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Overview of the course package on core modelling for transients

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Summary

This document gives an overview of the course package on Core Modelling for Transients. 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
NPP	Nuclear Power Plant
PWR	Pressurized Water Reactor
BWR	Boiling Water Reactor

Executive Summary

This document gives an overview of the course package on Core Modelling for Transients. 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, Nuclear reactor modelling; deterministic modelling; two-step approach; non-steady-state neutron transport; thermal hydraulics; fuel thermos-mechanics; numerical methods for coupling PWR, BWR,

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 core modelling for transients offered as part of the Work Package 5 (WP) 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

The objective of this course package is to develop a set of educational materials concerning simulation and experimental measurements at core level in non-steady-state conditions.

The simulation of non-steady-state situations requires the modelling of neutron transport, heat transfer, fluid dynamics, possibly fuel thermo-mechanics, and the interdependence between those fields of physics. This WP thus aims at developing course materials giving the students a full and comprehensive overview of:

- The principles of deterministic methods in non-steady-state conditions, their approximations, and their range of validity for core calculations.
- The principles of macroscopic modelling of nuclear thermal-hydraulics and fuel thermo-mechanics.
- The numerical techniques used for multi-physics coupling.

Hands-on training exercises include the development and implementation of some of the deterministic methods and the use of coupled tools used by the nuclear industry. These exercises are combined with measurements at research reactors to demonstrate the most important phenomena and to illustrate the use of the calculation methods.

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.

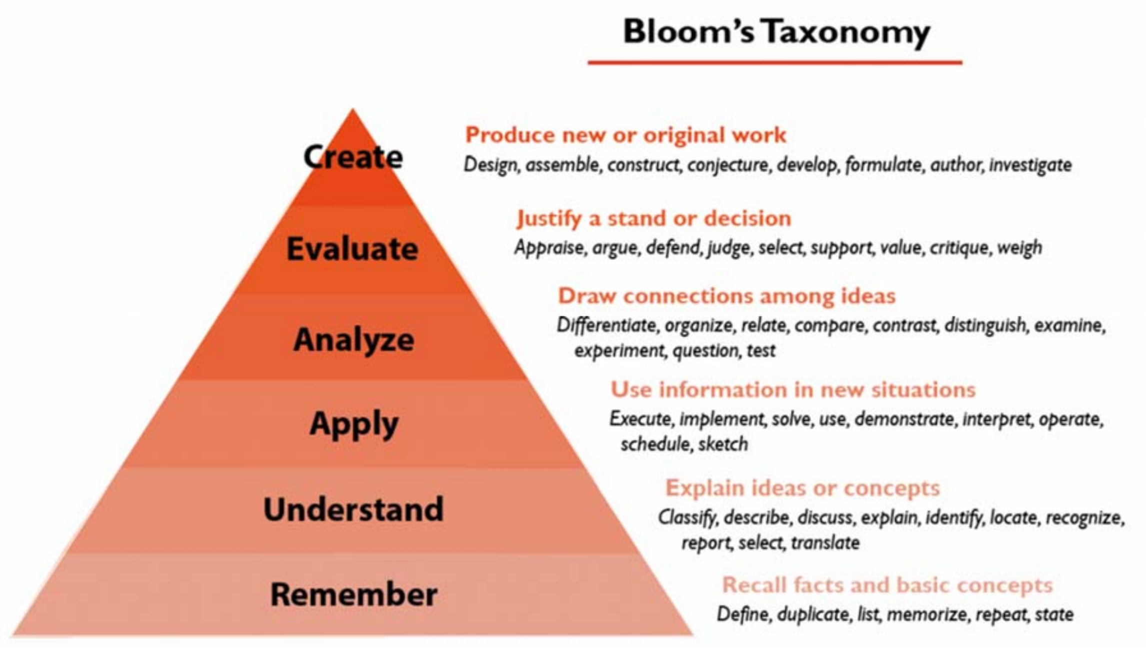

Figure 1. Illustration of Bloom's revised taxonomy for the cognitive domain, with higher order thinking skills at the top of the diagram – adapted from (The Vanderbilt University Center for Teaching, 2021).

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 those 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.

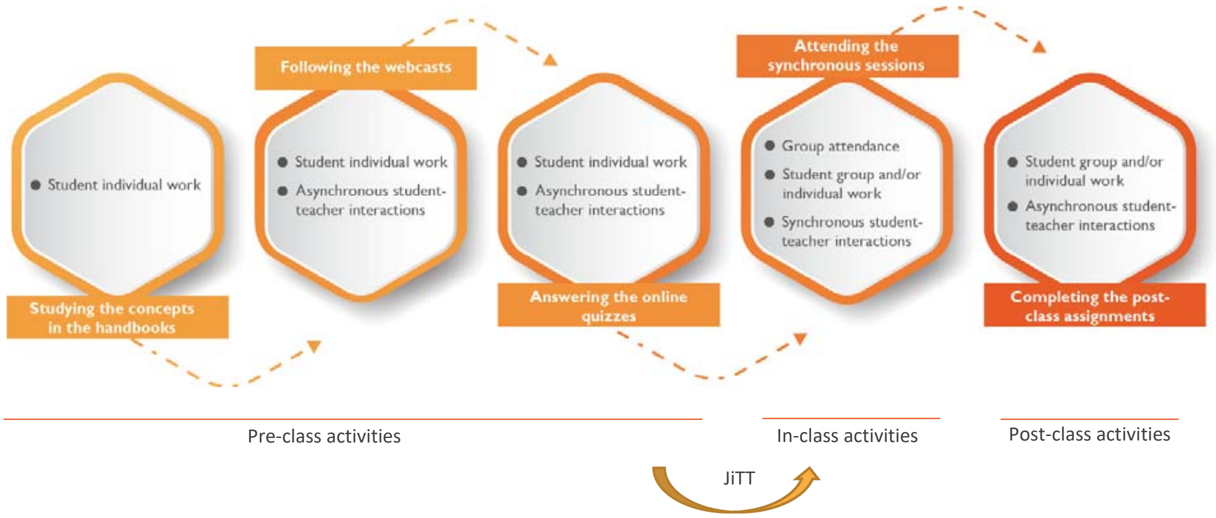

Figure 2. Illustration of the learning sequence.

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

Three handbooks have been specifically developed in WP5.

4.1. Handbook on non-steady-state neutron transport at core level

The handbook covers the methods used in non-steady-state neutron transport. Those include general space/time discretization methods, reduced order modelling or factorization techniques as quasi-static formulations. Special emphasis on reactor kinetics, linear and non-linear stability analysis, and space-time-dependent fluctuations (power reactor noise). The handbook consists of an introduction and four technical chapters and amounts to 158 pages.

- Chapter 1, "*Introduction*" (16 pages). This chapter starts with a reminder about the overall two-step calculation procedure. Then, the cross-section data functionalization is presented with details on the generation of cross-section tables for transient calculations.
- Chapter 2, "*General Space/Time discretization methods*" (45 pages). This chapter presents the main techniques used for spatial discretization of the multi-group diffusion equations with emphasis on the finite difference methods, nodal methods, and finite elements. The chapter also presents the techniques used for the time-discretization of the spatially discretized equations. Also, the reader will learn about the treatment of the time-dependence with respect to the prompt neutrons, and with respect to the delayed neutrons. The last part of the chapter is dedicated to the practical implementation in neutronic codes of the time-dependent discretization in core simulators. An example with TRACE/PARCS is given to complete the chapter.
- Chapter 3, "*Reduced-Order Modelling Techniques* " (30 pages). This chapter presents the basic concepts of non-linear stability analysis. First, essential terms for the mathematical description of the underlying problem are introduced. Then, typical non-linear phenomena which have been already observed in the frame of stability analyses of boiling water reactors are discussed. Following, some key aspects of model order reduction in the context of reactor dynamics modelling are provided.
- Chapter 4, "*Factorization Techniques*" (17 pages). The solution of the time-dependent problem in reactor physics needs to take into account the main physical phenomena relevant to the transient behavior of a nuclear reactor; such phenomena are characterized by very different time scales, ranging from the lifetime of prompt neutrons, the decay time of delayed neutron precursors, up to the effects associated to thermal feedback and the evolution of the fuel composition. In this section we summarize the factorization-projection techniques proposed by Henry (1975), discuss the physical meaning of the kinetic parameters, and describe the algorithms developed to treat time-dependent problems in nuclear reactors.
- Chapter 5, "*Small Space- and Time-Dependent Fluctuations in the Frequency Domain* " (50 pages). This chapter presents the general principles of the first-order neutron noise in its factorized form, explaining the determination of the fluctuations of the amplitude factor, and the determination of the amplitude of the shape function. The chapter continues with the general solution of the first-order neutron noise and concludes by explaining the noise source modelling with examples of the cases of one-group and two-group diffusion theory.

The table of contents of the handbook is as follows.

Table of contents of the Handbook on non-steady-state neutron transport at the core level

4.2. Handbook on core the macroscopic modelling of nuclear thermal-hydraulics and fuel thermo-mechanics

The second handbook outlines the methods used in the macroscopic modelling of nuclear thermal-hydraulics and fuel thermo-mechanics. The handbook consists of an introduction and two technical chapters and amounts to 78 pages.

- Chapter 1 "*Introduction*" (2 pages). This chapter describes briefly the main topics covered by the handbook, relating them to other areas of nuclear technology.
- Chapter 2 "*Nuclear thermal-hydraulics*" (35 pages). This chapter presents the fundamentals of fluid dynamics concerning the coolant behavior at a nuclear reactor. The text pretends to highlight the main phenomena occurring in the cooling channels and establishes the equations and models that must be used to analyze these phenomena. These equations are obtained initially from first principles for mass, momentum and energy and are, then, averaged spatially and temporally to produce the Reynolds Averaged Equations that are solved in thermal-hydraulics codes.
- Chapter 3 "*Fuel thermo-mechanics*" (41 pages). This chapter presents the main aspects of fuel behavior during irradiation and fuel modeling when using software in a multi-dimensional context. Some important aspects presented in this section are the solvers used for the thermal-mechanical properties, as well as the models used for the gap, for the neutronics and burnup, for the fission gas release, materials, and rheology.

The table of contents of the handbook is as follows.

Table of contents of the on core the macroscopic modeling of nuclear thermal-hydraulics and fuel thermo-mechanics

4.3. Handbook on numerical methods for coupling

The third handbook outlines the thermal-hydraulic to neutronic coupling, neutronic to thermal-hydraulic coupling, coupling coefficient and approaches. The handbook consists of an introduction and two technical chapters and amounts to 25 pages.

- Chapter 1 "*Introduction*" (3 pages). This chapter briefly describes the multi-physics neutronics/thermal-hydraulics coupling and the types of numerical problems to be solved, categorizing them into either linear problems or non-linear problems. Both cases are presented in detail in chapter 2 and chapter 3, respectively.
- Chapter 2 "*Solving linear systems*" (10 pages). This chapter gives an overview of the numerical techniques to be used for solving linear problems, typically encountered when solving a mono-physics problem. In this chapter the reader will learn about direct methods, iterative methods, and the case of eigenvalue problems.
- Chapter 3, "*Solving non-linear systems* " (12 pages). This chapter presents an overview of the approaches to be used for solving non-linear problems, where the discretized equations depend on each other in a non-linear manner. Since multi-physics coupling often give rise to nonlinearities, the various numerical techniques for dealing with multi-physics coupling are thus presented in this chapter.

The table of contents of the handbook is as follows.

Table of contents of the Handbook on numerical methods for coupling

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 Table1.

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
Development of a coupled model of a one-dimensional heterogeneous reactor using the JFNK method	CHALMERS/ Christophe Demazière	Hybrid Using MATLAB Grader	Provided in the T5.1-3 handbooks	Max. 15-20 onsite participants Max. 25-30 offsite participants
Use of coupled codes	UPV/Rafael Miro	Using SNAP, TRACE, RELAP5, PATHS and PARCS Codes to be used remotely on UPV servers		Non-Disclosure Agreement with the US NRC to be signed by each participant (participants not citizen of a CAMP country would generally not be approved)

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

Day 1	Day 2	Day 3	Day 4	Day 5
Start of the course: introduction of the teachers and participants, schedule for the week (1 hour)	Power reactor noise: interactive discussions + hands-on (4 hours)	Thermomechanics: interactive discussions + hands-on (4 hours)	Use of coupled codes (4 hours)	Stability analysis/Reduced Order Modelling: interactive discussions + hands-on (4 hours)
Non-steady-state core modelling: interactive discussions + hands-on on overall strategy +	Nuclear thermal-hydraulics: interactive discussions? (3 hours)	Numerical methods for coupling: interactive discussions (1 hour)	Use of coupled codes (3 hours)	Closing of the course: course certificates and course evaluation (1 hour)

general space/time dicretization methods (3 hours)				
Factorization techniques: interactive discussions + hands-on (3 hours)		Method implementation: development of a JNFK solver (2 hours)		

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
Estimation of the zero-power reactor transfer function 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
Measurement of reactor periods with control rods and water level 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
Cd blade or control rod drop 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
Reactor operation and stabilisation at power due to feedback effects at the BME Training Reactor	BME	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
Reactor transient induced by absorber sent in via the rabbit system at the BME Training Reactor	BME	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

6. Conclusions

As demonstrated in this report, the handbook on core modelling for transients was developed as a collective effort between different teachers and is 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.

7. References

Anderson L.W., Krathwohl D.R., Airasian P.W., Cruikshank K.A., Mayer R.E., Pintrich P.R., Raths J. and Wittrock M.C., A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives, Pearson, Allyn & Bacon (2000).

Jaiyeola A., Erim S., Balech S., and Stöhr C., Mapping analysis. GRE@T-PIONEeR deliverable D1.1 (2021).

Bishop J. L. and Verleger M. A., The flipped classroom: A survey of the research, ASEE National Conference Proceedings, Atlanta, GA, USA, 30 (9) (2013).

Demazière C., Operative structure. GRE@T-PIONEeR deviverable D1.2 (2021).

Demazière C., Apell P., Stöhr C. and Adawi T., Setting up a room to cater to online learners' needs, Proc. Conf. Nuclear Training and Education (CONTE 2017), Jacksonville, FL, USA, February 5-8, 2017 (2017).

Felder R. M. and Brent R., Teaching and learning STEM: A Practical Guide. John Wiley & Sons, Incorporated (2016).

Freeman S., Eddy S.L., McDonough M., Smith M.K., Okoroafor N., Jordt H. and Wenderoth M.P., Active learning increases student performance in science, engineering, and mathematics, Proceedings of the National Academy of Sciences of the United States of America, 111 (23), pp. 8410-8415 (2014).

Henry, A. F., Nuclear-reactor analysis, The MIT Press, Cambridge, MA (1975).

O'Flaherty J. and Phillips C., The use of flipped classrooms in higher education: A scoping review, The Internet and Higher Education, 25, pp. 85-95 (2015).

The Vanderbilt University Center for Teaching, "Bloom's taxonomy", available online. URL https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/ (2021).

Watkins J. and Mazur E., Just-in-time teaching and peer instruction, In Simkins S. and Maier M. (eds.), Just-in-time teaching: Across the disciplines, and across the academy, Stylus Publishing, Sterlin, VA, USA (2010).