# USE OF OPEN-SOURCE TOOLS IN EDUCATION AND TRAINING: EXPERIENCE FROM POLIMI AND EPFL

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Education and training of young generation is a key issue in maintaining the competences in nuclear community. This effort is recognized in different countries. For example, projects funded in the framework of Euratom are specifically required to allocate at least the 5% of the budget to E&T activities. In this light, a fundamental competence that is required by nuclear professionals is a critical employment of computational tools currently used in the academia, research centres, industry, SME, TSO, regulators, etc… A “critical” employment of these tools implies a multi-step process to be achieved. The first step is related to the knowledge and understanding of the basics concept of nuclear theory (e.g., neutronics, thermal-hydraulics, fuel behaviour, safety, instrumentation and control,...), while the second one is the use of the related software e.g. the capability to apply the tool to a given context. The third phase is the analysis of the results and the evaluation of the outcomes with the possibility to create something “new” (e.g. the implementation of a new model or functionality) when required. This is nothing more than the Bloom’s taxonomy [1] applied to the educational objectives of the use of computational tool in nuclear engineering. Even if the E&T process lasts for the entire life, it is important that young generation starts to familiarize from the very beginning of their professional path with the critical employment of these computational tools. In this light, the use of open-source tools represents a promising option to link all the different learning objectives (knowledge, comprehension, application, analysis, evaluation and creation) in a unique experience, taking benefit from the openness and transparency of the codes.

The use of open-source tools can allow to adopt a problem-based learning approach as teaching method for the nuclear knowledge as complementary to traditional learning. In particular, it allows not only to improve and attract the attention and the involvement of the students, but also to effectively link theoretical concepts and practical experiences, involving them in a recursive process that combines knowledge, competences to solve problem and the capacity to analyse results.

From a more practical point of view, the use of open-source tools in the education and training can:

* simplify the use of numerical tools, eliminating main issues of intellectual property (IP) and licensing
* lower the entry barrier for nuclear newcomer countries, thus promoting international collaboration;
* facilitate the sharing and the reuse of solvers, routines and exercises among different institutions and among students, without the need to start a model from scratch but instead focussing on the specific topic of a module / lecture. This is important in the case of short courses with a limited amount of time;
* motivate students and young researchers to implement, test and promote their development ideas since they can also rely on a typically active support community of developers and users;
* make possible the implementation of an efficient problem-based learning approach, specifically devising learning activities aligned with the intended learning outcomes [2];
* permit to explore the code structure and “change” the physics for a more comprehensive understanding of both the theory and the software
* increase the skills of the students with tools that are becoming more and more used in the working field
* provide widely applicable and reusable knowledge, not restricted to codes that can only be used is specific institutions

Open-source tools have been already adopted in universities and research centers for education and training efforts. Some examples from the M.Sc. in Nuclear Engineering of Politecnico di Milano and École Polytechnique Fédérale de Lausanne are here reported.

* Short introduction on OpenFOAM [3, 4] in the “Dynamics and Control of Nuclear Power Plants” course (PoliMi). In general, this is the first experience with a Linux environment. The course follows a step by step approach in which students can see all the different phases of a numerical simulation (geometry construction, mesh generation, simulation setup, analysis of the results) with continuous reference to the theory and concepts already taken in previous lectures of the course. Taking advantage from some tutorial already present in the OpenFOAM toolkit, student can see the structure of a solver, how the multiphysics coupling is modelled, the impact of variation of some parameters both on the numerics and on the results, up to an independent implementation of a simple one-group diffusion equation.
* Use of Modelica [5] in the “Laboratory of Nuclear Engineering” course (PoliMi), a project-based course where groups of students are requested to model components of a nuclear reactors (e.g. the primary loop of a PWR reactor). The use of open-source Modelica libraries avoids the students to be stuck in tedious numerical issues and focus the attention on the modelling phase. In addition, students can reuse component already developed by other students and they can easily made improvements starting from available components. The possibility to deal with these challenging but affordable task bring the students to search information (e.g., for parameter selection) in the available literature increasing their knowledge and the judgement capacity.
* Use of Phyton in “Fission Reactor Physics” course (PoliMi) as a programming language that helps students to solve problems with the support of numerical computations. It is used because it is freely available for different operating systems and online platforms, easy to learn, allows shorter development time, can be used interactively, and object-oriented programming (OOP) is possible. The lectures cover both the theoretical and numerical aspects required to analyse the propagation of a neutron population in a multiplying system, the governing equations describing reactor kinetics and the dynamics of a nuclear reactor for investigating the stability behaviour. In this course, students use the main mathematical libraries developed in Python (SciPy, NumPy, TensorFlow) and Matplotlib
* Organization of the “OPENER” summer school for international PhD students, where the use of open-source tools allowed to guide the students through the development of a simple but complete multi-physics solver for the analysis of representative nuclear engineering problems, thus enhancing their understanding of the underlying physics.
* Use of the open-source OpenFOAM library in the frame of student projects and Master Theses, which proved particularly beneficial in improving learning by avoiding counter-productive black-box approaches and by allowing for a deeper understanding, where a phenomenological approach is complemented by the possibility to fully understand the underlying theory, and to explore its implementation into a practical computer code. In addition, the use of an open-source library encourages the adoption of best practices in programming codes and the use of version control tools (e.g., Git) and it improves the development of solvers granting a better cooperation among the different contribution created during different Master Theses.

References

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