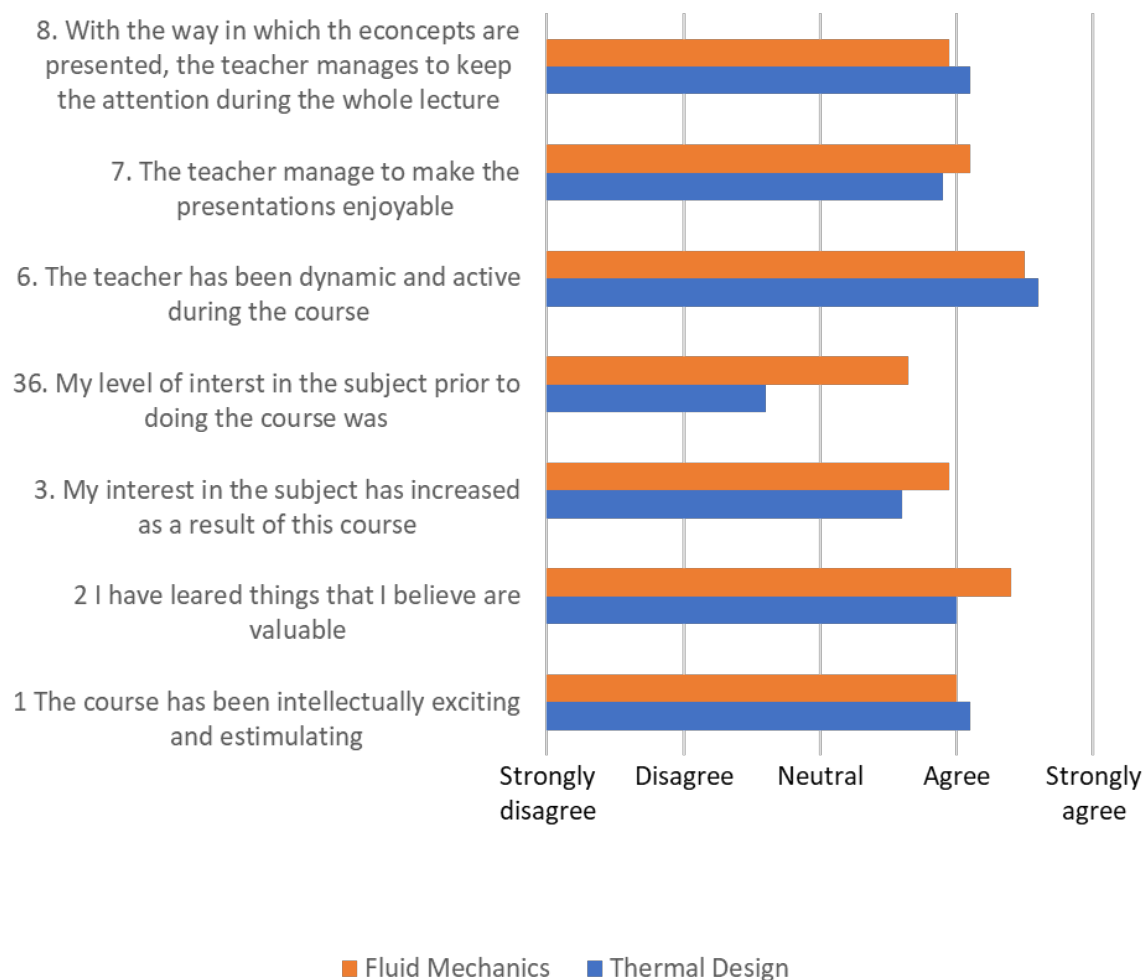


Fig. 1: Aggregate responses to the questions referring to the enthusiasm of the students. The top orange (bottom blue) bar corresponds to fluid mechanics (Thermal design).

Questions 1 to 3 refer to the interest that the subject arose on the students. For both subjects, the responses are positive. The results are particularly encouraging in the case of Thermal Design, as question 36 indicates that the students initially had little interest in the subject. Hence, it was the course itself which was able to provide for the noted enthusiasm.

Questions 6 to 8 can illuminate on the reason for this success. Indeed, question 6 indicates that the students find the teachers dynamic and active. This leads to enjoyable presentations (question 7) and makes the students able to keep the attention during the whole lecture (question 8).

Regarding the enthusiasm, it is relevant to remark that the method used for the tests has a great importance. In the case of Fluid Mechanics, the test was performed asynchronously, with the students answering the questions in their pace (with a time limit). On the other hand, Thermal Design used the platform QUIZZZ, in which the students answered the questions synchronously and which had gamification aspects. The second method has revealed much more effective to motivate the students. Also, it allowed the teacher to provide for instantaneous feedback, while the students still have the questions fresh.

## 4.2. Learning

Although inducing more enthusiasm was chosen as the means to improve learning, the ultimate goal of any teaching methodology is to facilitate the students to reach higher levels of learning. In this sense, Figure 2 shows the response to the question in the SEEQ related to their learning. The students of Thermal Design feel comfortable about their learning. The ones in Fluid Mechanics, instead, show a lesser confidence on their learning.

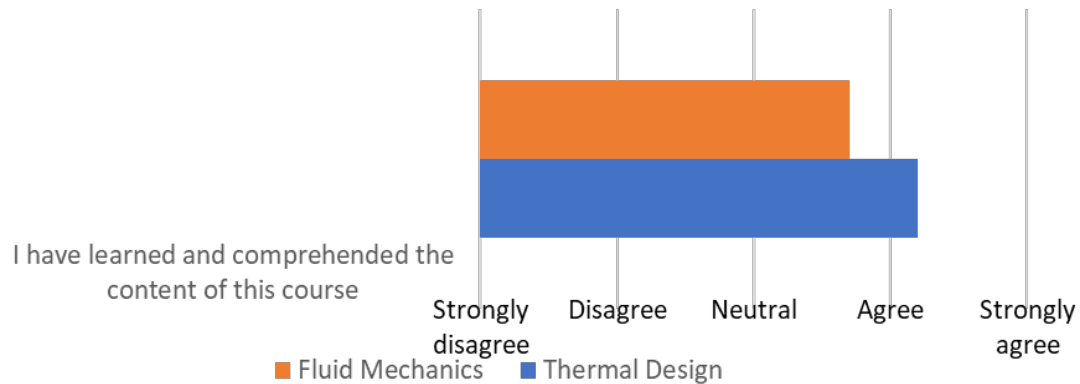


Fig. 2: Aggregate response to the question referring to the learning of the students. The top orange (bottom blue) bar corresponds to fluid mechanics (Thermal design).

The responses in to the KPSI questionnaire, shown in Figure 3, may illuminate this aspect. Indeed, the students of both subjects have improved significantly their level of knowledge. The students of Fluid Mechanics, however, started with a much smaller prior knowledge. Beause of this, and despite the massive improvement, a lower level was reached in the end. It should be noted, moreover, that this subject presents very general concepts (e.g. mass and energy balance or dimensional analysis), which are reused and strengthened in later courses (such as Thermal Design). Hence, it is not concerning that the students do not yet fully master these concepts.

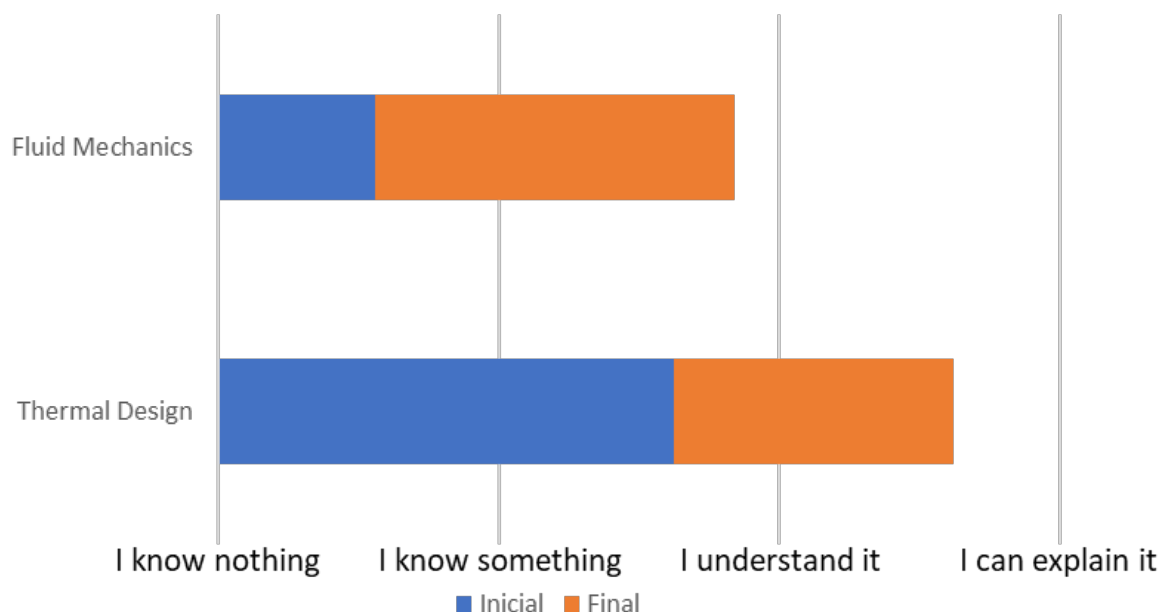


Fig. 3: Aggregated response to the KPSI tests

### 4.3. Organization

In any course, organization is key to ensure a good class dynamic. In a flipped classroom set-up, however, organization is even more important, given that the students must take action prior to a lecture. Figure 4 shows the SEEQ answers in this regard. Again, the responses are mostly positive for both courses, indicating that the organization was good enough. However, if the two subjects are compared, it is apparent that there is room for improvement in the subject of Fluid Mechanics. A possible shortcoming of this subject is that the recorded videos were a bit longer, which may have made it harder for the students to use them as reference material.

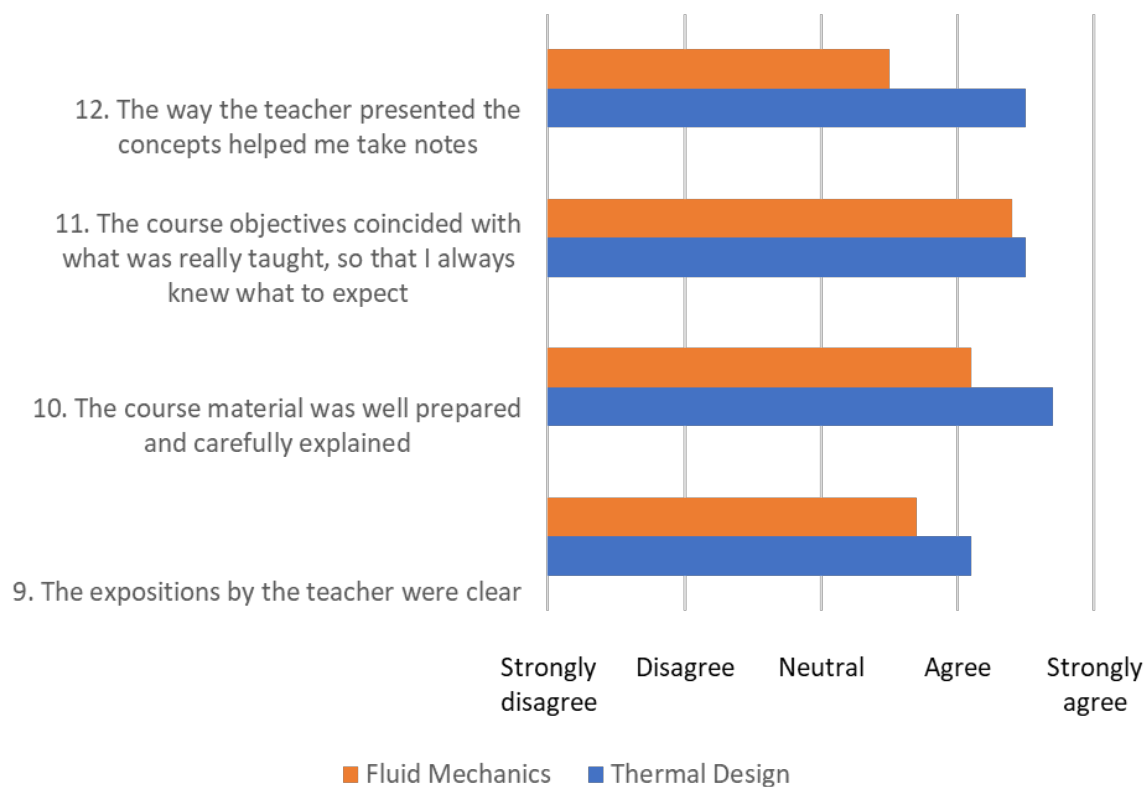


Fig. 4: Aggregate responses to the questions concerning the organization of the course. The top orange (bottom blue) bar corresponds to fluid mechanics (Thermal design).

### 4.4. In-Class and Student-Teacher Interaction

Another aspect that one must be cautious about when implementing a flipped classroom scheme is that it may degrade personal interactions, which are generally beneficial for the students. Here, the responses to the SEEQ survey are used to ensure that these measures were effective. The relevant responses are shown in Figure 5.

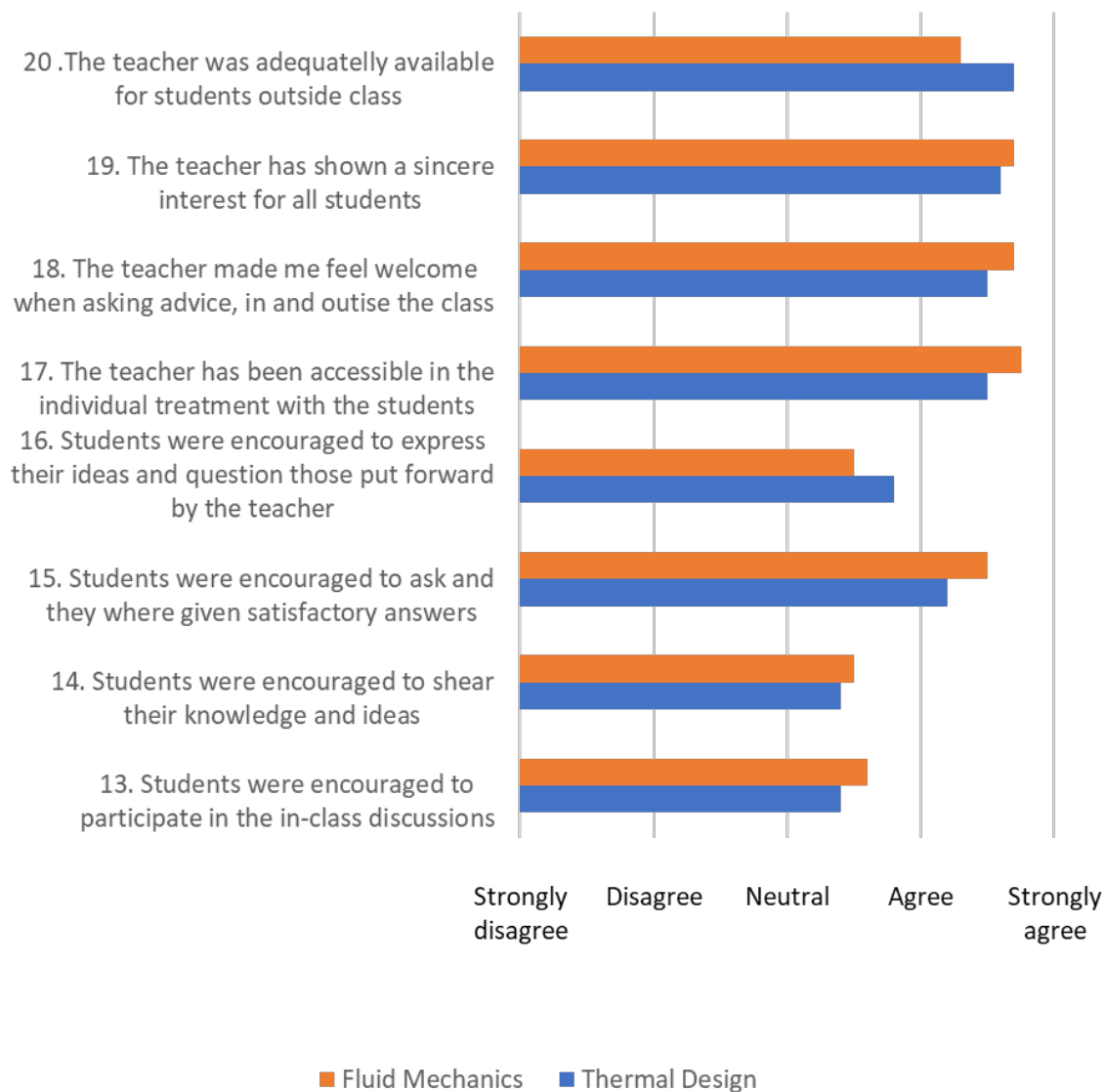


Fig. 5: Aggregate responses to the questions concerning the interaction of the students between themselves and with the teacher. The top orange (bottom blue) bar corresponds to fluid mechanics (Thermal design).

The questions 17 to 20 relate to how available and receptive the teacher is in the eyes of the students. In all cases, the responses are very satisfactory, with most students reporting that the teacher is sufficiently available and that they feel welcome when approaching the teacher. This reflects the point that a positive atmosphere is accomplished by the attitude of the teacher, rather than by how the concepts are shared.

When it comes to in-class interactions (questions 13 to 15), the responses are also fairly satisfactory. Particularly positive is that the students feel very comfortable asking questions. This, we believe, is encouraged by the proposed framework, as the in-class time is dedicated to reflect on the theory rather than just passing it to the students. As a counterpart, the students did feel a bit less inclined to share their own ideas and question those introduced by the teacher. Possibly, this is somewhat discouraged by the video format. Indeed, recording something gives it a stronger sense of permanence as compared to sharing them orally. It must be noted, moreover, that both subjects are fundamental, in the sense that the knowledge they are based on is very well-established. This certainly gives less room for interpretation, as compared to



subjects closer to the state-of-the-art. More room for interpretation can be found in the assumptions made when solving problems. This aspect will be consider next year.

#### 4.5. Work Load

An important aspect of any teaching innovation is to make sure that the improvements are not based on an excessive amount of work by the students. Indeed, while it may seem that more work from the students is positive, the extra time dedicated to a subject is often detracted from other courses. Hence, one subject is learned better in spite of another, which has an overall negative effect.

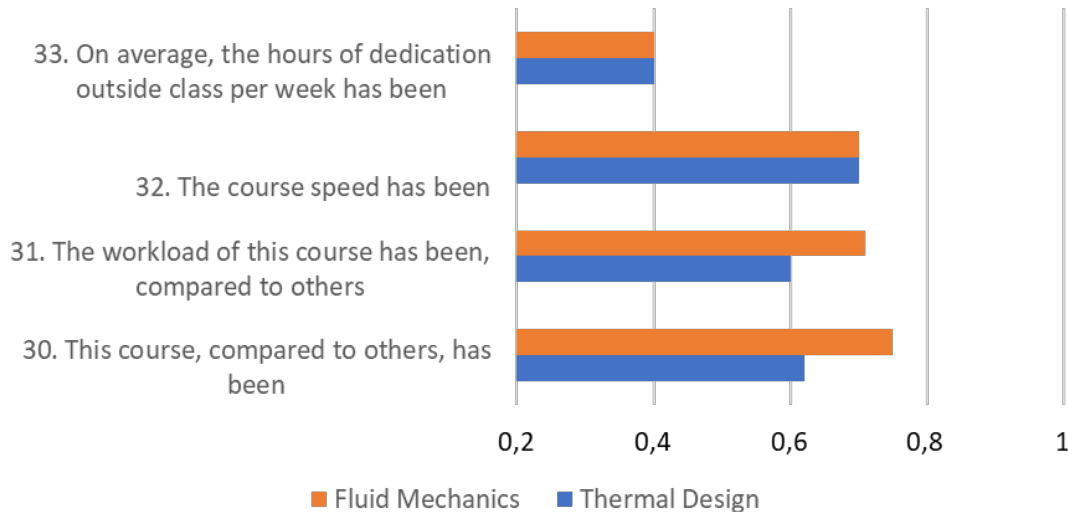


Fig. 6: Aggregate responses to the questions referring to the work load felt by students. The top orange (bottom blue) bar corresponds to fluid mechanics (Thermal design). The scale corresponds to Much easier(0.2) to Much harder (1) for question 30 Much smaller (0.2) to Much larger (1) for question 31, Much slower (0.2) to Much faster (1) for question 32 and, form question 33 to from 0 to 2 h/week (0,2), from 2 to 5 h/week (0,4), from 5 to 8 h/week (0,6), from 8 to 12 h/week (0,8) and more than 12 (1,0).

If we start by the hours of dedication, the average on both subjects is in 0,4, which corresponds to between 2 and 5 hours of dedication per week. This matches the expected dedication from the student (4.5 h/week for Fluid Mechanics and 3 h/week for Thermal Design). When it comes to the subjective perception of the students, they, on average, deem the course Thermal Design similarly difficult as other courses (values around 0.6) while the course Fluid Mechanics is deemed harder, although not reaching too high values. Both courses are deemed to progress slightly faster than average. Given that these are short courses (4.5 and 3 ECTS credits), this perception is somewhat expected. Nonetheless, too high values are not reached to be cause of concern.

In view of these results, it cannot be concluded that the teaching innovation has been achieve at the expense of overloading the students.

## 5. Conclusions

In light of the presented results, it can be concluded that the implementation of the proposed teaching methodology was successful. In general, an improvement of student motivation and learning has been achieved, in line with common observations attained when the flipped classroom approach is followed correctly (O'Flaherty & Phillips, 2015)). Following the insights by (Prunuske et al. 2012), we note that the success is based on focusing the in-class time to achieving a deep conceptual understanding. Also, teaching involvement and enthusiasm

has also been shown to be relevant to the success of the teaching methodology, as also indicated by Hamdan et al. (2013).

Another key aspect has been that of course adaptation and organization, to guarantee a smooth functioning of the course and alignment of expectations. Knowing of the importance of these issues (Tucker 2012), an effort has been put in this direction. Following the answers by the students, it seems that this has been appreciated by the students and contributed to the positive results obtained. This planning included choosing the right format for the pre-class material, where short videos seem to work best (Herreid & Schiller 2013), as well as preparing in-class activities. For instance, the tests done at the initial part of each lecture have been shown to be effective in motivating the students to review carefully the pre-class material (O'Flaherty & Phillips 2015). Also, it has been shown that gamification approaches (Subhash & Cudney 2018) can be beneficial in these tests. Finally, the various active methodologies used in the in-class time liberated by the flipped classroom approach have been shown positive, both in terms of student satisfaction and in terms of their learning.

Importantly, this has not been done at the expense of overloading the students. Moreover, it has been possible to keep good in-class interactions. The only thing to be aware of is that the students feel less inclined to express their opinion. It is believed, however, that this can be corrected in the future.

A final aspect to remark was the importance of proper IT research (Kurup & Hersey 2013). This has not been lacking in this case, which has allowed the teachers to focus primarily on the pedagogical (rather than the technical) aspects of the teaching innovation.

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