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Educational Initiatives to Develop Transversal Skills in the Nuclear Engineering Subjects at Universidad Politécnica de Madrid*

GONZALO JIMENEZ, JUAN JOSE PARDO, EMILIO MÍNGUEZ and DIANA CUERVO
Nuclear Engineering Department, ETSI Industriales, Universidad Politécnica de Madrid, José Gutiérrez Abascal, 2. 28006 Madrid (Spain). E-mail: gonzalo.jimenez@upm.es, juanjose.pardo.sierra@alumnos.upm.es,emilio.minguez@upm.es,d.cuervo@upm.es

Transversal skills are known to be often forgotten in the engineering studies plans or relegated to the will of the professors. The nuclear engineering subjects at the Universidad Politécnica de Madrid are taught in the last courses of the degree or at master and doctorate levels. Therefore, the alumni are expected to be almost ready for the working period of their lives. Throughout the last years, due to the Bologna process, some transversal skills evaluation initiatives have been implemented. Those initiatives were mainly based on doing an additional project, individually or in group, during the semester, and presenting it in public at the end of the semester. Thanks to those initiatives, noticeable lacks were identified in several transversal skills such as oral and written communication, creative thinking and team work. For example, some alumni confessed that it was the first time they had to expose a technical work in public. Those lacks in the transversal skills were also identified by engineering companies. Motivated by those issues, a new project to develop the mentioned skills in nuclear engineering subjects was raised. In the first phase during the courses 2011–2012 and 2012–2013, two subjects were selected as pilot: Nuclear Power Plants (4th course in degree) and Reliability and Risk Analysis (Master in Nuclear Science and Technology). They were chosen by the different level of knowledge, the numbers of students and their origins. The training has been improved during the second phase with the lessons learned of the first phase. In conclusion, following the alumni polls and evaluated results, the training was very effective and the alumni have a positive feedback on it. They think they have developed their transversal skills in a way they feel better prepared for their careers.

Keywords: transversal skills; nuclear engineering; project-based learning

1. Introduction

Engineering education has undergone a few changes throughout last twenty years. These changes are not only related to modifications already implemented but also open a broad range of possibilities. It is difficult to keep maintaining the idea that the main objective of students after reading a subject is reduced to passing an exam. The motivation for embracing the knowledge to be fully used along the student professional life could save a huge amount of time and resources during the learning academic process. In a highly changing technological society, the fact of being aware of what kind of requirements or needs are demanded by the engineering companies is essential to the success of student's careers. Many voices, such as Nguyen, [1] have point out for years that the engineer education must accomplish with a broad variety of competences, not only technical knowledge.

Implementation of the Bologna requirements at some of the Nuclear Engineering courses at Universidad Politécnica de Madrid has been used to take into account and integrate at the teaching-learning process those skills demanded by industry. This university, specifically the Industrial Engineering School (ETSII-UPM), has been identifying the key transversal skills that may complement the technical background to set a complete education to be ready for today's world. Those skills could be defined as; working capacity in an international environment, development capacity in an interdisciplinary group and ability for transmitting ideas through both oral presentations and written documents.

With the pre-Bologna academic plans, these required abilities as well as other important ones such as creative capacity, the acquisition of ethic standards and the ability to adapt to a changing world, were only addressed by making Final Degree Projects or Thesis [2]. It has to be underlined the fact that at ETSII-UPM it has been observed a tendency to move from classic engineering projects to theoretical-experimental projects or to organizational and economical studies in the Final Project Degree [3]. Therefore, these abilities, such as creativity, are much more developed than in the past.

During the last years, several improvement methods of transversal skills and some evaluation initiatives have been implemented. Some of the most interesting initiatives comes with the Project-Based-Learning (PBL) methodology, which intends that a group of students learn deeper the subject at the same time they developed transversal skills by

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doing a project together, [4].This methodology has been demonstrated to be a better tool for developing student's transversal skills. The usefulness of this methodology in the higher education has been studied deeply, as well as the difficulties to implement it, see [5–7]. Many examples of application of PBL can be found in the literature.

Some of the applications are a valuable approach of the PBL applied to practical projects, such as: a fluid dynamics laboratory [8] or a satellite navigation system [9]. Some researchers have been do an effort to adapt the PBL to the industry in those practical project [10], which could be a good opportunity to train the students with real life challenges. Other initiatives are more theoretical, adapted to the subject, such as sustainable industrial designs [11], material science projects [12] or machining project business plan [13]. The PBL methodology has been used as a tool for life-long learning. This application could be useful for highly technological areas, such as nuclear engineering [14].

The Nuclear Engineering studies have been always a paradigm of PBL projects and transversal skills training. The students that approach Nuclear Engineering (NE) for the first time have a strong engineering background. In many universities, the NE subjects are taught only at the Master Level [15]. One of the most interesting approaches in terms of transversal skills training for NE subjects is the use of full-scope simulators for teaching the reactor operation and control and the thermal-hydraulics and core neutronics [16]. With the use of those simulators, the students have the possibility of operating a nuclear power plants in groups and experience the feeling of being a power plant operator. Other similar approaches use other interesting tools to complement the simulator training, such as worksheet-exercises to learn core thermal-hydraulics [17].

From 2006, some PBL initiatives were implemented in Nuclear Engineering subjects at ETSII-UPM. Nevertheless, they had been reduced to the realization of a presentation at the end of course, individually or in groups of students.

Therefore, learning from all these existing PBL and transversal skills projects, a new approach were developed and implemented in the time of the two following academic years: phase one (course 2011–2012) and phase two (course 2012–2013).

The conclusion of the initiatives on the first phase exposed important deficiencies that most of student possessed that covered various fields such as oral and written expression, lack of creativity or abilities to work in a group. Some students stated it was the first time that they had made a public presentation on a technical matter.

Furthermore, to comprise these problems and to relate them with the features of the UPM, a study has being conducted on some subjects of MIT and Pennsylvania State University, as well as EC-2000 initiative, to identify other approaches and methods to address these major issues. Those initiatives were also complemented with other interesting approaches within ETSII-UPM.

Taking into account those studies, some extra initiatives were accomplished in the NE subjects to correct and improve, in a continuous process, more transversal skills. However, this process has presented some problems such as the control, feedback and correct evaluation of the implementation of the plan and the constraints, both economic and temporal, imposed by the educational system.

2. Methodology

In this section, the two phases of the educational initiative at the Nuclear Engineering subjects are detailed.

2.1 First phase of the initiative (course 2011–2013)

In the first phase during the course 2011–2012, two subjects were selected as pilot: Nuclear Power Plants (4th course in degree of the Industrial Engineering studies) and Reliability and Risk Analysis (Master in Nuclear Science and Technology). They were chosen by the different level of knowledge required, the number of students and their technological approach.

In the first subject, Nuclear Power Plants, some initiatives were implemented. The most important one was what it was called ''*We are going to build a nuclear power plant*'' competition, a ''*role play*'' activity based on PBL methodology. The class was divided in groups of three or four students. Each group developed a written report about a different model of an advanced reactor plant. At the end of the semester, each group had to make a 15 min exposition, in which the group, entirely, had to display their work. The differences among other similar activities were in the details: the students were told to be in a competition in which the professors represented an electrical company that wanted to buy a new power plant. Therefore, their role was as project engineers presenting their models design, trying to show their strengths, improvements and weaknesses, see Fig. 1 as an example.

In order to address this project, it was explained how to make properly a technical written report. Similarly, two weeks before the final exposition, the students were taught to present in public. They were also taught into ethics as they could not talk about the weak points of other reactors during their presentations, as in the real world should be. This education in ethics has been recognized as necessary

Fig. 1. An example of the "We are going to build a nuclear power plant" project studying the site location for the installation of a AP1000 reactor in the Madrid Area (students: Bárbara Arizmendi Gutiérrez and Teresa Rodríguez Hernández).

for engineering students [18], and especially in the nuclear field [19]. To motivate the students in the use of oral English, they had an additional score for presenting in that language.

In the second subject, Reliability and Risk Analysis, an important initiative was raised related with transversal skills. The most of the final qualification was the development of a group project in which safety evaluations techniques related with nuclear engineering were applied to other fields which were closer to the student's environment. For example, one of the projects evaluated the safety of a solar power plant as if it was a nuclear power plant, a very innovative approach that has never been done or at least is not published in public literature. Another interesting project was the evaluation of the stress produced in the operators actions involved in a nuclear power plant accident. The two PhD students trained acting themselves as operators in the Nuclear Engineering Department full scope simulator and registering their timing and stress based on their own experience. At the end of the semester the works were shared in a final presentation.

In addition, transversal competences such as creative thinking and team work were promoted, as well as some education in oral and written skills.

2.2 Second phase of the initiative (course 2012–2013)

In the second phase of the project, during the course 2012–2013, a most ambitious approach was done. As a first task, the transversal skill training of the most important Nuclear Engineering education institutions (MIT, Penn State, Tsinghua University, etc.) and ETSII-UPM new methodologies and ideas were analyzed. Some of those initiatives were implemented in pilot courses. The aim was to develop a complete transversal skills training program with the whole set of courses, as many of the students go through all the selected subjects to complete their grade or master in nuclear engineering. The Industrial Engineering School and the Universidad Politécnica de Madrid granted this educational project initiative with funding for a partial time scholarship for a student to help the team in the development of the project.

2.2.1 Feedback from the initiatives implemented by other universities regarding transversal skills

Throughout the course cited, the selected student spent several months gathering information about the development and implementation of some of these transversal skills on the respective curricula of various international universities as well as an analysis of EC-2000 initiative.

The selection of some universities to evaluate the way they develop their respective curricula was a cornerstone. The constraints which constitute the diverse educational systems bring the necessity of a continuous data exchange, essential if preparing students as complete as possible is one of the most important objectives. Therefore, it is of common interest to compare and contrast various activities that other educational institutions performed.

MIT was the first university to be analyzed. Forty one courses were studied. The information obtained from every course came from its website Open Courseware [20]. This is a web-based publication of virtually all MIT course content. OCW is open and available to the world and is a permanent MIT activity. The investigation procedure focused on those ones belonging to the Nuclear Science and Engineering field.

The second university was Pennsylvania State University. The information was obtained from its Website [21]. Twenty two courses were analyzed. As in previous case, the investigation procedure focused on some of those courses belonging to the Nuclear Science and Engineering field.

During the process, the courses offered were evaluated. A short report was made from each one of them that included documentation, information about the transversal skills that were addressed, as well as the method of evaluation of the course.

Regarding documentation, a classification of every course was accomplished concerning type, length and field dealt. A summary about objectives pursued and student profile to which the course aimed was accomplished.

With reference to the analysis of the use of transversal skills, a report was accomplished during the course. The previously cited report comprised every activity such as presentations, debates, papers, etc. These activities were classified depending on which kind of transversal skill expected to strengthen. At first, the selected transversal skills were: oral and written communication, creative capacity, capacity to work in a group and use of computer tools.

Finally the evaluation method chosen for the course was analyzed. In this part was included every type of activity that weigh in, and the percentages of each activity in the final grade.

After the valuation of various courses of different universities, the decision to incorporate the initiative EC-2000 was made. It is important to know the capacity to contrast with other educational institution. However what EC-2000 proposes is to intensify. EC-2000 was an initiative developed in the United States by several universities and institutions with the aim of expanding and implementing continuous improvement systems. It provides documentation, alternative methods, including protocols and instruments, for assessing specific outcomes.

The analysis of the results obtained in the study of different courses provided a basis for the application to other courses. In the first part, an analysis was performed based on the number of subjects required in a number of specific evaluation activities. The selected activities represented those that form part of the final assessment.

The first are periodic tasks. This item includes all activities that have to do such as homework, or exercises to be periodically delivered. For example, Nuclear and Radiochemistry course at PSU.

The second is a regular attendance at class. It had taken into account only those subjects assigned or specifically emphasized assistance or incentive as part of the final grade evaluation. For example, Design Principles of Reactor Systems at PSU sets that the attendance is mandatory and 0.5 points will be subtracted from the student's final grade per each class missed.

The third activity encompasses all kinds of tests as a test or measure of the student's abilities. Such testing may be conducted throughout the course, and may occur several times during it.
For instant, Reactor Engineering at PSU three exams are given (2 Midterm & 1 Final Exam), and the final grade is calculated based on the two best exams out of three.

The fourth activity is based on the inclusion of participation. It has taken into account only those subjects assigned or specifically remarks participation or incentive as part of the final grade evaluation. For example, in Introduction to Applied Nuclear Physics at MIT, the class participation is a 5% of the final score [22].

The fifth characteristic is taken as performing work. The difference between performing work and a regular work is that need greater time commitment, and often could be collectively performed with the respective presentation. For example in Nuclear Power Plant Dynamics and Control at MIT, the students can select one of two formats for their short paper: a summary and critique of a recent journal article on control of complex systems, or an essay on some aspect of reactor control, [23].

The last of the activities outlines as making presentations. For instant, Photon and Neutron Scattering Spectroscopy at MIT, the students have to make a 30 min presentation choosing among 9 different topics of the subject, [24].

As a summary of the study, the percentage of the number of courses of each university studied with the previously mentioned activities is represented as a comparison in Fig. 2. The results obtained show that most courses opt for periodically requiring tasks, as it could be observed in PSU (100%) and MIT (85%) tested subjects. For assistance, 18% and 12%, respectively, of the subjects encourage assigning class participation part of the grade. With regard to examinations, 96% and 76% of the subjects performed examinations for evaluation. 9% and 17% respectively of the subjects are given a portion of the final grade for participation. Finally, 14% and 27% respectively assigned part of the final grade to making presentations.

With regard to the number of selected transversal

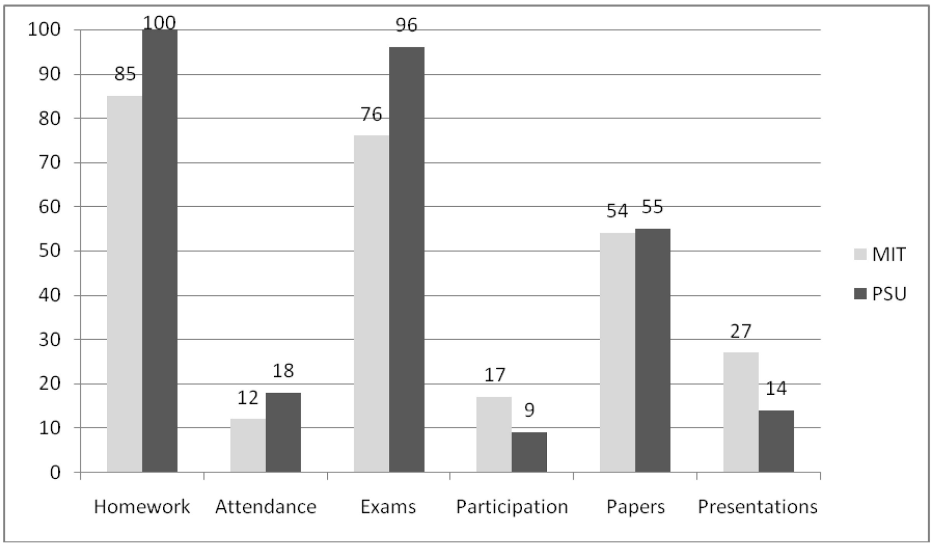

Fig. 2. The percentage of the number of courses of each university studied with the previously mentioned activities is represented as a comparison.

skills namely, oral and written communication, creativity, ability to working teams and use of computational tools, there has been notice that a lot of work has been done from those universities. With respect to the first cross-skill, oral and written communication, it has taken on the tasks performed, or that proposed projects or reports that require explanation of an idea or project descriptively, requiring the need for use communication skills. For example, in Neutron Interactions and Applications at MIT, the students are encourage to explain the importance and significance of their projects, to offer a critical view of the methodology employed and also to suggest ways to improve [25] .

Regarding the creative capacity, it has taken those characteristics that represent the student's need to provide some idea of their own, or to confront the problem critically and originally posed. For example in Magnetic Resonance Analytic, Biochemical and Imaging Technique at MIT, the students are told to be creative in their selection of topic for their final work [26].

With respect to teamwork, it has taken any activity that requires the collaboration of group work. The development of team work skills is essential for adaptation to the experiences in future jobs. It could be detected how other skills as creativity is suggest in the same activity. For example, in Fundamentals of Advanced Energy Conversion at MIT, the team work is optional but encouraged [27].

With reference to the development of the use of computational tools is included any activity that uses software packages, simulation codes and programming codes, for example the use of nuclear thermal/hydraulics codes at Design Principles of Reactor Systems at PSU.

In the second part of the study addressed one of the most important initiatives of the last twenty years when implementing cross skills: the EC-2000 plan. 90 different institutions emphasized the need for the modernization and renovation of educational programs in engineering. This need was interconnected and was attractive to the student remarked a key need that society demanded. Another key feature was the requirement that the curriculum be structured flexibly to adapt adequately to these demands.

The main objective of the initiative was to provide to multitude of schools with a series of mechanisms and tools for developing frameworks adapted to each institution that permit such continuous improvement.

The cornerstones of this initiative are called Outcomes. The outcomes could be defined as observable and measurable manifestations of applied knowledge. Defining such outcomes include cognitive, attitudinal and behavioral aspects [28].

The cognitive domain refers to things related to the acquisition of knowledge. The attitudinal-related field provides information about the effectiveness of an academic program. The behavioral-related field relates the reaction of students to both internal and external effects. In addition, this item explaining that knowledge should not only be acquired but applied to relevant situations.

Ec-2000 initiative, as collection, provides a series of 11 outcomes that could be used or selected by each institution for their specific needs, and provide a series of measures for the evaluation of these outcomes [29].

To evaluate the initiative, a report on several aspects was accomplished. First the report addressed the scope of the initiative, marking out which parts of curricula could be influenced. Secondly it was taken into account the approach of the initiative. Finally it was selected which methods could be useful to incorporate in the curricula. Despite the fact that EC-2000 is the result of a broad activity with multiple cases that could be applied to nevertheless, EC-2000 does not develop specific tools to specific cases, however, it develops a framework that will have to make suitable for each need of educational institution. In addition, constraints such as time, staff and economics resources should be included.

At first it was developed a report on the objectives sought by EC-2000. It included the background that led during the 90s to decision making that resulted in the initiative and its potential impact on the ability to adapt to countless frames.

In the report was included a summary of the process of implementing the plan, defining its steps and explaining which goals and tasks were pursued at each stage of the process as well as, the duration of each step in the process and problems that might be encountered along the achievement of it.

Finally reference was made to the most important part of the EC-2000 initiative; development and implementation of Outcomes, understood as methods specifically marking out the development and implementation of cross-cutting skills demanded by society as of today. These Outcomes give rise to a framework that will lead the continuous improvement process required in addition to a sound evaluation of the results throughout the process.

2.2.2 Implementation

Those international universities initiatives were also complemented with other interesting approaches within ETSII-UPM, such as Learning Through Play project, [30] and multidisciplinaty PBL [31].

As a direct feedback on the innovation project for the study conducted, some initiatives were implemented in the 2012–2013 course. In Nuclear Power Plants subject, there were established two one-hour debates during the semester. In the first debate, after 20 min of training in oral skills, the class was divided into two groups: one was pro-constructing a nuclear power plant in Madrid and the other was against it. High percentage of students was defending the position they were against at the beginning of the debate, to increase the effectiveness of the training. In the second debate, the nuclear waste problem was discussed. The class was divided in three groups, two pro different repository options and the third one pro dropping the waste to the sea, an option that is illegal nowadays all over the world. In both debates, training in ethics was made during them. With these two debates, they faced the two recognized challenges of nuclear energy: nuclear safety and waste management, so not only they were trained in transversal skills but in technical ones.

The other initiative implemented is to complement the Nuclear Power Plant subject with three Seminars that have been implemented in the last years at ETSII-UPM by the Nuclear Engineering Department:

- Basic Course of Nuclear Science and Technology (4 h): the objective of this course is to give an overview of the applications of Nuclear Science and Technology.
- Seminar of Nuclear Safety in Advanced Reactors (24 h): the objective of the seminar is to detail the new advances in nuclear safety, focus on the new reactors.
- Seminar of Nuclear Fusion (8 h): the objective of this seminar is to give a wide overview of the fusion technology. It includes a visit to the CIEMAT fusion reactor prototype in Madrid.

The program of these seminars has been adapted in 2012–2013 to be complementary to the Nuclear Power Plant's one. The lecturers are young professionals from the industry and the academia. The attendance is composed both of people from the industry and students of Nuclear Power Plants subject. This mix put into contact the students with professionals that are working in the field they are studying in the Nuclear Power Plants subject. The reactors described in the Seminar of Nuclear Safety in Advanced Reactors are chosen to be the same as the students have to work on in their group project, so they can ask directly to the industry experts their doubts during the project.

3. Results and discussion

Following the completion of the activities during the 2011–2012 and 2012–2013 courses it was initiated the analysis the results. It is common practice in school make a course evaluation once completed. This evaluation is performed through series of polls that must be completed by students; see Annex for the detailed composition of the survey.

The results shown in Fig. 3 refer to the subject Nuclear Power Plants during the years 2010–2011, 2011–2012 and 2012–2013. Students were asked to answer anonymously a series of question valuing each from zero (completely disagree) to five (completely agree). The evolution is clearly positive in all

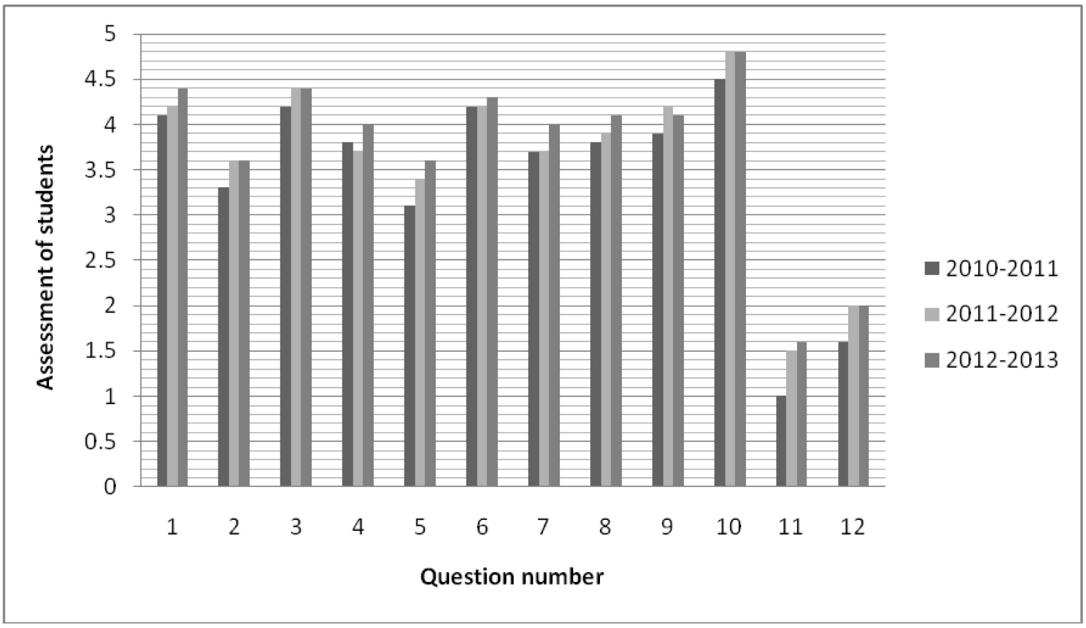

Fig. 3. Results of Student assessment in the subject Nuclear Power Plants.

the 12 areas, which is a good feedback of the methodology.

There is a clear tendency of improving the scores from the last year without transversal skills education in the subject. The students showed more motivation to attend to classes and improvements in their skills, which was the main objective of the project.

4. Conclusions

In conclusion, following the last years polls, the implementation of the methodology has been very effective and the students has a positive feedback on it. They feel they have developed their transversal skills in a way they feel more prepared for their careers. The training was improved during the second phase with the lessons learned of the first phase.

The future works are to standardize and consolidate the implementation of the transversal skills training in the nuclear engineering subjects in the new studies that will start in the next courses.

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Appendix: Academic survey at ETSII-UPM

1. The scheduled tasks of (theoretical, practical, individual work, group, etc.) relate to what is intended to learn in teaching.
2. In developing this educational activity there is no overlap with the content of other activities or unnecessary repetition.
3. I've improved my starting skills, in relation to the powers provided in the program.
4. The information provided by the teacher on teaching (objectives, activities, bibliography, criteria and evaluation system, etc.) is found easy to access and use.
5. The literature recommended by the teacher is useful to develop individual and group tasks.
6. I understand the subject without additional external support to the Center.
7. The course provides adequate teaching resources to be tracked (learning platforms, teaching materials, laboratory equipment, etc.)
8. The labs help the understanding of the subject.
9. Overall, I am satisfied with the teaching of the subject.
10. I attend class regularly.
11. Should be devoted to the subject (including class time, practice, study, etc.) an approximate number of hours per week ...
    0: less than 5 hours
    1: 5–7 hours
    2: 7–9 hours
    3: 9–11 hours
    4: 11–13 hours
    5: more than 13 hours.
12. I have attended the following number of tutorials
    0: Never
    1: 1 time
    2: 2 times
    3: 3 times
    4: 4 times
    5: more than 4

Gonzalo Jimenez has a degree in Physics by the Universidad Complutense de Madrid, a Master in Power Generation by the Universidad de Zaragoza and a Master and a PhD in Nuclear Science and Technology by the Universidad Politécnica de Madrid. He has worked and researched in nuclear safety since 2005 within engineering companies such as Socoin and Westinghouse Electric Company in Spain and in Belgium. Nowadays, is working as Assistant Professor in the Nuclear Engineering Department. He is also a board of directors' member of two Committees: Jóvenes Nucleares, the Spanish Young Generation in Nuclear and the Publications Committee of *Nuclear España*, the Spanish Nuclear Society monthly magazine. He has participated in several engineering education projects, at the national level and at European Level: such as ENEN III, Nushare or ECNET.

Juan José Pardo is a scholarship student at the Universidad Politécnica de Madrid, Spain. He has participated in a national education research project.

Emilio Minguez is Professor Chair of Nuclear Engineering in the College of Industrial Engineering (ETSII). Universidad Politécnica de Madrid. Since 2004 is Vice Rector for Academic Management and Professors. Vice president of ENEN. Member of Expert Group on Education, Training and Knowledge Management. NEA/OCDE. He has been Associate Dean in the College of Industrial Engineering (ETSII), and Chairman of the Nuclear Engineering Department. Member of the Board of the Spanish Nuclear Society (1985–1989). Member of the Steering Committee of the European Nuclear Worldscan (1985–1989). Member of the Expert Group related to Art. 31 of the Euratom Treaty (1998–2004). Expert in the CEE- Fission of the European Union (2002–2004). Author or co-author of about 200 papers in the following journals: Fusion Technology, Nuclear Technology, Laser and Particle Beams, Journal Quantum Spectroscopy and Radiative Transfer, Physics Letters B, Nuclear Europe, Nuclear Instrument and Methods.. He has been UPM coordinator of several European Project in Education, like ENEN III, Nushare, ECNET or Transnusafe.

Diana Cuervo is MSci in Naval Engineering, 1998, Ph.D in Nuclear Engineering, 2007, both at Universidad Politécnica de Madrid (UPM) and B.Sc in Physical Sciences, 2005, at the Universidad Autónoma de Madrid (UAM). She is an Associate Professor at the Department of Nuclear Engineering at UPM and has been working in the development and improvement of nuclear thermal-hydraulic codes and coupling with 3-D neutron-kinetics codes for the analysis of different nuclear power plant scenarios.