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Teaching Methodologies for Combustion Science within the European Higher Education Area

S. Molina*, J. Javier López, J.M. García-Oliver, A. García

Dpto. de Máquinas y Motores Térmicos. Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain.

* Corresponding author: Email: samolina@mot.upv.es; Phone: + 34 963879651

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Abstract

The main objective of the present work is the selection and integration of different methodologies among those applicable within the framework of the European Higher Education Area to combine teaching methods with high implication from both lecturers and students. The aim is to enhance the students' motivation, by means of which they should learn both combustion fundamentals as well as particular technological applications. Thus, the selected methods are master classes, guided work by means of learning based upon projects, simulations and numerical applications, tutoring and student independent work. This methodology is currently been applied within the Mechanical Engineer Degree of the Escuela Técnica Superior de Ingeniería del Diseño at the Universitat Politècnica de València. Results have been critically analyzed, paying attention to both the performance of the students as well as to some inconsistencies that have been found when applying the developed methodologies to large groups. The main result to be noted is the high comprehension level of the course concepts that has been attained by the students.

Keywords

Active learning methods; combustion; teaching methodologies; European higher education area

1. Introduction

The present contribution reports on the methodology implemented to deliver a Combustion Course within the Bachelor Degree in Mechanical Engineering at the Escuela Técnica Superior de Ingeniería del Diseño (ETSID) of the Universitat Politècnica de València. Before showing this approach, the importance of Combustion Science for Engineering will be addressed, together with the difficulties involved in teaching the course in a curriculum that is within the framework of the European Higher Education Area.

The study of Combustion Science within the Mechanical Engineering Degree is justified due to the fact that more than 90% (Spanish Ministry, 2011) of worldwide energy transformations involve oil, coal, natural gas or biomass as fuels. A combustion process that releases the energy stored in such fuels is therefore necessary. Consequently the knowledge of the phenomena involved in combustion must be acquired by students during, as the probability to be faced with a combustion-related problem during their professional career is very high.

Although there are exceptions, it was not very usual to find a specific course on Combustion in old university engineering curricula. Such contents were delivered rather within other courses, such as Chemistry to introduce fundamental concepts, or Thermal Machines or Thermal Power Stations to deal with more practical applications of Combustion. This can be due to the fact that Combustion is a strongly multidisciplinary subject (Turns, 2000), for which one needs many concepts developed in other courses found in university curricula (Chemistry, Thermodynamics, Fluid Mechanics, Mass and Energy Transport Phenomena, etc.), and when designing such curricula, single-disciplinary courses were preferably chosen (Desantes et al., 2009). However, the Combustion course was already part of some of the previous curricula at the Universitat Politècnica de València, in particular at the Industrial Engineering Degree, hosted by the

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Escuela Técnica Superior de Ingenieros Industriales (ETSII), and at the Aeronautics Engineering Degree, hosted by the ETSID. As a matter of coherence with new curricula for Bachelor Degrees in Energy Engineering (ETSII), Mechanical Engineering and Aeronautics Engineering (ETSID), a specific Combustion course has also been included.

Taking into account the current change process in the university system, which is due to a large extent to the recent modification in curricula (4-year Bachelor Degree) for harmonization with the European System, it is necessary to rebuild the teaching and learning methods. The student should have a more active role within this process, and he/she should not be a mere recipient of information (UK-HE 2007). New teaching methods focus on self-learning, guided and cooperative work, projects, case studies, etc. so that a constructive approach for the student's curriculum is achieved. To develop a course on a topic such as Combustion, where abstract concepts are traditionally developed with the help of more enjoyable laboratory exercises, new methodologies have been undertaken to make the student an active element for the development of the course. However, it must be noted that this course has more than 180 enrolled students, who are divided into 2 groups for theoretical classes and 25-student groups for laboratory exercises, which makes the application of such methodologies to enhance the student's participation highly complicated.

The present contribution starts from the experience of the authors in delivering Combustion courses in the Industrial and Aeronautical Engineering Degrees of the Universitat Politècnica de València. The main objective of the present work is the selection and combination of different methodologies, within the ones currently available, with the purpose of combining teaching methods with high implications for both students and lecturers, which motivate students and presents them both the fundamentals of such a subject, as well as its concrete applications. It must be noted that such methodology will be incorporated into a group with a large number of students.

After the present introduction, the document follows with the description of the methodology. After that, a discussion of the obtained results is presented, and lastly the conclusions.

2. Proposed methodology: integration of different teaching methods

The current methodology is the result of combining different teaching methods which imply the lecturer and the student in a similar way. Independently on the selected methods, the interaction between them is prioritized. The selection of the different methodologies is based on the Carpio's work and the experience (Carpio, 2008).

2.1 Methods with high implication of lecturer

In the next paragraphs, the selected methodologies will be presented. The following information will be defined: the main objective of the methodology, its implementation, the competences that the student is intended to achieve and, finally, the evaluation system that is applied.

2.1.1 Master classes

Their main goal is to perform a clear and systematic presentation of the essential theoretical contents for a proper development and comprehension of the rest of activities in which the course is scheduled (Biggs, 2011). Other important objective that master classes pursue is to help the lecturer become aware of the comprehension level that students are acquiring with his/her explanations. Particularly, classes are developed in a completely interactive framework in which short numerical applications are solved as well as the student participation is enhanced by means of questions. As a consequence, an

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environment with a continuous dialogue between student and lecturer is created; therefore, a previous preparation of the student becomes necessary (Collier, 1983).

Some of the competences that the student can develop thanks to master classes would be:

- Ability to allocate Combustion in the frame of the energetic transformations and capability to provide a combustion process definition.
- Capability to describe laminar and turbulent premixed combustion phenomena.
- Capability to describe laminar and turbulent mixing controlled combustion phenomena.
- Ability to identify physical and chemical phenomena which govern pollutant emissions generation.

Regarding the evaluation system, it is worthy to note that at the end of each of the 4 units of the complete course, a multiple choice test is performed by means of a digital platform developed at the Universitat Politècnica de València (PoliformaT). Tests are available for students during 60 hours. The number of questions varies from 5 up to 15 depending on the unit under evaluation. Incorrect answers do not introduce any penalty. Once the student decides to start the test, he/she has 2 minutes per each question. Once the time is over, the test is considered to be finished, and answers together with the total grade of the test are sent to lecturers via PoliformaT. The 4 tests associated to the evaluation of acquired knowledge during the master classes represent a 10% of the total grade of the course.

2.2.2 Guided work

Lecturer directs and guides students work by means of activities and exercises in which the student implements contents learned during the master classes (Carpio, 2008).

- Learning based upon projects and simulations: along each unit, the students performed 2 or 3 practical applications. These applications can be experimental or based on simulations. During these sessions, different abstract concepts are introduced to the students. These concepts will be treated in detail during the development of the master classes. The knowledge acquired by students is evaluated considering short exam answers provided by them during the own session as well as considering multiple choice tests that students carry out via PoliformaT during the next weekend after each practical session.

- Learning based on numerical applications: group of questions/exercises adapted for each student. Boundary conditions are defined considering each student identification number. These questions/exercises are solved after each of the 4 course units. All documents needed and required are exchanged via PoliformaT. For each exercise, students have two weeks to complete it. Time starts when the unit is finished. If the student presents the exercise during the first week, lecturers provide feedback to the student giving guides to solve the possible errors which are made by the student. Thus, the student is able to send again the exercise before the final deadline (2 weeks). By contrast, if the student presents the exercise after the first week has gone by, it is not possible to resend it again. Numerical applications (4) represent a 30% of total grade of the course.

The acquired capabilities by means of the guided work could be:

- Capability to quantify the premixed combustion phenomena.

- Capability to quantify the mixing controlled combustion phenomena.

2.2.3 Tutoring

Its main objective consists of completing the master classes. The tutoring is thought like a personalized meeting between lecturer and student. It can be performed individualized for a student or in small groups (Collier, 1983). In any case, in the tutoring framework, the dialogue is enhanced and also a previous preparation for both parts is required, especially from the student side (Anderson et al., 1997). With the aim of avoiding lecturer or students availability problems, the tutoring is performed on student demand via e-mail and it takes place in the lecturer's office. Nevertheless, if the doubt is generalized for a group of students, a classroom with the needed audiovisual media is fitted out to assist the students properly.

The most relevant capabilities that can be achieved with the tutoring could be:

- Capability to assume prominence and responsibility from the student side.
- Capability to start reflection mechanisms in the student.

2.2 Methods with high implication of the student. Independent work.

In contrast to master classes, which are basically carried out by the lecturer alone, the independent work make up the particular way to be followed by each student, in which learning is adapted to his/her particular circumstances and needs (Carpio, 2008; Posada Alvarez, 2004). The aim behind this method is to promote a learning based on the search and evaluation of new information that allows solving problems out of the text books, to perform a better diagnosis of them, being less dogmatic and more open minded to consider alternative possibilities (Abercrombie, 1980).

2.3 Work load per teaching method

Once the different selected methodologies have been defined, the time scheduled for each of them is described. The whole combustion course has 4.5 ECTS and therefore it implies that the total numbers of hours that can be spent in the different methodologies are 112.5 hours.

- Formal hours for face-to-face activities: 22.5 h (master classes); 22.5 h guided work (projects and simulations), 3 h exam.
- Formal hours for not face-to-face activities: 14 h (tutoring).
- Independent work: 33.75 h (study); 16.75 h guided work (numerical applications).

3. Discussion of the proposal and results

On the one hand, the methodology presented previously will be compared to that already used in two equivalent courses that were taught in the Industrial (at the ETSII) and Aeronautics (at the ETSID) Engineering Degrees. Since these two other subjects were delivered to students after choosing their major, both had a reduced number of students (<30). This last fact is in contrast with the context of the current course, where more than 180 students are enrolled. On the other hand, it is necessary to take into account that the proposed methodology is on the way of being introduced right now, as the subject is taught this year for the first time (academic year 2012-2013), and during the spring semester. Consequently, the results that will be presented and discussed will be, up to now, incomplete. Finally some observations, which seem to show some disadvantages or difficulties that may appear during the evaluation process, together with some proposals to overcome them, will be mentioned.

3.1. Comparison with its application to much smaller groups

In a previous work (Desantes et al., 2009), the methodology designed to be used in two courses equivalent to that of the present work but taught in the Industrial and Aeronautics Engineering degrees was presented. As mentioned above, the main difference between these two subjects and the subject now under analysis is the number of students enrolled in them, both having a single group of less than 30 students. When comparing the introduction of both methodologies, the following remarks can be done:

- The thematic units are almost equivalent, since both the contents and the guidance of the master classes are very similar. Consequently, despite its more difficult application, a more interactive character is intended to be given also now to the master classes, since this increases the student involvement.
- The study of laboratory practical applications (both experimental and numerical) is still maintained, since this helps not to lose the realism and applicability of the theoretical concepts studied.
- Even if with smaller groups some team works were performed, with a continuous and careful monitoring of its development, this activity is completely not viable in a big size group, since it will consume all the lecturer's time and energy. The alternative is to propose some individual works (customized, as mentioned before), which allow the student to face a real problem, to propose a tentative solution, to receive some feedback from the lecturer to know whether he/she is on the right way or not, and, finally, to propose a definitive solution with higher probability of success. It was observed that this procedure improves significantly the student response, as will be demonstrated in the next section.
- Finally, in the context of a subject with such a big number of students, the “true” continuous evaluation that could formerly be applied with a smaller group was

given up. However, an effort was done to impose a working rhythm to the student by introducing some evaluation activities (with a limited weight in the final grade), in an attempt to evaluate the student in a more continuous way. Lastly, removing the final exam of the course wasn't considered appropriate, because it allows to ensure that the student has acquired all the basic knowledge to pass the course.

After this comparison, it can be concluded that the transition from a small to a big group requires some unavoidable adaptations, not changing the spirit, but the style, to harmonize an evaluation with a high reliability degree with a reasonable amount of work for the lecturer.

3.2. Obtained results

As mentioned previously, the results that can be presented right now are incomplete, since this subject is currently being taught, and it is new this academic course (2012-2013). Up to now (at the moment of writing this paper) the evaluation activities that have already taken place (the results of which are already available) are: 2 evaluation tests for the theoretical contents, 4 tests to evaluate the completion of the laboratory sessions, and 1 customized individual work. Even if the final results of the course are not yet available, there are some aspects that are worth mentioning:

- The results of the different tests are excellent (see Table 1). The most unfavorable case has an average grade of 7.6. Even if these results are not fully reliable (even more if the observations described in section 4.3 are taken into account), they show that the student has done an effort to work out the different parts of the subject. This small (or big!) effort will surely have a beneficial impact on the final result.

Table 1. Results obtained in the tests already performed.

	Theory 1	Theory 2	Lab. 1	Lab. 2	Lab. 3	Lab. 4
Max. grade	10	10	10	10	10	10
Min. grade	3	3.3	0	0	2	4
Avg. grade	7.6	8.2	8.7	8.0	8.8	7.9

- Concerning the customized individual work, the fact of giving the student (if he/she wishes it) the opportunity to receive some feedback about what is wrong and what is correct, has significantly improved the obtained results, as demonstrated in Figure 1. In this Figure it can be observed how the histogram of grades for the 61 students that sent a preliminary result of their work (Figure 1a) is improved when they deliver their final result (Figure 1b). Regarding this group of students, initially the average grade is 5.1, whereas the final one is 9.3. For the rest of students (98 students), who delivered only their final results, the average grade is 8.2. It can be observed, then, that the students having some feedback from the lecturer have achieved higher grades compared to those not taking benefit from this possibility.

Hence, it can be concluded that better results can be enhanced with a reasonable effort of the lecturer: on the one hand, because a working rhythm is set to the student and, on the other hand, because of the fact of giving him/her some feedback.

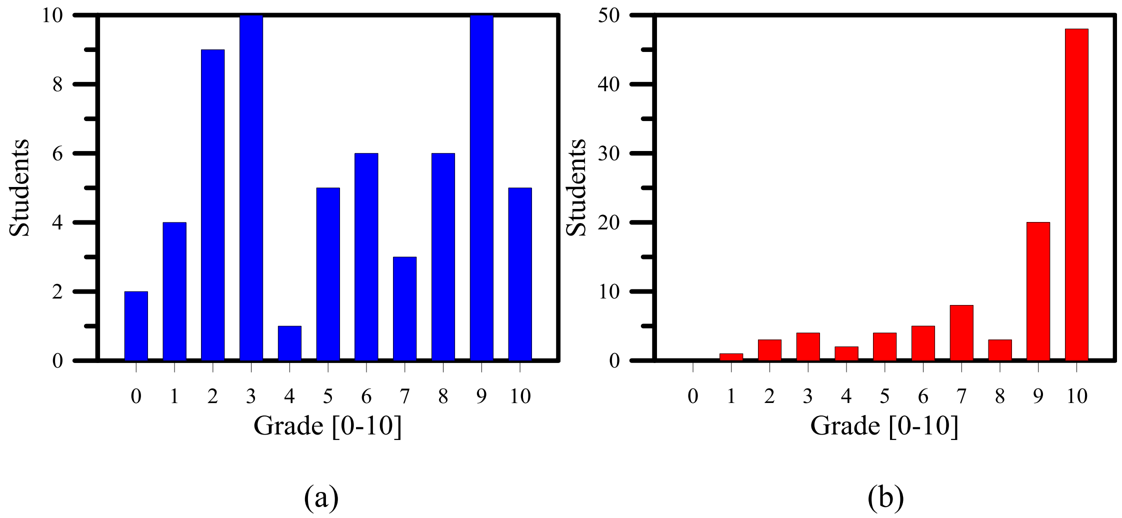


Figure 1. Variation of the histogram of grades for the preliminary hand out (a) and for the final hand out (b) of the first customized individual work of the subject.

3.3. Observed difficulties

The detailed analysis of the results obtained by the students showed some possible difficulties that may appear when trying to apply some of the evaluation techniques employed in this subject, especially concerning the tests done by the students in a remote way (not in-person exam) via the digital platform of UPV (PoliformaT). As an example, in Figure 2 the relationship between the grade obtained in the test and the time spent to complete it is shown (it corresponds to the evaluation test of the first block of the subject, done by 166 students). In the Figure a linear fit to the data is also plotted, to show the trend between these two parameters. Surprisingly, this plot shows that the grade is higher as the time spent to do the test is shorter. Even if this result can be, somehow, logical (it shows that the cleverest students take less time to complete the test), it is really strange taking into account the following consideration: the test consisted of 10 questions, and assuming that half a minute is required to read, understand and answer a question, a minimum of 5 minutes is needed to complete the test. However, some students have obtained a grade of 8 or 9 doing the test in less than 5 minutes (see colored area in the Figure).

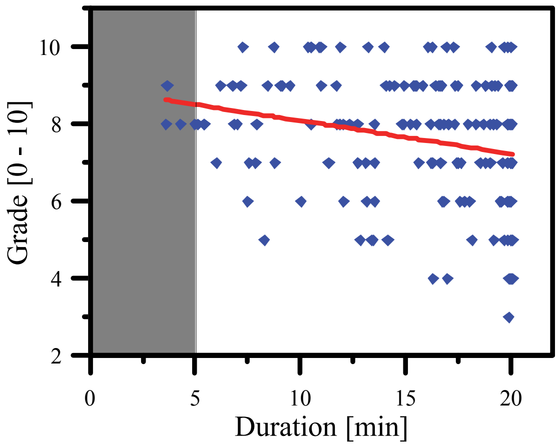
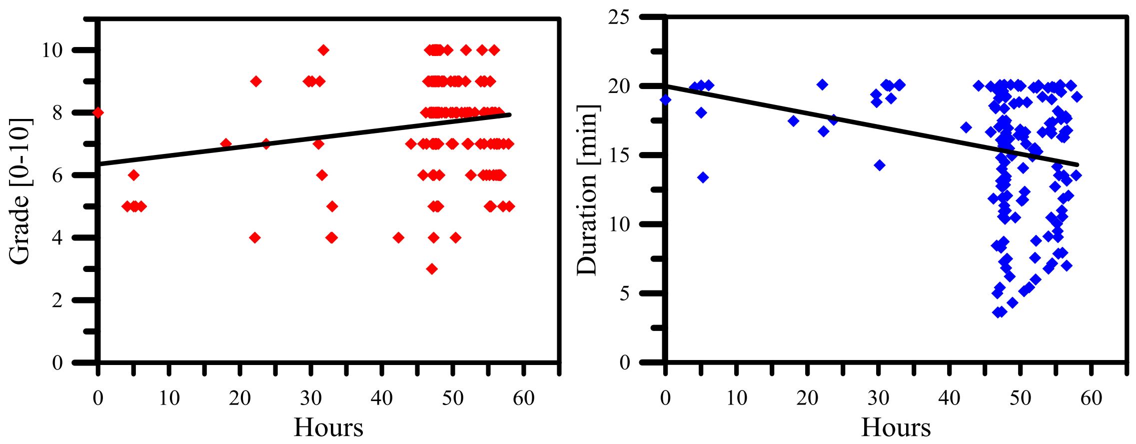


Figure 2. Relationship between the grade obtained in the test and the time spent to complete it.

With the goal of better understand the previous result, some other information that will help for this purpose is shown in Figure 3: on the left (Figure 3a), the relationship between the grade and the moment at which the test was done is shown (it is worthy to know that the tests are open during two and a half days -60 hours-, and the students can do it at anytime during this period; this time is given in hours, starting from the time that the test is available for the students). It can be observed that, curiously, the grade is higher as time goes by… And, on the right (Figure 3b), the relationship between the time spent to complete the test and the time when it was done is shown. In this case it is observed that, as time goes by, the students need less time to complete the test (and, based on what was said before, they obtain a higher grade). These observations raise the suspicion that the information "flows" among the students, which seem to learn from each other in such a way that the students doing the test later seem to recognize the questions that their colleagues have already answered, and they are able to complete the test faster and better at the same time.

Probably this fact does not affect all the students but, for sure, it seems to affect some of them. For this reason it is strongly advisable not to give too much weight to this type of evaluation, otherwise this will lead to an unfair overall evaluation. In fact, this weight needs to be defined based on a delicate equilibrium: big enough to motivate the student for studying the subject, but small enough to avoid passing the course unfairly. This is the reason of the moderate weight of this type of evaluation that was chosen in the context of the present course.



(a) (b)

Figure 3. Correlation between the grades obtained in the test and the moment at which it was done (a), and between the time spent to complete the test and when it was done (b).

4. Conclusions

Different teaching methods have been evaluated and chosen within the framework of the European Higher Education Area to be implemented into a Combustion course delivered at the ETSID of the Universitat Politècnica de València. Such methodology is based upon the interaction between the lecturer and the student, and is being applied for groups with large number of students. Among the main results, the high grades obtained by students have to be noted, which are independent of the area that is being evaluated (theoretical lectures, guided work…). In spite of the fact that such an estimator is not definitive to determine the success of the methodology, it can be considered as a first good approximation. However, certain deficiencies have been detected due to the dissemination of information among students when using the evaluation system by means of the UPV digital platform, which questions some of the grades obtained by some students. Such information dissemination has been quantified numerically. When eliminating such results, grades are still high, showing a high degree of comprehension of the concepts by the students.

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