# PARTICIPATION OF UPM IN GREAT PIONEER, A EUROPEAN PROJECT FOR EDUCATIVE INNOVATION IN NUCLEAR ENGINEERING

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## Abstract

Universidad Politécnica de Madrid (UPM) is participating in the European Project devoted to new teaching methodologies Graduate Education Alliance for Teaching the PhysIcs and safety of NuclEar Reactors, Great Pioneer, leading two of the six work packages devoted to the educative tasks.

This project proposes an innovative pedagogical approach for long life education in the field of reactor physics and safety. This approach is based on the use of a flipped classroom methodology including the use of hybrid synchronous sessions where the students may be attending onsite but also remotely. UPM has participated in the development of material for the courses "Nuclear Data for Energy and Nonenergy Applications", "Core modelling for core design" and "Core modelling for transients". These courses were given in November 2022, and January and February 2023. The material prepared for these courses includes handbooks, webcasts and quizzes for the asynchronous sessions and presentations, practical exercises and active quizzes for the synchronous sessions. All the material developed for the different courses was delivered, monitored and graded via the Learning Management System SOUL, a moodle based platform developed by Tecnatom that is available for the project.

The asynchronous phase was designed to be 4 weeks long and during this time the students were preparing the synchronous session phase by studying the handbooks, watching the webcast that were developed as complement and answering the quizzes. The synchronous phase concentrated on 5 consecutive days to allow attendance for participants from different countries. Participation in the courses was very satisfactory reaching 50 students as average for course and being around 15 onsite participants and the rest remote. Completion rate of the initial participants was 57% and completion rate of the participants qualified for the synchronous sessions was 80%. Success of the first edition has permitted to extend the project to have a new edition beginning in September 2023 (https://great-pioneer.eu/courses/).

**KEYWORDS:** INNOVATIVE EDUCATION METHODOLOGIES, SYNCHRONOUS AND ASYNCHRONOUS TEACHING, FLIPPED CLASSROOM

## 1. INTRODUCTION

Although the future of nuclear energy varies depending on the European country in question, there is a generally critical situation regarding the lack of qualified personnel for workforce replacement. This is necessary both for the commissioning and operation of power plants in some countries and for the safe decommissioning of plants in others, or even for both simultaneously. This technology demands professionals with highly specialized qualifications and deep theoretical knowledge, as well as practical experience that is difficult to obtain. The shortage of qualified personnel is due to several factors, with varying degrees of significance depending on the country and its current situation in relation to nuclear reactor operation.

One of these factors is the generational gap that is occurring due to the retirement of many professionals who entered the sector during its peak development in the 1970s and early 1980s. This is exacerbated by the lack of interest among new professionals in pursuing careers in this sector, primarily due to public opposition to the use of this technology, often stemming from a lack of understanding. Furthermore, many training programs in the field of nuclear engineering have been on the brink of disappearing or have disappeared due to this lack of student interest, which has reduced the availability of specialized courses.

Considering that, in countries with reactors under construction or planned projects and those where reactors are being operated until the end of their life cycle with subsequent decommissioning, it is essential to have professionals with specialized training in nuclear engineering to carry out these projects. These professionals also need to be well-versed in various areas within the nuclear field, ranging from reactor design to decommissioning, including safety analysis, radiological protection, nuclear data analysis, core thermohydraulics or plant thermomechanics, and more.

Furthermore, these professionals must stay up-to-date in a complex technology field with a significant component of development and innovation, necessitating constant revision of educational programs.

## 2. OBJECTIVES OF THE EUROPEAN PROJECT GREAT PIONEER

The European project "Great Pioneer," part of the Euratom H2020 program, aims to bring together the efforts of various European educational institutions with extensive experience and prestige in training nuclear engineers [1]. The goal is to develop an educational program that includes advanced and specialized postgraduate courses (Master's and Ph.D.) to offer to personnel in the nuclear industry (utilities, engineering firms, regulatory organizations, research centers, etc.). The universities involved in this project are Chalmers Tekniska Hoegskolaab, Sweden, Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland, Technische Universitaet Muenchen (TUM) and Technische Universitaet Dresden (TUD), Germany, Budapesti Muszaki Es Gazdasagtudomanyi Egyetem (BME), Hungary, Politecnico di Torino (POLITO), Italy, Universidad Politecnica de Madrid (UPM) and Universitat Politecnica de Valencia (UPV), Spain, European Nuclear Education Network (ENEN), Belgium, and LGI Consulting, France.

These courses aim to cover both the theoretical and experimental and computational aspects. One noteworthy aspect of the project is the students' access to experimental research or training facilities. Another differentiating feature is the use of innovative teaching techniques that incorporate active learning pedagogical methodologies through a decentralized approach. These aspects will be explained in detail in the following section.

Additionally, another significant objective of the project is the preservation of knowledge in universities and the establishment of networks that facilitate information exchange among these institutions, as well as promoting student mobility by connecting professors and students. This will foster synergy among educational institutions, facilitating feedback between them.

This initiative also promotes the improved utilization of experimental centers and modeling environments, facilitating the exchange of students who can gain experience in these facilities or centers and offsetting the high cost of using these facilities by ensuring a sufficient number of students have remote access to them.

It is important to highlight that two significant groups in the project are the Advisory Board, composed of Gesellschaft für Anlagen- und Reaktorsicherheit gGmbH (GRS), Swedish Radiation Safety Authority, International Atomic Energy Agency (IAEA), The Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD NEA), and Hungarian Atomic Energy Authority, and the End-Users Group, including Studsvik Scandpower AB, Vattenfall, Westinghouse Electric Sweden AB, MVM Paks Nuclear Power Plant Ltd, and Institut de Radioprotection et de Sûreté Nucléaire (IRSN). The participation of these groups will ensure the quality of the courses and teaching materials, ensuring that course content remains aligned with user needs.

## 3. DESCRIPTION OF THE MATERIALS AND METHODOLOGIES USED FOR THE COURSES

Courses included in the project are based on the development by experts in different areas of the Nuclear Engineering field of material that was delivered, monitored and graded via the Learning Management System SOUL, a moodle based platform developed by Tecnatom that is available for the project (Figure 1). This type of platforms allows to distribute the different types of material for the courses in a well-organized way being accessible by the students at his convenience [2].

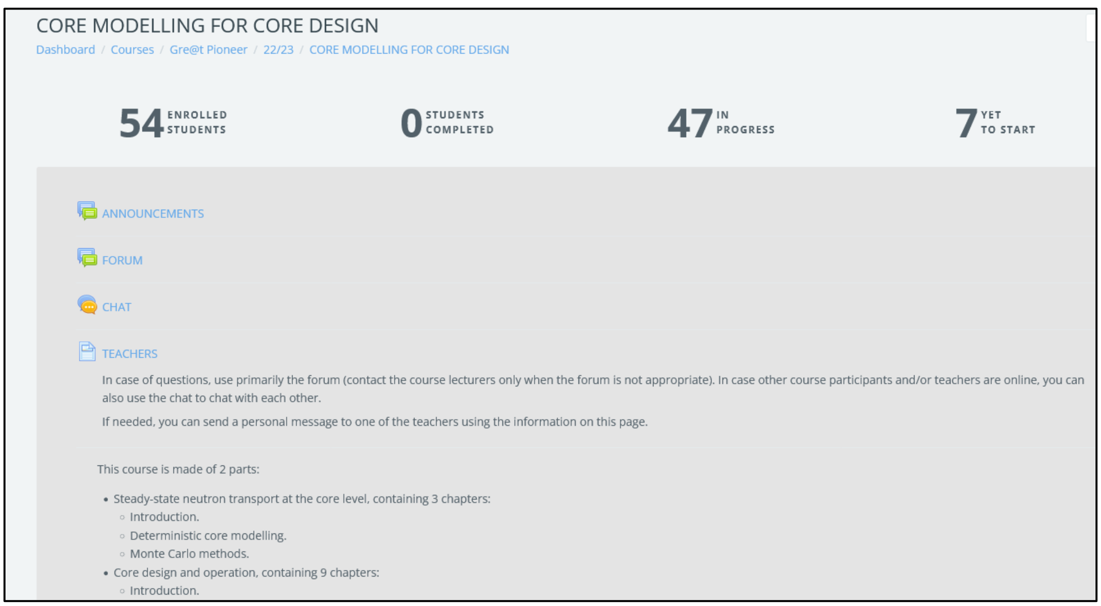


**Figure 1: Learning Management System SOUL for the "Core Modeling for Core Design" course**

All the courses within the project maintain the same structure that it is based on two well distinguished phases, an asynchronous phase to be followed by the students remotely at a self-pace base, and a synchronous phase that can be attended on-site or on-line [3].

The first one, the asynchronous part, includes as main resource several handbooks that allow to the students the study of the contents covered by the course in high detail previously to the beginning of the synchronous sessions (Figure 2).

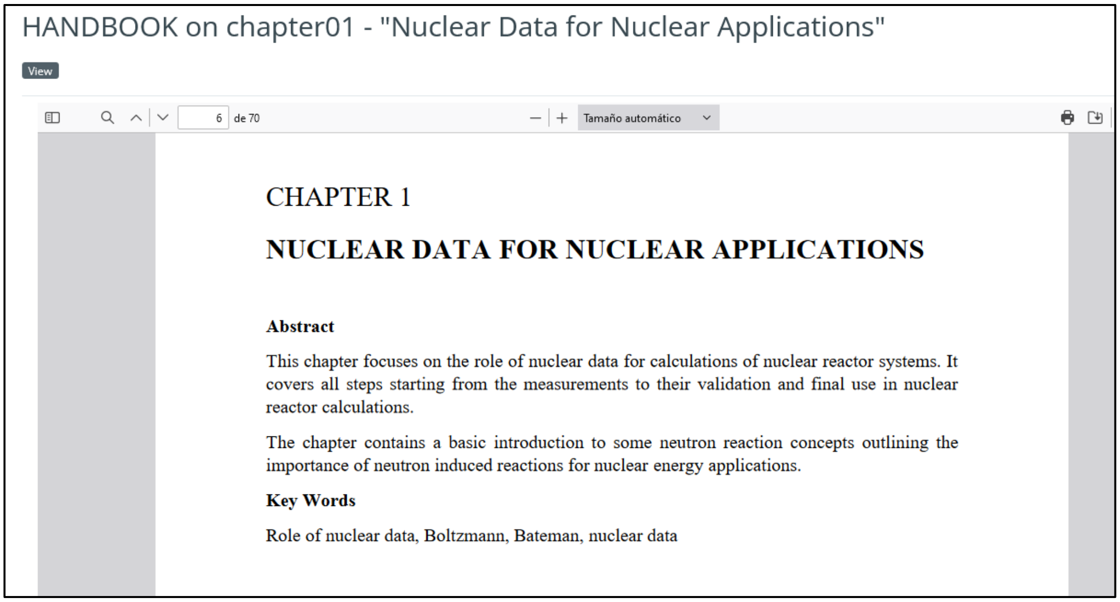


**Figure 2: Handbook chapter example**

In order to clarify some of the contents exposed in the handbooks, the platform also includes a set of web-casts around 10 minutes long each that explain in detail some of the concepts included in the handbooks (Figure 3). These web-casts have been prepared by the instructors of the course and can be visualized as many times as needed in order to understand the topics covered.

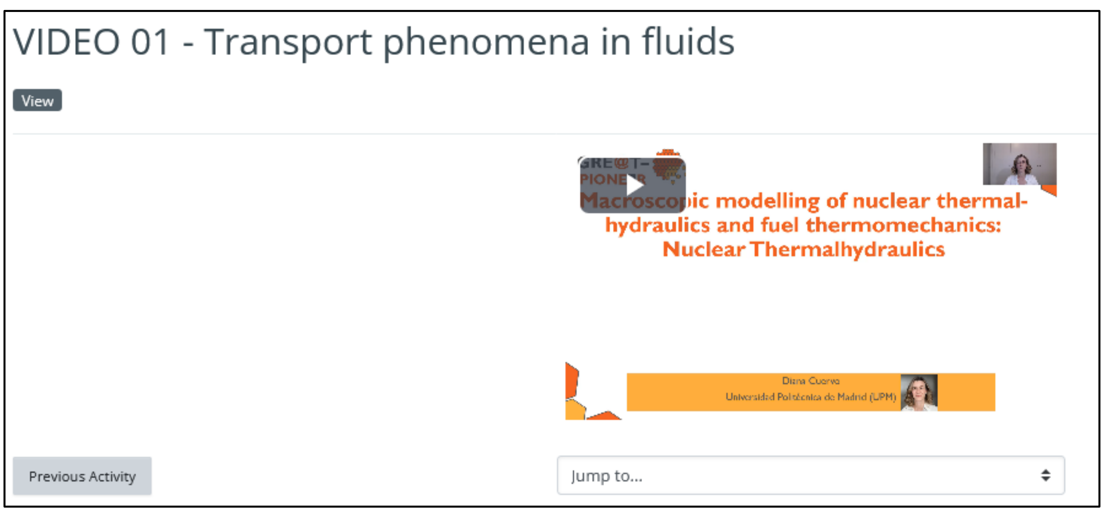


**Figure 3: Web-cast activity at the LMS**

As final phase of this part of the course, the students have to answer different types of quizzes that allow the instructors to know the level of knowledge about the topics covered by section of the course. In order to qualify for attending the synchronous sessions the students need to watch at least 50% of all lectures and answer 50% of all quizzes by the previous Friday of the beginning of the synchronous phase.

The asynchronous phase was designed to be 4 weeks long and during this time the students were preparing the synchronous session phase by studying the handbooks, watching the webcast that were developed as complement and answering the quizzes. During this time instructors were available for answering questions addressed by the students about the contents of the material or about interaction with the platform.

The synchronous phase concentrated on 5 consecutive days (working days) to allow attendance for participants from different countries. Participation could be selected by the students to be remote or on-site. Remote participation had the advantage that no traveling costs had to be paid by the students. On the other hand, on-site participation was highly appreciated by the students as a close interaction with the instructors was established not only during lectures and activities but also during brakes and lunches. This allowed to the students to learn also about other topics related with the nuclear engineering industry and research directly from the experts participating as instructors.

Synchronous sessions were mainly devoted to clarification of especially difficult topics from the handbooks and webcasts, but also to perform practical applications of these topics using different simulation codes and mathematical and programming software. The software used was available for both types of students in different ways: connecting to a server, installing free licence software at their own computers or executing directly on SOUL platform as it is the case for Matlab that can be used through Matlab Grader interface.

These interactive sessions were complemented by interactive quizzes and exercises that were opened at the beginning of each session or at a particular time when the instructor considered that students should be able to answer if they understood the exposed topics. These active quizzes and exercises allowed using SOUL capabilities to summarize the student answers to have an idea of the level of acquisition of the concepts by the students or to use it as a formative activity. In case the instructors observed a general lack of knowledge by the students, this active session allowed to review those contents that were not understood correctly.

Active participation of the students in the activities at the synchronous sessions was graded by the instructors in order to evaluate the knowledge and skills achieved and to issue the course certification for the participant. This was performed through the Gradebook included in SOUL (Figure 4). The participants had a period of one month after termination of the synchronous sessions to finalize the quizzes and tasks. At least a 50% of success in the evaluation activities was demanded for this certification.

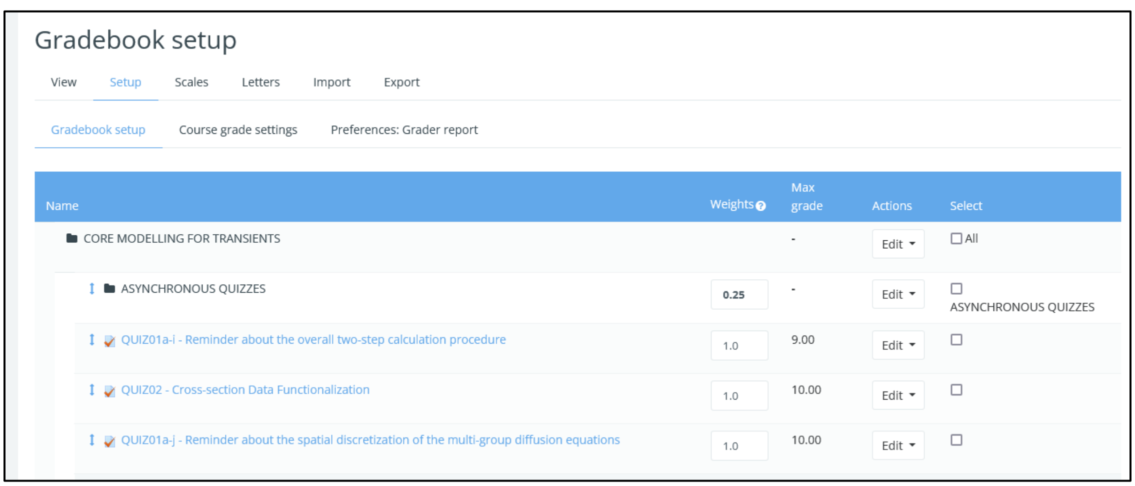


**Figure 4: Gradebook setup for evaluation of the student's performance**

## 4. UPM PARTICIPATION IN THE PROJECT COURSES

The authors of this paper, nuclear engineering professors at the UPM, have participated at three different courses developed within the project. These courses were "Nuclear Data for Energy and Nonenergy Applications", "Core modelling for core design" and "Core modelling for transients". First edition of these courses was given in November 2022, and January and February 2023.

The first one, "Nuclear Data for Energy and Nonenergy Applications", includes 10 chapters covering many topics related with nuclear data treatment:

- Nuclear Data for Nuclear Applications.
- The Experimental Nuclear Data
- Evaluated Data Libraries
- Nuclear Data Visualization Tools
- Tools for Processing Nuclear Data
- Benchmarking and Validation
- Sensitivity Analysis and Uncertainty Quantification
- Nuclear Data Adjustment Methodologies
- Nuclear data needs: Target Accuracy Requirements
- Overview of International Organizations

UPM was leading the work package of the project in charge of preparing the course as well as developing most of the material.

Regarding the second one "Core modelling for core design", includes 2 parts:

- Steady-state neutron transport at the core level, containing 3 chapters:
  - Introduction.
  - Deterministic core modelling.
  - Monte Carlo methods.
- Core design and operation, containing 9 chapters:
  - Introduction.
  - PWR core design and steady-state operation.
  - PWR technical specifications.
  - PWR operational maneuvers.
  - PWR incore fuel management.
  - BWR core design and steady-state operation.
  - BWR technical specifications.
  - BWR operational maneuvers.
  - BWR incore fuel management.

Also in this case, UPM was leading the work package for coordination of the course. In this case the participation in preparation of the material was focused on the PWR topics.

And finally, "Core modelling for transients" that is made of 3 parts:

- Non-steady-state neutron transport at the core level, containing 5 chapters:
  - Introduction.
  - General space/time discretization methods.
  - Reduced - Order Modelling techniques.

- Factorization techniques.
- Small space - and time - dependent fluctuations – power reactor noise.

- Macroscopic modelling of nuclear thermal-hydraulics and fuel thermo-mechanics, containing 3 chapters:
  - Introduction.
  - Nuclear thermal - hydraulics.
  - Fuel thermo - mechanics.
- Numerical methods for coupling, containing 3 chapters:
  - Introduction.
  - Solving linear systems.
  - Solving non - linear systems.

UPM instructors were in this case focused on the Nuclear Thermal-hydraulics aspects.

These three courses were taught at the Universidad Politécnica de Valencia were exist a dedicated classroom for hybrid learning with ambient microphones and speakers, interactive screens, student and instructor computers, and beamer.

Participation of the students in the Great Pioneer courses was very satisfactory reaching 50 students as average for different courses and being around 15 on-site participants and the rest remote. Completion rate of the initial participants was 57% and completion rate of the participants qualified for the synchronous sessions was 80%. After finalizing the course, satisfaction questionnaires were fulfilled by the students about the different sections of the topics that have shown high grades.

## CONCLUSIONS

This project aims to have a significant impact in the field of knowledge preservation. The teaching methodology is innovative, extending the possibility of access to specialized training for students who may not be able to travel to the location of the instruction due to time or financial constraints. This methodology will also facilitate the acquisition of knowledge on a permanent basis by including interactive and practical sessions. The scope of the theoretical content is extensive, and since it is structured in modules, it will allow for content updates if necessary.

UPM has extensive experience in the field of nuclear engineering education, and their participation in the project will contribute to the project with the knowledge acquired over the years in the areas of nuclear data processing, core design, and transient analysis.

Success of the first edition of the courses has allowed to submit a project extension request that has been approved by European Commission and will enable to the partners to have a new edition of the courses that has been already initiated with the course “Nuclear Data for Energy and Nonenergy Applications” given in UPV from September 4th to 8th and will continue with the rest of them as stated in schedule included in the project website [4]. This information will be also spread through social networks [5].

## AKNOWLEDGEMENTS

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