GRE@T-PIONEER: TEACHING COMPUTATIONAL AND EXPERIMENTAL REACTOR PHYSICS USING INNOVATIVE PEDAGOGICAL METHODS

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ABSTRACT

The GRE@T-PIONEeR project is a Horizon 2020 project financed from the 2019-2020 European Union's Euratom research and training programme. The objective of the project is to preserve the competences and skills in computational and experimental reactor physics and nuclear safety. This is achieved by developing a set of advanced courses offered to PhD and Post-Doc students, nuclear professionals, and to MSc students (as specialisation courses). The courses are given as flipped classes in a hybrid learning environment, where students can decide to attend the interactive hands-on sessions either on-site or on the web. The paper presents the project set-up and the main concepts that are followed, both content-wise and pedagogy-wise. The main actions that have been undertaken during the first 11 months that the project has been running are also summarised. The project will lead to a state-of-the-art education using innovative pedagogical approaches having student learning as primary focus.

1. Introduction

With the advent of cheap computing power, modelling and simulations represent an increasingly important part of a nuclear engineer's work. These tools rely on sophisticated models, databases, and algorithms, which the engineer needs to understand, so that the tools are used most efficiently and in relevant applications. Although reactor physics has always been a core discipline in nuclear engineering, computational reactor physics is often taught via advanced courses with fewer students. Due to the decrease of student enrolment in nuclear engineering programs in Europe, maintaining those courses has become increasingly difficult. In response to the closing of such specialised courses, a new Horizon 2020 project, titled GRaduate Education Alliance for Teaching the PhysIcs and safety Of NuclEar Reactors (GRE@T-PIONEeR) was accepted for funding in 2020 [1]. The project started on November 1st, 2020 for a duration of three years and gathers ten partners throughout Europe: Chalmers University of Technology (Sweden – coordinator), Ecole Polytechnique Fédérale de Lausanne (Switzerland), Technical University of Munich (Germany), TU Dresden (Germany), Budapest University of Technology and Economics (Hungary), Politecnico di Torino (Italy), Universidad Politécnica de Madrid (Spain), Universitat Politècnica de València (Spain), the European Nuclear Education Network (Belgium) and LGI Consulting (France).

The project aims at developing and providing specialised and advanced courses in computational and experimental reactor physics at the graduate level (MSc and PhD levels) and post-graduate level, as well as to the staff members working in the nuclear industry. Beyond the technical contents of the courses being developed, the novelty of the project lies with the use of innovative pedagogical methods aimed at promoting student learning. In order to maximise the time students spend with the teachers, flipped classes are offered. The self-paced learning elements rely on handbooks specifically written for the various courses, short videos summarising the key concepts, and online quizzes allowing one to test their understanding of those concepts. These elements need to be taken before attending interactive sessions organised under the close supervision of the teachers. The interactive sessions are based on active learning, during which the students have to implement and use the techniques they learned in hands-on training exercises designed to promote learning. The exercises are computer-based modelling assignments (either implementing algorithms and techniques from scratch or using already existing nuclear simulation tools) and hands-on training sessions on research reactors. In addition to the flipped classroom pedagogy, most of the interactive sessions are offered in a hybrid format: the students can decide to attend the interactive sessions either on-site or online. The sessions are also given in a condensed format. Combined with the hybrid set-up, the courses are very well suited for lifelong learning.

The paper is structured as follows. The pedagogical set-up and principles on which the project relies are first presented. Thereafter, an overview of the courses and hands-on training sessions is given. The paper concludes with describing the advancement of the project and gives a brief outlook on future activities.

2. Pedagogical set-up

The pedagogical approach followed by the consortium 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 [2]. In order to make room for such activities in a course curriculum, flipped classrooms are 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 class [3].

According to Bloom's revised taxonomy for the cognitive domain, illustrated in Fig. 1, students go through various thinking skills while learning [4]. This process starts from low-order thinking

skills, such as remembering and understanding the course concepts, to high-order thinking skills, such as applying, analysing, evaluating the course concepts and creating.
In the traditional format, engineering students are traditionally exposed to new concepts for the first time in class. As a result, only low-order thinking skills are triggered in the classroom. If the amount of new information provided to the students is too large, they will also have difficulty in processing the contents and will often become passive. This leads to the necessity for the students to go through the same contents as in the classroom but on their own and after the in-class sessions. Moreover, the students will have to deal with the course concepts at higher thinking orders mostly outside of the classroom and again on their own, unless dedicated in-class sessions are planned for such a purpose in the course curriculum.

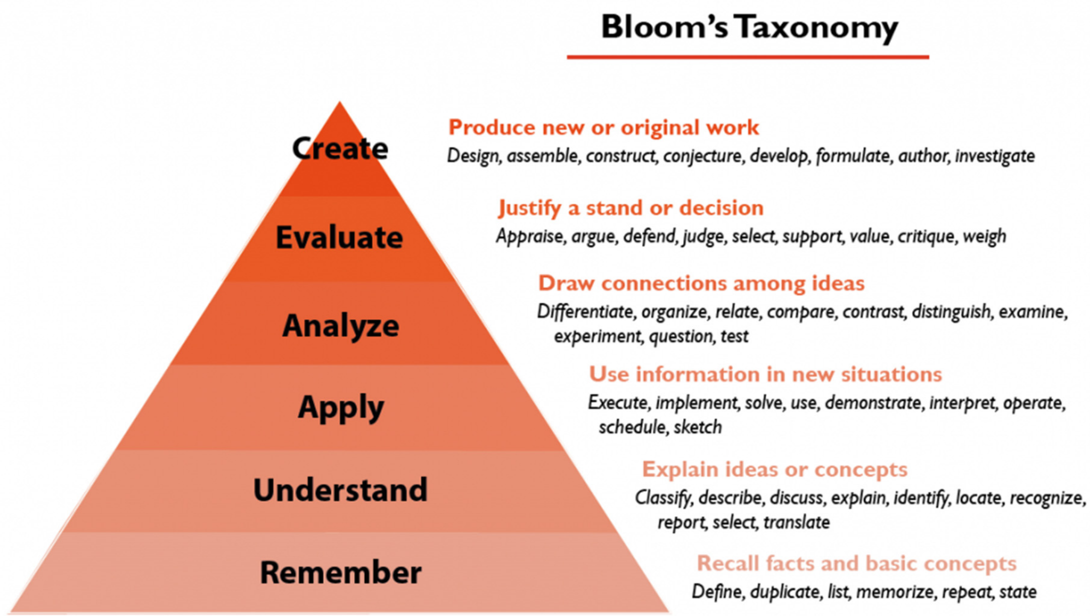

Fig 1. Illustration of Bloom's revised taxonomy for the cognitive domain, with higher-order thinking skills at the top of the diagram (adapted from [5]).

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 in class or via video conferencing for synchronous interactions. As a consequence, 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 [3], [6]. The key aspect of flipped classrooms is freeing time in the classroom in order to organise engaging activities with the students under the teacher's supervision, thus favouring active learning.

Moreover, in GRE@T-PIONEeR, the flipped classrooms 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 [7] and one at Universitat Politècnica de València. 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.

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 (virtually for the remote attendees and in real life for the on-site audience) for synchronous interactions. As a result, and making use of a Just-in-Time-Teaching (JiTT) philosophy [8], the teachers are able to adjust their synchronous teaching sessions to the students' needs. This further improves student learning.

The flexibility with the virtual learning environment and with the self-paced learning thanks to the flipped classroom make the course offering particularly attractive to students who do not have the possibility to travel and to staff members in the nuclear sector who cannot always come on-site to follow the courses. In addition, the 24/7 availability of recorded lectures and electronic resources is an aspect making the resources well suited for continuous education of staff members and life-long learning.

Active learning represents the core of the pedagogical approach implemented in the project. A large part of the efforts is thus spent on designing active learning elements that are suitable to the topics being covered, to the use of computer-based modelling environments or of training reactors when relevant, and to the hybrid nature of the courses. The structure and formats of the activities can often be categorised as follows [9]:

- *Individual activities*. Each student is asked to carry out the required activity on their own in a given time-period, after which a wrap-up is organised by the teacher. During this wrap-up, the teachers might ask some students to share the results of their activity with the class.
- *Small group activities*. Small groups of students are formed, and they are asked to carry out the required activity collectively in a given time period. Depending on the size of the groups, extrovert students might nevertheless be the ones driving the activity, at the expense of the more introvert students. Like for individual activities, a wrap-up discussion is led by the teacher, where a few selected groups share their results.
- *Think-pair-share activities*. Each student is first asked to carry out the required activity on their own. Thereafter, students are paired. Each student then has to discuss the activity with his/her peer, before a wrap-up is organised by the teacher, possibly asking a few pairs to share their results. In this set-up, the students can learn from each other. Compared to small group activities, personal opinions emerge more easily, with less influence from possible imbalance between extrovert and introvert personalities.

3. Course offerings

The project develops advanced and specialised courses in reactor physics and nuclear reactor safety while making use of synergies between the different consortium members. Theoretical aspects are covered in dedicated courses and are directly linked to training sessions involving the use of research and experimental facilities, as well as of computing and modelling environments. A set of coherent courses and training packages are offered, building upon each other while following the same pedagogical approach. Student learning is put at the core of all the activities. Links between the various modules give the students a better feeling about the inter-relations existing between the different topics being covered. This holistic approach is essential for providing critical-thinking skills to the students, while each module goes in depth into the covered topics. The course modules are nevertheless designed so that they can be taken independently from each other, in case some students are only interested in given topics.

Although variations exist between the various course modules, the overall methodology for the course development relies on a flipped classroom approach offered in a hybrid learning environment. More specifically, this includes:

- *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 live-broadcasted with synchronous interactions between the students and the teachers. Various active learning methods are implemented depending on the topics, the set-up of the course module, and the course moment. Using JiTT, the synchronous sessions are 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 a Learning Management System (LMS).

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 chapter 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. Using active learning techniques, students are more engaged and learn more efficiently. Moreover, this last part of the wrap-up sessions is where the degree of interaction between the students and teachers is highest. Thanks to the flipped nature of the courses, the activities address higher order thinking skills, during which teacher support is essential.

For each of the studied topics, the learning sequence for the students is made of several parts, as illustrated in Fig. 2. The first ones include studying the handbooks, watching the webcasts, and completing the 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, either in the classroom for the on-site attendees or via the web for the remote attendees. 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 have to apply, analyse, and evaluate the studied concepts while solving post-class assignments, thus using high-order thinking skills in Bloom's revised taxonomy. Discussion fora are also used for peer-instruction, with interventions from the teachers when necessary.

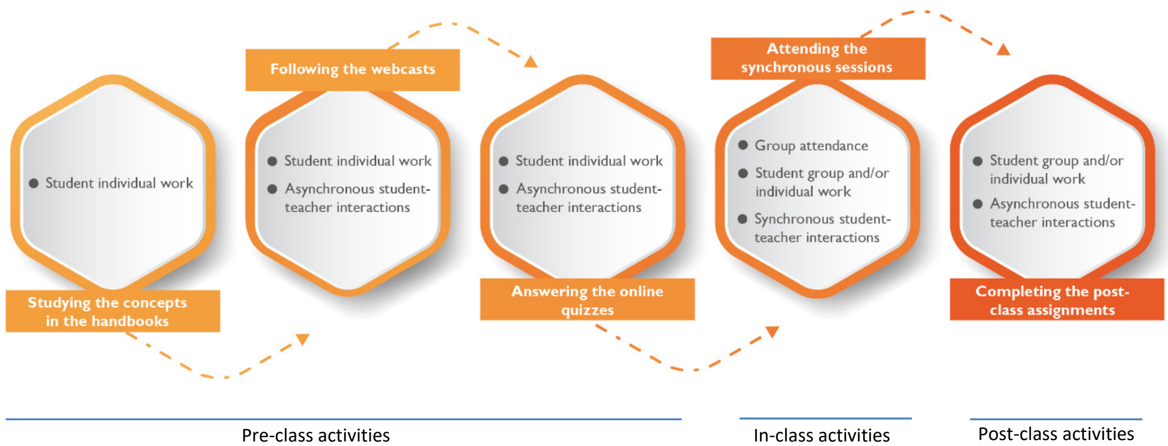

Fig 2. Illustration of the learning sequence.

The consortium heavily relies on the use of digital resources and tools, with the objective of promoting learning. In this respect, several aspects are taken into consideration [9]:

- *Making a variety of learning resources available*. The goal of providing a variety of resources is to improve learning.
- *Facilitating active student engagement*. Digital tools promoting more engagement, both in in-class activities and out-of-class activities, are used, such as quizzes, computer-assisted demonstrations or exercises or interactive multimedia tutorials (on which the students could also train at their own pace as out-of-class activity).
- *Enhancing student-faculty and student-student interactions*. Digital tools increasing the availability of the teachers to answer student questions or issues outside of the planned in-class sessions are used. Such tools also allow students to more easily communicate with each other outside of the in-class session times or ordinary working hours.
- *Providing formative and summative feedback to the students*. In addition to providing feedback to the students when they complete given tasks used for grading them (summative feedback), a much better way to influence student learning and motivate them is to continuously provide feedback to them while they learn (formative feedback).
- *Providing adaptive, individualised, self-paced instruction*. Since students learn differently, the pace at which they can process some new materials might vary significantly from one student to the other. By providing flexible teaching materials that the students could consult e.g., at home at their own pace, learning can be more efficient. Such flexible learning approaches are also very well suited to students with cognitive disorders, such as dyslexia or autism.

Regarding the technical contents of the courses, different course modules are developed. The structure of the modules follows the various steps a nuclear analyst needs to go through, from the preparation of the nuclear cross-sections, to full core calculations. More precisely, the following topics are covered:

- Nuclear cross-sections for neutron transport, focusing on:
    - The generation and evaluation of nuclear data libraries.
    - The processing of nuclear data libraries for use in nuclear applications.
    - The assessment of nuclear data uncertainties.

- Neutron transport at the fuel cell and assembly levels, focusing on:
    - The principles of probabilistic methods in steady-state conditions for fuel cell and assembly calculations.
    - The principles of deterministic methods in steady-state conditions, their approximations, and their range of validity for fuel cell and assembly calculations.
    - The use of those methods for macroscopic cross-section generation.
- Core modelling for core design, focusing on:
    - The principles of probabilistic methods in steady-state conditions for core calculations.
    - The principles of deterministic methods in steady-state conditions, their approximations, and their range of validity for core calculations.
    - The use of those methods for reference calculations or for core design, operation and safety analysis.
- Core modelling for transients, focusing on:
    - 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.
- Reactor transients, nuclear safety and uncertainty and sensitivity analysis, focusing on:
    - The principles of nuclear reactor safety and system behaviour.
    - The principles of uncertainty and sensitivity analysis applied to reactor transients.
- Radiation protection in nuclear environment, focusing on:
    - The principles of health physics and radiation protection regulation.
    - Instrumentation for radiation protection in nuclear installations.
    - Shielding calculation methods (both deterministic and probabilistic methods), neutron and gamma transport, and deep penetration problems.

The corresponding hands-on training sessions merge computer-based modelling exercises, with laboratory exercises at training reactors. For the former, the sessions are based either on existing software used by the nuclear community or on developing algorithms in given programming platforms. For the latter category, three facilities are used: the CROCUS reactor at Ecole Polytechnique Fédérale de Lausanne, the AKR-2 reactor at TU Dresden, and the BME training reactor at the Budapest University of Technology and Economics. The various exercises are:

- For nuclear cross-sections for neutron transport:
    - Use of the main software associated to nuclear data libraries (focusing on verification, processing, adjustment, visualisation, sensitivity and uncertainty analysis, benchmarking and validation).
    - Neutron transmission and pile oscillator measurements.
    - Activation experiments.
    - Doppler effect measurements.
- For neutron transport at the fuel cell and assembly levels:
    - Development of a multi-group one-dimensional heterogeneous neutron transport solver using the method of collision probabilities.
    - Use of deterministic lattice codes.
    - Use of Monte Carlo codes.
    - Neutron spectrum measurements.
    - Time-of-flight measurements.
    - Measurements of spectral indices.
    - Measurements of macroscopic data (diffusion length, absorption cross-section, migration area).
- For core modelling for core design:

    - Development of a multi-group one-dimensional heterogeneous diffusion solver using finite differences.
    - Use of deterministic codes for core calculations.
    - Illustrations of core designs and operational problems using deterministic codes.
    - Use of Monte Carlo codes for full core calculations.
    - Control rod calibration/worth experiments.
    - Critical experiments.
    - Spatial neutron flux distribution experiments.
    - Kinetic parameters measurements.
    - Measurement of the moderator temperature coefficient of reactivity.
- For core modelling for transients:
    - Development of a coupled model of a one-dimensional heterogeneous reactor using the Jacobian-Free Newton Krylov method.
    - Use of coupled neutronic/thermal-hydraulic codes.
    - Measurement of the zero-power reactor transfer function.
    - Measurement of the reactor period.
    - Rod drop measurements.
    - Reactor operation and stabilisation experiments.
    - Reactor transient experiments.
- For reactor transients, nuclear safety and uncertainty and sensitivity analysis:
    - Use of system codes for investigating given reactor transients.
    - Power excursion experiments.
    - Measurement of shutdown margins.
    - Reactor SCRAM experiments.
    - Reactor operation experiments.
- For radiation protection in nuclear environment:
    - Gamma and neutron dose measurements.

Some of the experiments at the training reactors are complemented by modelling exercises for either comparing the calculations to the experiments or estimating the quantities necessary to evaluate/exploit the measurement data.

4. Advancement of the project

After 11 months since start, the project is well on track.

Concerning the development of teaching materials, the work focused on two main lines of actions: (a) the development of the various handbooks and (b) the planning of the development of the hands-on training exercises.

Concerning (a), various planning meetings were organised to discuss and agree on the contents of the various handbooks and on how to share the responsibilities of the development of the different chapters of the handbooks. All handbooks are being prepared, with some of them being close to be completed. Careful attention is paid to making the handbooks open access at the end of the project. This requires obtaining the necessary permissions for re-using figures from existing materials, and possibly adapting those.

Regarding (b), a thorough review of the proposed hands-on exercises was completed. Several aspects were considered: access to the tools and facilities for remote students, restrictions based on student nationalities, issues of cybersecurity for remote access to the facilities and their data, planning of the actual hands-on training exercises at the three training reactors, required licenses for using the various software (both on-site and remotely), and GDPR compliance. A precise list of all exercises was established, with the responsibilities for the development and execution of those. As the level of remote access varies considerably between the facilities, the exact format of the exercises was defined, together with the maximum number of on-site attendees. The exercises on the training reactors are planned to be offered during three distinct periods in the spring/summer of 2023, with one period per reactor. The set-up was decided so that a student can decide to attend all exercises at all facilities. Even if we anticipate that most students might focus on one facility only, this planning offers more flexibility in case of unforeseen circumstances that may lead to the cancellation of some laboratory experiments or the impossibility for a student to attend a given exercise.

Beyond the development of teaching materials, an inventory of the e-learning platforms and distant learning facilities accessible to each consortium partner was carried out. Since the courses are offered outside of the regular education at each partner organisation, using the Learning Management System (LMS) of the respective organisation was found to be impossible. After a careful evaluation of different solutions and LMS, the consortium thus decided to purchase an LMS on its own, planned to be made available to the consortium on November 1st, 2021. For the recording of videos, two recording studios are accessible to the consortium: one at Chalmers University of Technology and one at Universitat Politècnica de València. In addition to those recording studios, each organisation will also use their own screencasting software which allows one to record their computer screen, with audio and video of the lecturer. Finally, concerning Active Learning Classrooms (ALCs) that can be used in a hybrid set-up, two rooms will be used by the consortium: one at Chalmers University of Technology and one at Universitat Politècnica de València. Access to all electronic resources is handled via the LMS. Learning analytics capabilities are also implemented in the LMS, so that student learning can be directly assessed and exploited for JiTT, as well as for improving the course modules.

In parallel to those activities, a mapping of the competences in the nuclear sector was carried out, together with an assessment of the future needs and skills requirements, following the nuclear job taxonomy classification [10]. For that purpose, a survey was distributed to various stakeholders and interviews with experts and Human Resources managers were conducted. Four areas were identified as critical for securing long-term competences: reactor physics, new techniques (Small Modular Reactors – SMRs, Generation-IV reactors and fusion technologies), nuclear operations, and decommissioning. Based on this mapping, an inventory of the existing training offers in the four identified areas was completed. 77 programs/courses across Europe, the Middle-East, Russia, and the USA were evaluated along various skills (technical skills, knowledge skills and core skills). The results of the mapping analysis and the evaluation of the existing training offers are being compiled in a report to be issued at the end of November 2021. Moreover, the pedagogical methods used in those curricula were scrutinised. The purpose was to identify good examples to increase the efficacy of teaching/learning. The use of advanced educational techniques in nuclear science and engineering, as well as in other sectors, was benchmarked. Interviews with four teachers using innovative pedagogical methods were carried out. Such inspiring examples will also be part of the aforementioned report, together with some recommendations for adaptation of educational programs and courses, with the objective to make those more attractive for the younger generation. The outcomes of the above activities will be presented at a collaborative workshop taking place right after this conference on November 18th, 2021 in Brussels. The workshop will also include time for group discussions during which the workshop participants will co-construct the adaptations of educational programs using the principles of design thinking. Although the basic pedagogical set-up to the followed by the GRE@T-PIONEeR project has already been established, the recommendations made for program adaptations and the outcome of the workshop will be used for the design of the active learning sessions undertaken by the consortium.

Since interactions with the various stakeholders (students, teachers, professionals, and the public at large) are essential to guarantee the success of the project, various communication means were implemented in the early phase of the project. This includes a website, of which the frontpage is given in Fig. 3, a LinkedIn account and Twitter account and the newsletter which will summarise the results and updates of the project. For the time being, the focus of the communication activities was on the innovative pedagogical aspects of the project, while the teaching materials are being developed. A project brochure and roll-up have also been developed. Finally, in order to guarantee an efficient project management and communication within the consortium, an internal web-based platform for document sharing and communication was implemented.

5. Outlook

Maintaining the availability of competences in critical areas such as reactor physics, reactor modelling, experimental reactor physics, and nuclear safety, represents the main objective of the GRE@T-PIONEeR project. This is achieved by developing a set of courses building upon each other and by implementing innovative pedagogical approaches, the purpose of which is to maximise the efficacy of teaching/learning, to preserve knowledge, and to attract new students to the field. Beyond the ongoing development of teaching resources (handbooks, quizzes, videos, and hands-on training exercises), the consortium will soon focus on the implementation of active learning techniques fitting the purpose of the project and the technical content of the courses. The actual delivery of the courses is currently planned in late 2022/early 2023.

Fig 3. Frontpage of the GRE@T-PIONEeR website.

6. Acknowledgements

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7. References

[1] https://great-pioneer.eu/

[2] 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).

[3] 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).

[4] 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).

[5] The Vanderbilt University Center for Teaching, "Bloom's taxonomy", available online. URL https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/ (2021).
[6] 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).
[7] 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).
[8] 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).
[9] Felder R. M. and Brent R., Teaching and learning STEM: A Practical Guide. John Wiley & Sons, Incorporated (2016).
[10] Chenel Ramos C., Nuclear job taxonomy – Final report. Report EUR 29126 EN, Publications Office of the European Union, Luxembourg (2018).