INTERACTIVE LEARNING EXPERIENCE IN MECHANICS OF MATERIALS: THE 'SIMMIT' PROJECT

Yves Chemisky*[1], George Chatzigeorgiou[1], and Fodil Meraghni[1]

[1]*Arts et Métiers ParisTech, LEM3 UMR 7239 CNRS, France*

Summary This communication presents a methodology and tools that take advantage of research projects developments in the field of mechanics of materials for education outreach. Such new learning experience should meets the requirements of efficient interactive learning : ease of use, hands-on oriented, interactive exposure to theoretical concepts. It also has to be linked to state-of-the art scientific and industrial design numerical tools. Based on the new generations students audience expectations, an interactive method has been developed to facilitate the exposure of student to theoretical concepts and hands-on experience. Interactive learning notebooks are utilized, combined with high-efficiency scientific libraries wrapped in the widely-utilized Python language. Such methodology thus allows to easily link the theoretical concepts to industrial softwares and numerical tools, through their Python language scripting interfaces.

INTRODUCTION

Interactive Learning is a pedagogical approach that incorporates interactive experience into course design and delivery. It has evolved over the years, and benefits of the state-of-the art digital technology in terms of human-machine interaction and communication. Among the tremendous number of digital tools available (video and audio support, online communication, serious games), interactive coding is an efficient choice to expose students to basic scientific computing while learning theoretical concepts with a hands-on oriented approach. Such a different learning angle necessitate a paradigm shift in education. In particular, the new audience skills and expectations, and the new technology capabilities have to be included in the design of courses and preparation. A second aspect of interactive content is the interaction and compatibility with up-to-date simulation tools and numerical analysis packages in the field of mechanics of structures and materials. Also, compatibility with optimization methods, data mining, analytics and machine learning is necessary to explore the wide toolbox available to the new generation of engineers and scientists. Concerning the adaptation to new audience, such courses have to match with the Z generation of students expectations [**?**]. Their members have indeed grown up with internet and communication technologies, and they have a savvy use of interactive human-machine tools [**?**]. They therefore naturally highly expect tailored learning, sharing content within a community, and human-machine interaction at any stage of their learning experience. To adapt to such audience, new courses require a quick access to interactive, technology-oriented hands-on experience to facilitate the learning process of theoretical concepts in physics. On the second hand, the design of courses need also to be oriented towards the deep understanding of simulation methods in engineering. Indeed, students should be very familiar with finite element analyses (FEA) packages, material science libraries, optimization algorithms and workflows. Most of the advanced techniques for the simulation of materials nowadays relies on third-party packages dedicated to the behavior of materials, such as DIGIMAT, Z-Mat, MOOSE or SMART+. According to which concepts in mechanical of materials are approached, such transition from numerical research tools to educational material invite us to review the learning experience we propose. Indeed, since the development and/or use of efficient integrated numerical tools is a new requirement for engineers in Mechanics and Materials, a proper paradigm in education must be adopted. We have summarised three important features of an innovative interactive tool: (i) It must be compatible with integrated tools and solutions for the analysis of a material or mechanical system; (ii) the tools and knowledge exposed must be adapted to numerical simulation methods commonly utilized in industry (iii) it must easily interact with other numerical and/or scientific libraries and analytics

SIMMIT : AN INTERACTIVE TOOL

Such conclusions have led to the definition of an interactive learning package, named *simmit* which stands for "*Simulation in mechanics and Materials : interactive tools*". Such tool is proposed in an open-access format, to build a community of contributors around it and facilitate exchanges between users. The objective is eventually to facilitate the transmission of knowledge, concepts and contents that are traditionally utilized in advanced numerical simulation in Mechanics of Materials, from theoretical concepts to practical use of numerical tools for simulation and analytics.

The learning experience of students is typically depict in Figure **??** in dashed lines. Theoretical concepts in mechanics of materials and continuum mechanics are assimilated in one hand, and in a second hand they learn the use of software as well as high-level programming language to connect and interoperate input/outputs of such softwares and build workflow to analyse, optimise, present results. The two aspects are usually disconnected, since there are no tools to combine them. One way to connect the two aspect is to develop a library in a high-level language, such as Python, that will allow to develop an interactive

*Corresponding author. Email: yves.chemisky@ensam.eu

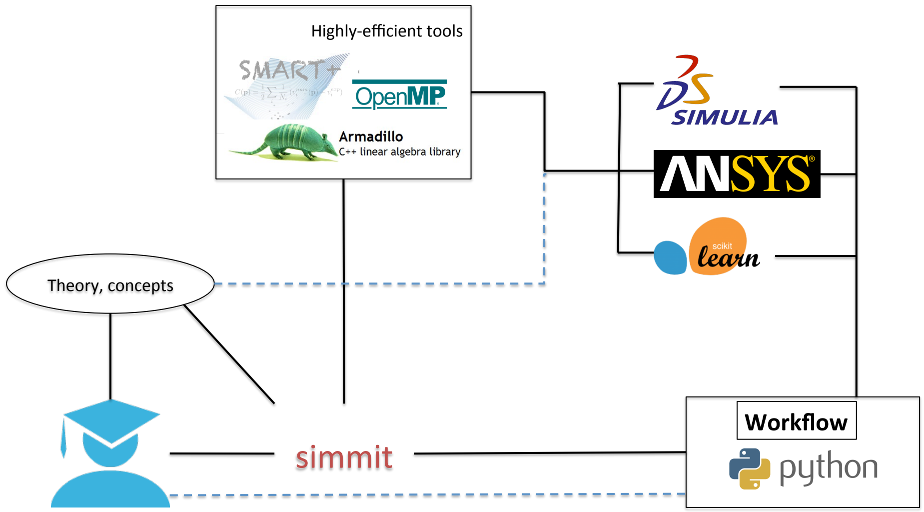

Figure 1: Flowchart describing the learning process of numerical simulation tools, and theoretical concepts in mechanics of materials. Blue Dashed lines present the actual experience and blue plain line represent the interactive experience with simmit

learning experience of theoretical concepts. Python language is a general-purpose, high-level programming language [**?**]. It is widely utilized in the scientific community, notably thanks to scientific packages such as Numpy and Scipy. Moreover, the integration of numerical tools in interactive notebooks has been possible using IPython notebooks since, as an interactive computational environment, they combine code execution, rich text, mathematics, plots and integration of other media. Thus, to propose an interactive learning of Mechanics of Materials using Python blocks in notebooks, the *simmit* library has been developed to expose functions commonly utilized in continuum mechanics, solid materials constitutive relations, non-linear response of materials, physical strain mechanisms, and multi-scale analysis. Note that many python libraries can be utilized for data science, linear algebra, optimization and machine learning to produce a comprehensive set of numerical tools for the analysis of the mechanical behavior of Materials.

Moreover, since most of the research tools rely now on computationally efficient APIs (Application Programming Interface), a good solution is to expose some of the functions proposed in such APIs to be able to integrate them in interactive Python notebooks. In such a case, the efficiency of the original library is maintained (i.e. since it relies on robust linear algebra libraries and multithread packages). The simmit toolbox thus highly relies on a scientific library, named Smart+ [**?**] that regroups a whole set of tools for the numerical simulation of materials. Smart+ has been primarily developed to interact with FEA packages, for instance *Abaqus*, thus focusing in computational efficiency rather than ease of use. The simmit toolbox include Smart+ and Python wrappers developed to allow an easy access in interactive notebooks. As a result, such library will allow learn and use theoretical functions that are usually not accessible in efficient APIs of simulation packages. Moreover, simmit allows to interoperate with such packages, to build tailored solutions in the field of mechanics of materials, as depicted in in Figure **??**.

CONCLUSION

New methods and tools in the field on interactive learning experience are required, according to the next generation audience and societal demand. We have demonstrated that the *simmit* toolbox fulfill those requirements, being compatible with integrated tools and solutions for the analysis of a material or mechanical system, adapted to numerical simulation methods commonly utilized in industry, and can easily interact with other numerical and/or scientific libraries and analytics. It also contains all the necessary tools required for the study of mechanics of materials. The development of a full interactive course based on this tool is ongoing, and will be proposed as a massive open online course.

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