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D7.1 - Overview of the course package on radiation protection in nuclear environment

WP7

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Summary

This document gives an overview of the course package on WP7: Radiation protection in a nuclear environment. More precisely, the objectives with the course package, the pedagogical approach used, the course package structure, the overall contents of the developed handbooks and of the hands-on training exercises are presented.

Approval

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Abbreviations and Acronyms

Acronym	Description
ECTS	European Credit Transfer and Accumulation System
JiTT	Just-in-Time Teaching
LMS	Learning Management System
SOUL	Smart Open Universe of Learning
WP	Work Package

Executive Summary

This document gives an overview of the course package on WP7: Radiation protection in a nuclear environment. More precisely, the objectives with the course package, the pedagogical approach used, the course package structure, the overall contents of the developed handbooks and of the hands-on training exercises are presented.

Keywords

Active learning, blended learning, flipped classroom, hybrid teaching, radiation protection, health physics, shielding calculation

1. Introduction

The EU-funded GRE@T-PIONEeR project aims at developing a specialized education in reactor physics and nuclear reactor safety for PhD and postdoc students, for nuclear engineers, and taken as advanced courses for MSc students. The education encompasses both theory and hands-on training exercises, the latter heavily relying on the use of research/training reactors and of computer-based modelling environments. The aim is for the students to be able to perform nuclear reactor safety simulations understanding all the approximations on which such simulations rely. This is considered essential knowledge in the education of highly skilled nuclear safety analysts. The use of pre-recorded lectures and electronic teaching resources allows students to learn at their own pace and get prepared for the hands-on training sessions. Those sessions, offered both on-site and remotely, use active learning methods under the close supervision and support of the teachers, thus promoting student learning.

In this report, an overview of the course package on radiation protection and shielding calculation offered as part of the Work Package 7 (WP7) is given. More precisely, the objectives with the course package, the pedagogical approach used, the course package structure, the overall contents of the developed handbooks and of the hands-on training exercises are presented.

2. Objectives of the course package

Radiation protection is a crucial part of the operation of a nuclear installation and a specific interdisciplinary field requiring knowledge of reactor physics, particle transport calculations, shielding design, instrumentation, health physics and radiation protection standards and regulations.

The WP aims to modernize the radiation protection briefing obligatory for any student or trainee entering a nuclear installation, like the participating research reactor where the laboratory exercises are performed. Furthermore, the WP couples radiation protection and health physics with the neutronics calculation tools and methods touched upon in WP3 and 4 and presents the specificities of shielding and dose rate calculations. The course material developed covers:

- The principles of health physics and radiation protection regulation.
- The instrumentation for radiation protection in nuclear installations.
- The shielding calculation methods (deterministic and Monte Carlo), neutron and gamma transport, and deep penetration problems.

Hands-on exercises involve tools to design and evaluate biological protection of reactors from the simplest approximations to sophisticated Monte Carlo and deterministic models. In combination with these exercises, research reactor laboratory exercises aim to familiarise the students with the radiation protection instrumentation and practice in nuclear installations and measure shielding material properties and perform measurements for some of the calculated shielding problems.

3. Reminder about the pedagogical approach

This Section is a reminder of the pedagogical approach developed and applied across the GRE@T-PIONEeR project. This approach was already described in more detail in the deliverable D1.2 (Demazière, 2021).

3.1. Active learning as the core strategy

The pedagogical approach used and applied throughout the GRE@T-PIONEeR project essentially relies on the concept of *active learning*, according to which students learn much more efficiently when they participate to engaging activities in the classroom with the support from the teachers (Freeman et al., 2014).

Learning can be considered as a process. One paradigm often used to define the various learning steps is Bloom's revised taxonomy of the cognitive domain (Andersson et al., 2000). This process, illustrated in Figure 1, is defined as a sequence of various skills the students develop, starting from lower-order thinking skills to higher-order thinking skills. In the lower order thinking skills, students try to remember and understand the course concepts they were presented. In the higher order thinking skills, students try to utilize such concepts on their own. Those skills include applying, analysing, evaluating the course concepts and creating. What the various skills represent and contain is more precisely exemplified in Figure 1.

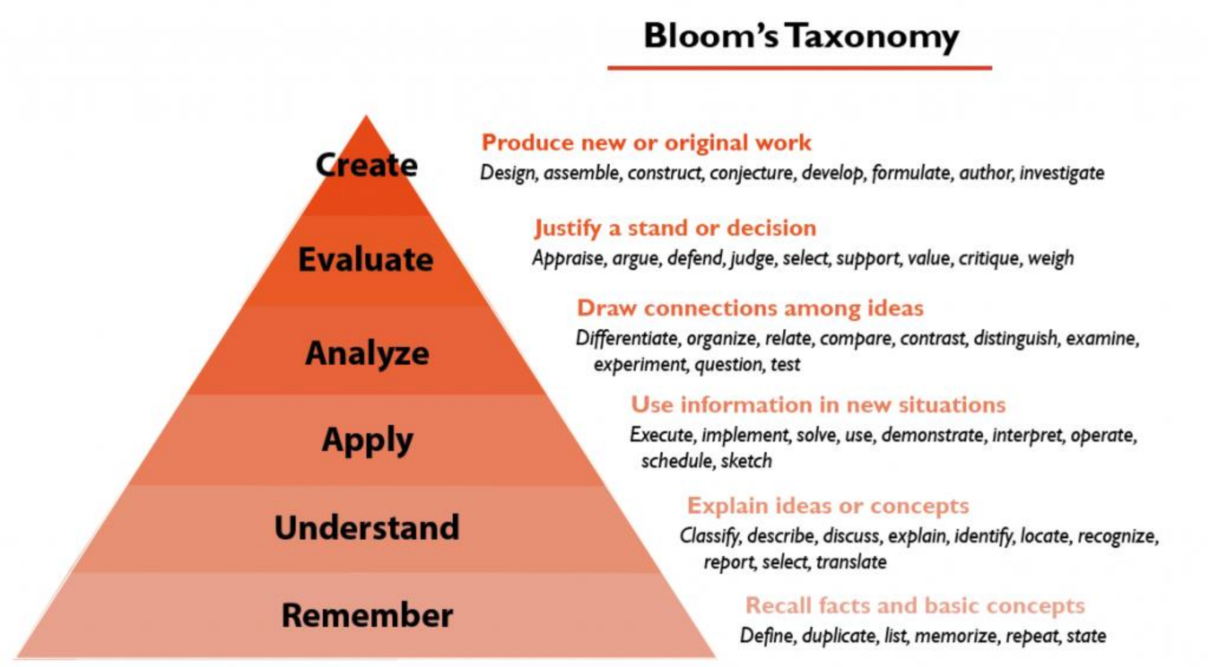

Figure 1. Illustration of Bloom's revised taxonomy for the cognitive domain, with higher order thinking skills at the top of the diagram – adapted from (The Vanderbilt University Center for Teaching, 2021).

In GRE@T-PIONEeR, teachers push the students to develop as high as possible thinking skills. Higher order thinking skills are triggered when students are given the possibility to utilize the concepts they were introduced to. This requires from the teachers designing some engaging activities in which the students are actively involved, during which active learning takes place. The main incentive is the fact that one learns much better by doing and experiencing oneself, a principle called in everyday' s jargon "learning by doing". Practice is the essence in reaching higher order thinking skills in Bloom's revised taxonomy.

Many definitions of active learning exist. The one generally accepted is given by Felder and Brent (2014) as follows: "Active learning is anything course-related that students in a class session are called on to do other than simply watching and listening to a lecture and taking notes."

Many active learning techniques exist. A non-exhaustive list of examples is given in the GRE@T-PIONEeR deliverable D1.1 – Section 7.4 (Jaiyeola A. et al., 2021).

3.2. Flipping to increase pedagogical support

In order to make room for such activities, a flipped classroom is used, with the traditional delivery of lecture-based contents moved outside of the classroom: lecture and materials usually presented in class are instead made available to the students on the web and before (Bishop and Verleger, 2013).

In the flipped classroom model, students learn asynchronously as they can choose when and at what pace to watch/read the course material. In contrast to the traditional teaching format, low order thinking skills are practiced during this asynchronous phase before the students meet the teachers and other students for synchronous interactions. Therefore, the time spent with the teachers can be used more effectively to engage students in high order thinking activities, clarify difficult concepts and provide individual support.

Since the students attend the synchronous sessions much better prepared than in a traditional teaching set-up, flipped classrooms were demonstrated to lead to much better learning outcomes and to contribute to a deeper learning compared to traditional teaching (Bishop and Verleger, 2013; O'Flaherty and Phillips, 2015). The key aspect of flipped classrooms is freeing time in the classroom to organise engaging activities with the students under the teacher's supervision, thus favouring active learning.

Another advantage of the above teaching set-up with respect to synchronous versus asynchronous learning is the possibility for the teachers to gather data about student learning before they meet the students for synchronous interactions. As a result and making use of a Just-in-Time-Teaching (JiTT) philosophy (Watkins and Mazur, 2010), the teachers are able to adjust their synchronous teaching sessions to the students' needs. This further improves student learning.

3.3. Course package structure

The overall methodology for the course implementation relies on the following elements:

- *Handbooks* covering the theoretical aspects of the covered topics.
- *Pre-recorded lectures* (or *webcasts*) available for on-demand viewing and extracting the main features, results, and concepts of the handbooks. The webcasts are recorded with the teacher's voice and, when possible and relevant, video, while using on-screen annotations, thus making the webcasts vivid.
- *Online quizzes* associated with the webcasts, focusing on conceptual understanding, with immediate feedback to the students on their learning. The quizzes are designed in such a way that thinking skills beyond merely remembering concepts are triggered, including the applying, analysing, and evaluating concepts in Bloom's revised taxonomy. Such active learning elements encourage a deep approach to learning. Moreover, embedding quizzes in the pre-recorded webcasts allows for splitting of the lectures (webcasts) into smaller chunks, increasing student attention and thus improving the conditions for learning. As an additional benefit, the quizzes allow the teachers to continuously monitor students' comprehension of key concepts.
- The possibility to *pose questions* to the teachers while watching the lectures. When possible, students are offered to rate, on a voluntary basis, the pre-recorded lectures and to provide comments. Such comments, at the lecture level, provide meaningful information about student learning and can also be used to improve the design of the handbooks, videos, and quizzes.
- *Active learning sessions* in forms of wrap-up and tutorials with synchronous interactions between the students and the teachers. Various active learning methods are implemented depending on the topics and the set-up of that particular course moment. Using JiTT, the synchronous sessions are also designed to address the students' needs.
- Use of *discussion fora* monitored by the teachers. The fora are utilised as a post-class activity to maintain engagement, favour collaboration between students and are also used for providing additional feedback and help to the students.

The entire management of all electronic resources is done via the Learning Management System (LMS) SOUL from Tecnatom (Smart Open Universe of Learning).

All the collected information – the answers to the quizzes, the questions sent to the teachers, the rating of the pre-recorded webcasts, as well as additional comments provided by the students – are used to prepare the synchronous sessions designed to meet the students' needs, building on the concept of JiTT. The sessions contain four key parts: 1) providing a brief summary of the key concepts and their relation to the structure of the covered topic so that the students could relate the details to the overall picture, thus favouring a more holistic approach to learning; 2) answering the questions that the teachers received; 3) going through the quizzes in an interactive way and discussing different alternatives; and 4) going through specifically designed activities, exercises, tutorials or hands-on training. This last part of the synchronous sessions constitutes the most important part, both in terms of devoted time and impact on student learning. Moreover, this last part of the wrap-up sessions is where the degree of interaction between the students and teachers is highest.

For each of the studied topics, the learning sequence for the students is made of several parts, as illustrated in Figure 2. The first ones include studying the handbooks, watching the webcasts, and completing the online quizzes. Interactions with the teachers are only possible in an asynchronous fashion, using the communication channels of the LMS. Synchronous interactions become possible during the synchronous sessions. Various active learning techniques are used in such synchronous sessions, representing the course moments during which the students and the teachers interact the most. Finally, the students apply, analyse, and evaluate the studied concepts while solving assignments, thus using high order thinking skills in Bloom's revised taxonomy. Although the biggest part of the assignments is solved during the interactive sessions, the students may be given some extra time to finalize the assignments after the sessions. Discussion fora are also used for peer-instruction, with interventions from the teachers when necessary.

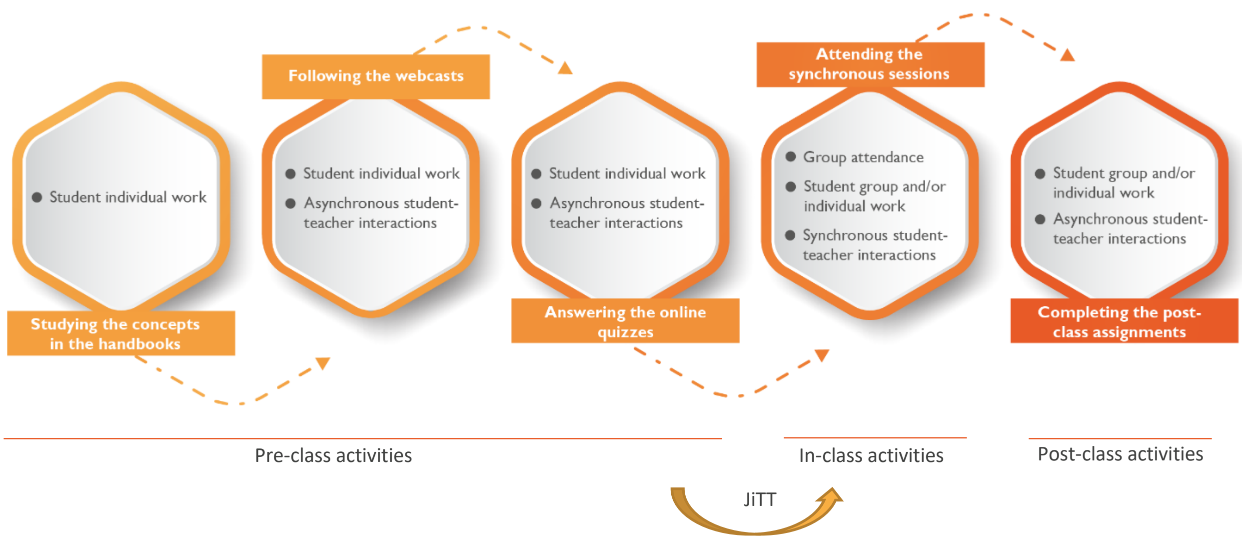

Figure 2. Illustration of the learning sequence.

Hands-on training sessions are split into two categories. The first category typically corresponds to wrap-up sessions, discussions, tutorials, code usage and method implementation and are organized separately for each course module. The second category represents hands-on training exercises organized on one of the training reactors available to the consortium (CROCUS at EPFL, Switzerland; AKR-2 at TU Dresden, Germany; BME Training Reactor at BME, Hungary). It should be emphasized that such hands-on exercises are common to all course modules and are organized as a one week to ten days session given after all course modules were given.

The pre-class activities represent roughly one week of full-time studies. Likewise, the in-class activities also represent one week of full-time studies. The course modules are thus worth 3 European Credit Transfer and Accumulation System (ECTS) each. The attendance of the hands-on activities on the training reactors gives some extra ECTS depending on the length of the corresponding sessions.

Moreover, in GRE@T-PIONEeR, the synchronous sessions of the first category are offered in a hybrid learning environment: students can decide to travel to the host organisation for following the synchronous sessions, or they can follow such sessions remotely on the web. The synchronous sessions are organised in specifically designed interactive teaching rooms: one available at Chalmers University of Technology, Sweden (Demazière et al., 2017) and one at Universitat Politècnica de València, Spain. Such rooms are furnished with movable chairs, tables, and whiteboards enabling the use of a more student-centred pedagogical approach. This is of significance when a flipped classroom model is implemented, so that the in-class activities can focus on higher order thinking skills. In addition, the rooms are equipped with audio and video hardware and software that allow synchronous interactions between the on-site and off-site participants in form of digital content sharing, audio interactions, and video communication.

Such teaching rooms allow for courses to be offered to remote students in a pure virtual learning environment without any need to travel. The rooms make offering the synchronous sessions to both the on-site and off-site attendees possible. Furthermore, the two audiences can interact with each other.

The planning of the different hands-on sessions is summarized in Table 1.

Table 1. Summary of the synchronous hands-on training sessions.

WP	Course module	Week number/year	Location
2	Nuclear data for energy and nonenergy applications	46/2022 (November 14-18, 2022)	UPV, Spain (+ possible remote attendance)
3	Neutron transport at the fuel cell and assembly levels	50/2022 (December 12-16, 2022)	CHALMERS, Sweden (+ possible remote attendance)
4	Core modelling for core design	2/2023 (January 9-13, 2023)	UPV, Spain (+ possible remote attendance)
5	Core modelling for transients	6/2023 (February 6-10, 2023)	UPV, Spain (+ possible remote attendance)
6	Reactor transients, nuclear safety and uncertainty and sensitivity analysis	10/2023 (March 6-12, 2023)	UPV, Spain (+ possible remote attendance)
7	Radiation protection in nuclear environment	13/2023 (March 27-31, 2023)	CHALMERS, Sweden (+ possible remote attendance)
2-7	Exercises at AKR-2	April 2023 (+ backup in August/September 2023)	TUD, Germany (only some of the course elements will be made available to remote attendees)
2-7	Exercises at CROCUS	End of May/beginning of June 2023 (+ backup in September 2023)	EPFL, Switzerland (only some of the course elements will be made available to remote attendees)

2-7	Exercises at BME Training Reactor	June 2023 (+ backup in August/September 2023)	BME, Hungary (only some of the course elements will be made available to remote attendees)

4. Overall contents of the developed handbooks

Two separate handbooks have been developed in the framework of WP7: one on health physics principles and radiation protection, regulations and one on shielding and dose rate calculations.

4.1. Handbook on health physics principles and radiation protection regulations

The handbook starts with an overview of the fundamentals of radiation protection. It covers the biological effect of ionising radiation, radiation protection regulations, the protection from internal sources, the instrumentation for radiation protection in nuclear installations and environmental monitoring. The handbook amounts to a total of 51 pages.

The table of contents with the number of pages of each chapter and section is the following:

1		Fundamentals of radiation protection	15
	1.1	Physical fundamentals	8
	1.2	Natural and artificial sources of ionising radiation	2
	1.3	Dose concepts (external and internal)	3
	1.4	Applied dose quantities for regulation	3
2		Biological effects of ionising radiation on human body	4
	2.1	Deterministic effects of ionising radiation	2
	2.2	Stochastic effects of ionising radiation	2
3		Regulation of radiation protection	6
	3.1	Regulation on international level (ICRP, IAEA)	2

4.2. Handbook on shielding and dose rate calculations

The handbook discusses the methods for protection from external sources, the measurement and calculation of external dose. Concerning the shielding calculations methods, it separately presents the analytical calculations and their corrections, the deterministic and Monte Carlo methods focusing on the special challenges and solutions related to deep penetration problems. The handbook amounts to a total of 49 pages.

The table of contents with the number of pages of each chapter and section is the following:

5. Overall contents of the hands-on training exercises

As earlier mentioned, the hands-on training exercises are divided into a one-week long set of synchronous session specific to the considered WP and three sets of hands-on activities common to all WP and offered at each of the training reactors – see Section 3.3 and Table 1.

The details of the WP-specific hands-on exercises during the synchronous sessions are detailed in Table 2, whereas the planning of the activities is given in Table 3.

Table 2. Description of the hands-on exercises offered during the WP-specific synchronous sessions.

Exercise	Responsible organization/person	Format	Background knowledge	Restrictions
Radiation protection: dose calculations hands-on exercise	G. Radócz (BME)	Hybrid	Provided in the Radiation protection handbook	Max. 15-20 onsite participants Max. 25-30 offsite participants
Radiation shielding: hands-on exercise analytical solutions, point-kernel method, etc.	R. Macian (TUM)	Hybrid	Provided in the Shielding calculation handbook	Max. 15-20 onsite participants Max. 25-30 offsite participants
Radiation shielding: demonstration with PARTISN, hands-on exercise (output, data processing, visualization, evaluation)	M. Szieberth (BME)	Hybrid	Provided in the Shielding calculation handbook	Max. 15-20 onsite participants Max. 25-30 offsite participants
Radiation shielding: hands-on exercise with OpenMC	Sz. Czifrus (BME)	Hybrid	Provided in the Shielding calculation handbook	Max. 15-20 onsite participants Max. 25-30 offsite participants

Table 3. Planning of the various activities during the WP-specific synchronous sessions.

	Day 1	Day 2	Day 3	Day 4	Day 5
morning	Start of the course: introduction of the teachers and participants, schedule for the week Radiation protection: interactive discussion, dose concepts, internal-external dose, etc.	Radiation shielding: interactive discussions on analytical solutions, point-kernel method, etc.	Radiation shielding: interactive discussions on deterministic methods, special methods for deep penetration, challenges, advantages	Radiation shielding: interactive discussions on MC methods, special methods for deep penetration, challenges, advantages	Radiation shielding: hands-on exercise with OpenMC, simple problems, comparison with deterministic
afternoon	Radiation protection: dose calculations hands-on exercise	Radiation shielding: hands-on exercise analytical solutions, point-kernel method, etc.	Radiation shielding: demonstration with PARTISN, hands-on exercise (output data processing, visualization, evaluation)	Radiation shielding: hands-on exercise with OpenMC, basics	Radiation shielding: hands-on exercise with OpenMC, simulating BME TR measurements, comparison with deterministic Closing of the course: course certificates and course evaluation

The details of the hands-on exercises on the training reactors are given in Table 4.

Table 4. Description of the hands-on exercises offered during the hands-on exercises on the training reactors.

Exercise	Responsible organization/person	Format	Background knowledge	Restrictions
Gamma and neutron dose measurements at AKR-2	TUD/Carsten Lange and Alexander Knospe	3 h to one day Onsite Possibility of hybrid format (audio/video sharing)	Dedicated set of lecture notes provided	Max. 8 onsite participants

Neutron dose measurements at CROCUS	EPFL/Alessandro Scolaro, Vincent Lamirand and Mathieu Hursin	4 h Onsite Possibility of hybrid format (audio/video sharing + remote control of acquisition systems)	Basics in reactor physics and radiation matter interaction	Max. 4-6 onsite participants
Gamma dose measurements at CROCUS	EPFL/Alessandro Scolaro, Vincent Lamirand and Mathieu Hursin	4 h Onsite Possibility of hybrid format (audio/video sharing + remote control of acquisition systems)	Basics in reactor physics and radiation matter interaction	Max. 4-6 onsite participants
Neutron and gamma dosimetry shielding materials at horizontal channels at the BME Training Reactor	BME/Richárd Milecz-Mitykó	4-6 h for measurements and 4-6 hours for evaluations (morning/afternoon) Onsite Possibility of hybrid format (audio/video sharing) for the evaluation sessions + pre-recording of measurements	Dedicated set of lecture notes provided	4-5 participants/group with max. 2 groups in parallel Radiation protection briefing required before entire the first time
Introduction to the radiation monitoring system at the BME Training Reactor	BME/Richárd Milecz-Mitykó	4-6 h for measurements and 4-6 hours for evaluations (morning/afternoon) Onsite Possibility of hybrid format (audio/video sharing) for the evaluation sessions + pre-recording of measurements	Dedicated set of lecture notes provided	4-5 participants/group with max. 2 groups in parallel Radiation protection briefing required before entire the first time

The synchronous session in WP7 has the special role to deepen the student's knowledge of radiation protection and engagement in radiation safety, which is essential for all the experimental sessions at the research reactors. The synchronous session also contains exercises directly related to certain measurements at the training reactors, which allow the student to compare calculational and experimental results and learn about modelling in practice.

6. Conclusions

As demonstrated in this report, the handbooks on health physics principles and radiation protection regulations and on shielding and dose rate calculations were developed as a collective effort between different teachers and are already available. Likewise, the planning and content of the corresponding synchronous sessions were established. Beyond the development of such sessions, the coming months will also be devoted to the development of the webcasts, quizzes and on the structuring of all electronic resources on the LMS.

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