EXPERIENCES IN DEVELOPING AND APPLYING A NEW METHODOLOGY IN MASTER’S DEGREE

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Abstract

In the subject Advanced Energy and Thermal Machines of the Master’s Degree in Industrial Engineering a great effort was made to apply a new methodology based on the development of activities directly related to the real or professional applications together with the use of computer codes to solve these real problems.

The simulation based learning has been the basis of the application of this new methodology. The goal is that students can achieve a high level of theory knowledge together with a high capacity of autonomy in solving problems.

For that, a plan has been stablished to be implemented gradually. According to this plan, the subject is clearly defined in each of the sections: objectives, contents, methodology, activities and assessment looking for the constructive alignment. Besides, new materials have been created.

In this paper, the experiences and results obtained in the process of improving the way of teaching this subject are shown and analyzed from the point of view of the teacher and from the point of view of the student.

Keywords: Innovation, technology, simulation based training.

1 INTRODUCTION

New bachelor’s and master’s degrees where created following the Bologna Process [1]. In the Universitat Politècnica de València, students must achieve the master’s degree in industrial engineering [2] to be able to sign industrial projects as engineer. This master started in the academic year 2014-2015 and it has 120 ECTS spread over two academic years. Some of the subjects were rearrangements of the subjects included in the previous industrial engineering degree, but some others were newly defined. One of these new subjects was Advanced Energy and Thermal Machines (AEMT) that is taught in the second semester of the first year of the master.

The teaching of the subject AEMT is shared by two departments. The first part of the subject is Nuclear Engineering’s responsibility and the second part is Thermal Engines and Machines’ responsibility.

From the very beginning, it was a great concern that the subject was mainly practical showing the different applications of the theory concepts to the professional work. For that, a very ambitious plan was defined and applied in this subject. The plan consists of three main tasks:

− Task I: Selection of the software
− Task II: Adaptation and creation of teaching materials
− Task III: Creation of different guides

The development of ICT together with an increase in the assessment of student learning in the new Master’s degrees requires a rethinking of the face-to-face (traditional) teaching work towards a model based on self-learning and non-presence from students. The simulation tools of physical, industrial or purely numerical processes have certain advantages for teaching such as:

- are viable alternatives to experimentation in laboratories or installations given the reliability and ability of the simulation to reproduce real or hypothetical situations, i.e. situations of industrial risk.
• the economic cost of the simulations may be insignificant compared to the facilities of an industrial laboratory or process that is intended to be studied or designed
• stimulates the experimentation of students since once the workflow is internalized in the simulations, the modification of the simulation conditions (initial, contour, etc.) quickly results in new situations that must be analyzed to draw conclusions of our system; This experimentation and exploration of new situations are essential in the processes of self-learning that the student must do.

The subject has 3 years of experience and during this time the number of students enrolled has been increased from 169 in the first year to 304 in 2016-2017. Students are grouped in 6 theory groups and 18 labs groups. Such a high number of students make the task of guiding the process of learning of all students very difficult. Therefore, in one hand the use of computer tools is very helpful to students to carry out their autonomous study of the subject. And on the other hand, the use of these tools in class helps teachers to track the learning progress of students.

In this paper, the experiences in applying a teaching methodology in the subject AEMT are presented. The paper is organized as follows: the second section is devoted to the explanation of the methodology and the plan established. In the third section, the different activities and new materials created during the three years of the subject are explained. Finally the conclusions and future work are summarized in the fourth section.

2 METHODOLOGY

The objective set by the staff of professors is that the subject AEMT serves as the background practical knowledge to be applied in the professional work of the graduate students in the fields of equipment that uses a fluid in two-phase flow and turbomachines.

The first step to achieve this target consists in choosing the proper contents and creating the materials. The second phase is the definition of each section of the teaching guide:

− Competences
− Transversal competences
− Teaching-learning methodology
− Assessment

The learning outcomes are defined by means of specific and transversal competences. The list of the specific competences is shown in Table 1.

The transversal competences that are trained in this subject are the following:

− (01) Comprehension and integration
− (02) Application and practical thinking
− (03) Analyzing problems and solving them
− (13) Specific instruments

Table 1. Competences trained in the subject AEMT.

<table>
<thead>
<tr>
<th>Competences</th>
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<tr>
<td>1 Have adequate knowledge of the scientific and technological aspects of:</td>
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<tr>
<td>mathematical, analytical and numerical methods in engineering, electrical</td>
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<tr>
<td>engineering, energy engineering, chemical engineering, mechanical</td>
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<tr>
<td>engineering, continuous media mechanics, industrial electronics,</td>
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<tr>
<td>automation, manufacturing, materials, quantitative methods Management,</td>
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<tr>
<td>industrial computing, urban planning, infrastructures, etc.</td>
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<tr>
<td>2 Knowledge and abilities for the design and analysis of machines and</td>
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<tr>
<td>thermal motors, hydraulic machines and installations of heat and industrial</td>
</tr>
<tr>
<td>cooling and equipment.</td>
</tr>
<tr>
<td>3 Knowledge and skills that allow understanding, analysing and managing</td>
</tr>
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<td>the different energy conversions.</td>
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The contents are organized in 5 didactical units; the first is the general introduction to the subject and there are two for each part of the subject:

1. **Introduction**
   1.1. Industrial examples of AEMT: Equipment and facilities

2. **Two phase flow transport equations**
   2.1. Two phase flow properties
   2.2. Two phase flow transport equations
   2.3. Two phase flow transport equations in 1D
   2.4. Flow regimes
   2.5. Closure equations. Correlations

3. **Boiling and Condensation in industrial equipment**
   3.1. Boiling. Critical Heat Flux (CHF) models
   3.2. Condensation

4. **Compressible flow**
   4.1. Introduction to compressible flow
   4.2. Expansion and compression in tubes
   4.3. Study of nozzles

5. **Study of multistage turbomachines**
   5.1. Multistage turbomachines
   5.2. Basic equation in turbomachinery
   5.3. Impulse turbomachines
   5.4. Reaction turbomachines
   5.5. Aspects of the design of turbomachines

The assessment of the subject is done in two different acts, one for each part of the subject. Exams consist of open answer questions and numeric problems.

As it was mentioned, a plan has been established to introduce the use of computer tools and simulation [3]. The plan is structured in three tasks:

- **Task I:** Selection of the software

  Software alternatives for different applications can be huge. It is necessary to make a detailed analysis of alternatives of physical and mathematical models to be implemented, highlighting the advantages and disadvantages of each one. This student-oriented work aims not only to list different model alternatives (i.e. convection heat exchangers), tables of materials, etc., but also to compile which places on the internet are adequate, interesting and reliable as sources of information.

- **Task II:** Adaptation and creation of teaching materials

  Once the software has been selected, the teaching contents and competences of the subject and degree to which this plan is intended should be developed. We talk about Adaptation of Materials when there is a teaching material or simulation cases in other programs and that have to be transferred to the new situation; this adaptation does not have to be trivial since some deficiencies of the generated software, such as graphical representation, material data libraries, physical models, etc. may have to be filled.

  On the other hand, we talk about Creation of Materials when the main objective is to develop exercises, cases, examples of simulations, etc. Those materials do not exist previously.

  In addition, the necessary teaching support materials will be developed, whether for Adaptation or Creation, for being used in the subjects in which the degrees are structured. These materials can be manuals, tutorials, presentations, etc.

- **Task III:** Creation of different guides
The general stages of which usually all calculation programs include are: i) Pre-processing; ii) Solver; iii) Post-processing. In this task we want to elaborate the necessary materials (manuals, tutorials, presentations, videos, etc.) for the correct use of them and to maximize the performance of the simulations. These materials should explain each of the stages in order to correctly establish the flow of tasks to be performed in each simulation.

Each lecture will follow the following general structure:

- Objectives of the unit.
- Introduction.
- Segments of information (information development).
- Most common mistakes.
- Remember that…
- Relevant bibliography.

Also included in this section is the development of didactic units in presentation format (Power Point) with special emphasis on a clear and structured presentation.

The methodology followed is a hybrid method that combines participative master classes with integrated classes for solving problems by hand and using a computer tool. The computer codes selected in Task I to solve the problems are Matlab® [4] [5] and Microsoft Excel®. We have chosen these tools due to the following reasons:

- They are available for students in free access computers at university and also are free to be used in personal computers as the university pays for licenses,
- Students have used them prior to this subject, therefore they have the required level for that course,
- These programs are usually used by professional engineers.

Following the plan, the use of the computer codes in classes has been introduced gradually. In the first year, students had only the resolution of a collection of different problems by hand. In the second year, Matlab® solutions were brought to students and presented by teachers in classroom and in the following years, classes were focus to use the computer code at the same time that it is solved by hand. This will be able because of the creation of Virtual Labs with Matlab® that will be available for students via web.

3 ACTIVITIES

The activities of the course include the resolution of problems and the practical classes.

As the procedure of solving problems is a little bit tedious at the first attempt, a guide has been handed out to students. The guide comprises different schemes of the steps that must be followed to solve the problems. In figure 1, one of these schemes is shown:

Figure 1. Guide for solving problems.
A set of problems have been created. These problems can be solved using Matlab and by hand. Solutions using Matlab are available for students in PoliformaT platform. In figure 2 one of the Matlab programs is shown:

```matlab
%% Lecture 3.2 - Problem 1
%% Input variables
Dh = 0.3; % m, Hydraulic diameter
AH = pi* Dh^2/ 4; % m^2, Area
%% Fluid properties
Gm = 10750; % kg/m^2/s
xst = 0.096; % Static quality [ 0.0 - 1.0 ]
p1 = 7.2*10^6; % MPa
p2 = 0.0; % MPa, relative pressure
%% Steam tables properties
prop = SteamTable('px', p1/10^6, xst);
%% Densities
rliq = prop.rliq;
rvap = prop.rvap;
%% Slip Ratio (Chisholm):
slip = sqrt(1 - prop.x * (1 - prop.rliq/ prop.rvap));
```

Figure 2. Matlab code for resolution of problems.

In the first part of the subject, practical classes are devoted to introduce how the two-phase flow computer codes work and the interpretation and management of the input and output data. There are two practical sessions in which the code TRACE [6] is used to reinforce the theory concepts about boiling and condensation processes. Besides, a user-friendly tool is used to create the model and the input file and also to run the code. This tool called SNAP [7] is shown in figure 3:

4 CONCLUSIONS

In the subject Advanced Energy and Thermal Machines of the Master’s Degree in Industrial Engineering in Universitat Politècnica de València, a plan was established with the goal of transforming the way of teaching through the use of computer codes for solving problems. This plan is structured in three phases or main tasks that have been implemented gradually.

As a result, the subject has become more interesting and attractive not only for students but also for teachers because of the direct application of the theory concepts.

In the near future, Virtual Labs included in the institutional repository of the UPV will be free to be used by all students enrolled in UPV not only for industrial engineers. Besides, different teaching materials will be created like screencast videos, teaching articles, etc. to be able to apply the flipped teaching methodology and also to create an Open Course Ware (OCW).
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