HYBRID EDUCATION CONTENT AND PLATFORM FOR BACHELOR CURRICULUM IN TECHNOLOGY AND ENGINEERING

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ABSTRACT

During coronavirus time, academic organisations and education institutions have been faced to amazing and radical changes from one day to the other of their teaching contexts, practices, materials and standards and so on. Due to pandemic, in many countries professors, teachers, educators have been obliged to switch on remote education and teaching models with numerous virtual and digital solutions that at the beginning were more or less efficient and professional based. The paper will present a experiment feedback for large hybridation of technology and engineering curriculum for bachelor degree in French higher education system. The educational content and platform has been developed by the consortium of 14 different universities and higher education institutions. In the global topics covered by the project, a specific focus will be given in the paper on subject dealing with engineering design, systems engineering and sustainanibility.

Keywords: Hybrid Learning, Product Developement, Systems Engineering (SE), Ecodesign, Design education

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1 INTRODUCTION

During the coronavirus (COVID19) pandemic time, academic organisations and educational institutions were faced overnight with amazing and radical changes needed to their teaching context, practices, materials, standards and so on. Due to the pandemic, in many countries, professors, teachers and educators have been forced to switch to remote education and teaching models with numerous information and communication technologies (ICT) and digital solutions that were at the beginning more or less efficiency. Such a situation lead by effective medical and legal decisions also gave the opportunity to empirically demonstrate and partly verify the feasibility of remote and virtual teaching as well as blended and hybrid education.

Six months into pandemic the French ministry of Higher Education launched a large call for proposal named “Hybridation des formations de l'enseignement supérieur” (meaning “Blending of Higher Education Curriculum”) linked to the “Investissement d'Avenir” program operated by the French National Agency for Research - https://anr.fr/fileadmin/aap/2020/aap-ia-ncu3-2020.pdf. The call for proposal specifically targeted the bachelor degree with no specific discipline restrictions.

The academic group S.mart (www.s-mart.fr) - a division of the French Association for Mechanical Engineering which deals with the subject of Factories of the Future and Industry 4.0 - has decided to apply for promoting its expertise for higher education. The definitive consortium was composed 14 universities and academic institutions in the field of technology and engineering education. The submitted project entitled <ET-LIOS> for Open Technology and Engineering Education for Competitive and Sustainable Factories of the Future. The project was operationally led by the Université de Technologie de Compiègne. It aimed to develop and disseminate open education content under Creative Commons Licences. It was granted of 2,5 MEuros allowing the development of contents focusing on technological and engineering training based digital network infrastructures for the virtualization of software solutions and the host of the developed teaching content.

Globally, the paper focuses on the presentation of the challenges and issues for blended education. It also details a part of the developed contents dealing with engineering design and sustainability. The obtained results and potential changes for teaching models are also discussed.

The paper is structured as followed. After a brief research review on the models and practices of blended and hybrid teaching, the detailed presentation of <ET-LIOS> project will be done. Then the specific topics of design, simulation and prototyping based on Computer-Aided x / Product Lifecycle Management (CAx/PLM) systems; then systems engineering and Model-Based Systems Engineering (MBSE); and sustainability will be detailed. Various teaching experiments based on hybrid or non educational model will be explained. Lastly, the main results of <ET-LIOS> project will be discussed regarding the challenges for better students' progress in their skills and know-how acquisition for their future practitioner position.

2 RESEARCH AND EDUCATION REVIEW

In the mid-90's, Kozma (1994) opened the debate of internet as a new support for teaching and discussed the impact and influence of media in education and learning. In the early 2000s, the remote and virtual education grew in order to take advantage of ICT in the improvement of learning and teaching. McCray (2000) underlined the interest of ICT in online courses and argued for the added value of merging online instructions and traditional classroom. Osguthorpe and Graham (2003) defined the basis of blended learning environments and detailed future directions for such kinds of education models. Frazee (2003) discussed the dynamic of virtual and online classroom for the assessment of student learning.

In an Organisation for Economic Co-operation and Development (OECD) working report, Zitter and Hoeve (2012) defined the preliminary architecture for the development of hybrid learning environments. Graham (2013) proposed the assessment of emerging practises in blended teaching and learning.

Halverson et al. (2014) presented the result of a review on the first decade of blended education with online and remote courses. Helms (2014) proposed a second review in the field including some advice and recommendations for professors and teachers.

Linder (2017) structured the necessary teaching models and fundamentals for blended education based on new generations of ICT and on the growing use of massive open online courses (MOOC). Hall-

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Rivera (2017) analysed the required technology including new digital and virtual collaborative solutions.
Of course, during the COVID19 pandemic, the urgent need to use in remote education of digital platforms and virtual meeting solutions have been largely implemented and operated (Gopal et al., 2021; Anushalalitha, 2023). Therefore numerous real experiments took place for many universities and academic institutions with several kinds of success because teaching should be delivered. However, this also led to numerous limits for knowledge acquisition and learning of students and effective practises in technological field (Rassudov and Korunets, 2020). Such a reality also drives to a definitive change of the educational and teaching strategies but also on the operational issues of learning (McCormack and Caldwell, 2022).
Then after the large experiments during the full pandemic time, the educational question on how to improve the hybrid or blended teaching models and practices is open? As now we are back on standard teaching context this provides additional question what future plans for knowledge acquisition and learning of students based on hybrid education?

3 DETAILED PRESENTATION OF THE <ET-LIOS> PROJECT

As above mentioned the <ET-LIOS> project was led by the Université de Technologie de Compiègne on behalf the French academic group S.mart (formerly AIP-PRIMECA). S.mart federates more than 80 universities, faculties and internal academic departments as well as public or private engineering schools with the ambition of bringing the topics around Factories of the Future and Industrie 4.0 to the academic level in education, research, innovation and know-how transfer. S.mart is structured around 10 regional centres administratively hosted by a university or engineering school and associated institutions whose purpose is to pool educational or scientific expertise, technological platforms and software resources in support of higher education training objectives (bachelor, master and PhD degrees, etc.). From 2012 till 2020 S.mart was represented by the Université de Technologie de Compiègne as a legal person (according to the legal statutes of the S.mart in force).
As part of the proposed project, the ambition is to pool the experiments acquired in the various S.mart centres, French universities and academic institutions during the COVID19 period in terms of distance learning and continuity of training in the technological and scientific fields, in particular for subjects like Factories of the Future and Industry 4.0 such as:

- 3D Design-Simulation-Prototyping;
- Advanced Manufacturing and Metrology;
- Cyber-Physical Production Systems and e-Maintenance;
- Digital Twin and Virtual Commissioning of Automated Production Systems;
- Smart Systems Engineering and Multi-Disciplinary Modelling;
- Sustainable and Responsible Design.

The strong culture of pooling resources and sharing experience leads the community, under the leadership of general management team of S.mart, to frequently organize thematic training and dissemination days and more recently, especially during the pandemic time, to publicize the skills developed on many subjects through the holding of webinars (accessible on S.mart's website).
The objectives of the <ET-LIOS> project aimed at providing educational resources and platforms adapted to a hybridization of scientific and technological teaching or even, if the evolution of the health situation justified it, a complete remote switchover. The specificity of technological teaching and access to industrial machines and equipment made this issue even more crucial and impacting in order to preserve the teaching time that we considered essential on technological resources while ensuring the times of initiation, preparation and restitution on remote mode.
The <ET-LIOS> project was structured around two major sub-projects. The first dealt with the implementation of ICT based infrastructures for the virtualization of shared software resources supported and administered by the regional centers. The second focused on the development of teaching modules which, for their production, call on the expertise and experimentation of members of the S.mart community. The passage of proofs of concept (from the COVID19 pandemic time or having benefited from previous projects developed within S.mart) on a larger educational scale that can be used by the entire educational community and S.mart experts requires extra developments and to give robustness to the contents, changes and ports of the teaching supports.

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Regarding all subjects developed within <ET-LIOS> project, the teaching modules proposed on 3D Design-Simulation-Prototyping, Smart Systems Engineering and Multidisciplinary Modelling, and Sustainable and Responsible Design are certainly of main interest to be highlighted in the paper. So they are presented in the following sections.

3.1 3D Design-Simulation-Prototyping

Designing an industrializable, innovative and environmentally friendly product remains an iterative process that mobilizes many methods and techniques, from (reverse) designing, engineering and prototyping. Even if the community of component designer-integrators has long believed and advocated that engineering (structural analysis) would always have the leadership over "design" (layout of shapes and contours), the new topological optimization technologies for additive manufacturing, where the number of usable materials increases considerably, suggests a completely different approach where the structure becomes the main or even an exclusive component of the design. The new shapes generated by the constraints of optimized topology (here we tend to use just the necessary quantity of materials) can also bring a style sought by the customer.

In a context of digital thread and additive manufacturing (Pei et al., 2019), design and simulation software vendors offer all-in-one solutions where the chaining of modules tends towards the automation of tasks. Manufacturers, particularly in the field of mechanical engineering, are also following a trend that makes teams from design and calculation validation offices work together very early in the product design process. This approach is facilitated by a generalization of the virtualization of proofs of concept and prototypes, and their certification with a perspective of Factories of the Future and Industry 4.0.

The hybridization of the teaching of this concurrent engineering approach (Feilding et al., 2014), of the 3D design-simulation-prototyping chain seems quite appropriate and presents a real opportunity to put the undergraduate learner very early in this industrial approach. However, this hybridization faces several obstacles:

- Remote access to these collaborative softwares requires ad-hoc ICT platforms and network.
- The digital thread is too complex to set up in its entirety for undergraduate students and requires specific pedagogical developments to put the requested activity into practice.
- 3D printing of prototypes by students is very time-consuming and access to printing equipment is not organized for remote use.

3.2 Smart Systems Engineering and Multi-Disciplinary Modelling

In the context of the designing of connected, monitored, controlled and adaptive things, the engineer integrates structural, sensory and motor functions linked by intelligence. The design and production of these complex, light and resistant components, endowed with intelligence, capable of carrying out measurements and activating movements or adaptations of their behaviour, requires the implementation of new skills.

Training in the specialities of smart materials and structures, mechatronic and robotic systems, but also more general in scientific and technological training now includes training modules in multi-domain and multi-disciplinary design (Zheng et al., 2019). The ambition of these courses is to develop the student skills to:

- Clarify and/or design the architecture of a multifunctional structure through system engineering.
- Design, with a final perspective of integration, the mechanical, electronic and digital functions.
- Analysis and simulate said functions in an environment allowing strong couplings between disciplines.
- Manufacture prototypes of intelligent and/or adaptive components or systems which integrate their structural, sensory and motor functions.

3.3 Sustainable and Responsible Design

The challenge of this module is to allow the appropriation of the stakes and the systemic modelling of the interactions Man, Technologies and Nature according to several spatio-temporal scales. These models will help companies reduce or, at the very least, respect planetary limits in the design of socio-technical systems while avoiding rebound effects.

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It is therefore a question of allowing learners to:

- Know how natural cycles work (water, carbon, biodiversity, etc.)
- Represent and model the Technology-Human interaction (diagrams of physical and physiological influences (function, choice, etc.); Analysis of the social life cycle, donut theory, etc.)
- Represent and model the Technology – Nature interaction (material flow analysis, life cycle assessment, planetary boundaries, etc.)
- Represent and model the Man-Nature interaction (needs, functions, vital connection, etc. from the individual to the community)

The proposed module is composed of six educational building-blocks according to an already made survey on the French degrees in technology and engineering (Perpignan et al., 2020):

- Issues associated with climate change (example: climate fresco, etc.)
- Issues related to biodiversity (example: fresco of biodiversity, etc.)
- Problems associated with resources (example: Game on the consumption of abiotic resource, etc.)
- Human and health impacts (based on Henderson's needs model)
- Consideration of planetary boundaries (Model of planetary boundaries, Donut theory in relation to social justice => sustainability indicators to assess, design, ...)
- Links between evolutions of technologies and earth system (examples of historical analysis of co-evolution technology (technical and society) / system (physico-biological) earth...)

4 MAIN RESULTS OF THE PROJECT

The project ran for two years and ended when the pandemic period more or less disappeared. Then the technological teaching contents and engineering modules developed during the project were delivered for hybrid learning but the educational context changed. Of course, the added-value of hybridization is kept for specific sessions such in pre-processing of physical classroom (clarifying teaching objectives, statement of learning issues and instructions for the physical lectures) or in post-processing (collaborative debriefing via chat session or video providing final and effective answers to practical lecture allowing students to understand their learning mismatch and errors).

The main results and feedback of the <ET-LIOS> project on the three above-mentioned teaching modules are detailed below.

4.1 Results on the module dealing with 3D Design-Simulation-Prototyping

In this module, according to initial aims, the following results were achieved:

- Ensuring that each design case studies supporting lecture leads to prototyping work and not only to the conceptual or embodiment stage of engineering design;
- Systematically providing a virtual/real comparison in the learning practices and know-how;
- Offering a learning process which includes to trial and error, and an appropriate progress/sequencing thanks to remote learning and hybrid principles;
- Taking into account the initial knowledge and the learning progression of students.

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Figure 1. Street scooter details

One of the experimented case study focused on the design, simulation and prototyping of a scooter (Figure 1): the design work was developed in Dassault Systèmes' 3D Experience software; the simulation work was run with ANSYS and ALTAIR HyperWorks; and the prototyping was processed with Metal Additive Manufacturing. Such learning experiments were led alongside 100 bachelor degree seniors and master degree freshmen. The lecture duration was about 40 hours distributed with 16, 16 and 12 hours respectfully distributed among design, simulation and prototyping. The students group were sized up to 20 students for CAD (Computer-Aided Design), CAE (Computer-Aided Engineering) and PLM work. For the prototyping work, smaller groups were made composed of 10 students regarding the technical constraints and standards of manufacturing workshop.
The main feedback to be mentioned are first the positive use of short videos to explain the lecture's objectives and teaching aims. Second, the tutorial developed to train students and explain to them the main features of the design and engineering softwares. Of course the teachers interaction with their student during the use of the software is never the less unquestionable? After 8 hours of learning the CAD basics, students become autonomous, run the working sessions by themselves to follow step-by-step tutorials and progress by their own means till the next session with a professor takes place.

4.2 Results on the module dealing with Smart Systems Engineering and Multi-Disciplinary Modelling

The training on Smart Systems Engineering and Multi-Disciplinary Modelling mainly focused on the following educational aims:

- Design and engineering the multifunctional architecture of a smart system using a system engineering approach and MBSE principles including SysML (Systems Modelling Language) diagrams;
- Design, with a final integration perspective, the mechanical, electrical, electronic and software functions;
- Model and simulate the above-mentioned functions in an environment allowing strong integration and coupling between disciplines;
- Assemble prototypes of smart and adaptive components or systems integrating their structural body, sensory and actuating functions.

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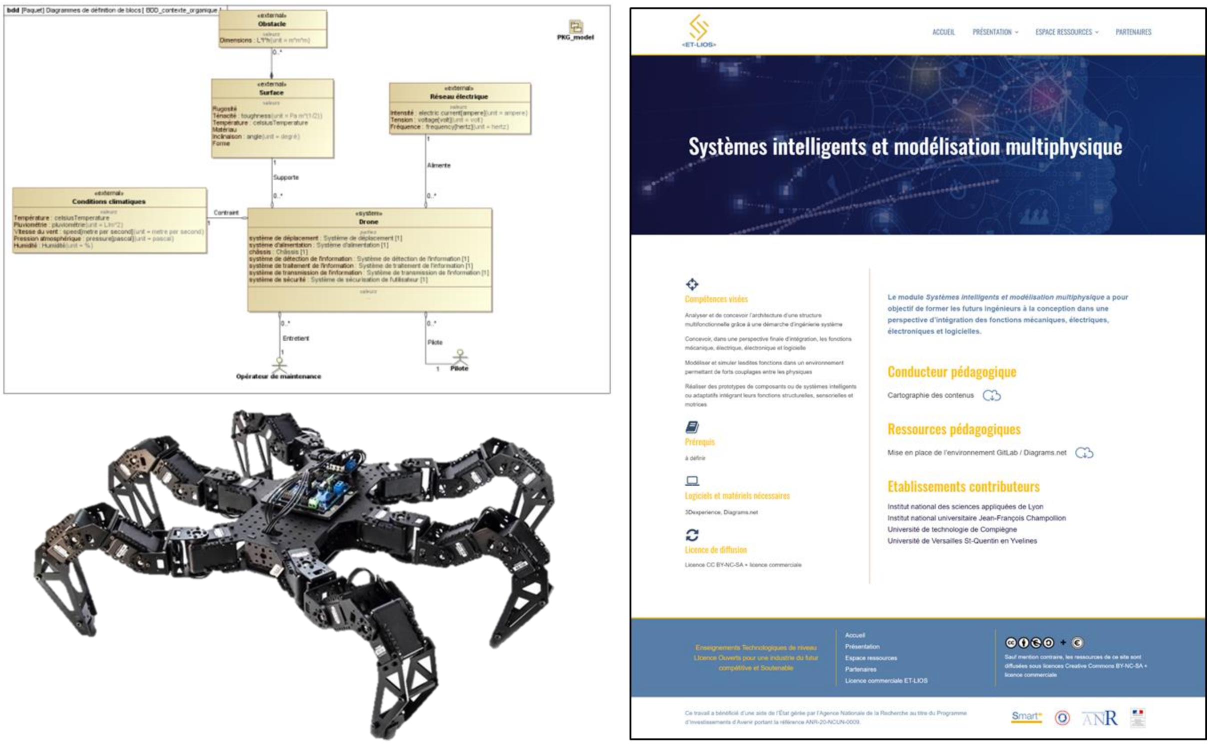

Figure 2. Spider drone case study for the smart systems engineering

The spider drone case study (Figure 2) allows to highlight all steps of the V model stage from the requirements engineering to detailed design of each functions dealing with mechanical, electrical, electronic and software sub-systems or parts. The steps of verification, validation and qualification were mainly supported by multi-disciplinary modelling and simulation. The teaching experiments were led with 40 master's degree freshmen, lasted 100 hours and included half of the time in autonomous work to design the spider drone. This design work was preceded with lessons to the preliminary practice of requirements engineering and the detailed design of system's architecture with Block Definition Diagrams and Internal Block Diagrams. The spider drone programming and testing lectures were given under the supervision of professors. The conceptual perspective of systems engineering is still difficult to grasp for students even though if tutorial and diagram examples were available. The positive aspect was the practice and experiment sessions with the spider drone.

4.3 Results on the module dealing with Sustainable and Responsible Design

For the module dealing with Sustainable and Responsible Design, the main aims were:

- Enabling the dissemination of sustainability issues in higher education for teachers and students (bachelor's and master's level): Proposal for a specific and integrated program based on sustainability skills;
- Developing the educational content of the platform and ensure its maintenance;
- Ensuring the development of a network for content contributors and co-learning, addressed with the creation of a common and shared educational database.

The teaching content developments for sustainable and responsible engineering (Figure 3) were structured in 14 videos and about 30 sub-modules for student to learn according to targeted macro-competencies on: systems thinking, lifecycle engineering, earth limit, climate change, sustainable design, ethics and social responsibility. Professors from 10 different universities and academic institutions have been trained to allow for a larger amount of students to be trained and a comparison of their progress regarding common views and conceptual frameworks. This approach enabled a training experiment composed of more than 200 students from each year of the bachelor’s degree but also first year master’s providing a large number of feedback. No specific background was required to follow the proposed module. Students were strongly enthusiastic regarding the important subject which is sustainability development. But the practical work for student needs to be improved according on serious game or project-based learning approaches.

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Figure 3. Development of teaching content for sustainable and responsible design

5 CONCLUSION AND FUTURE WORK

The <ET-LIOS> project has involved around 100 professors and lecturers from 14 different French universities and academic institutions. Six teaching modules were developed in numerous topics dealing with Factories of the Future and Industry 4.0. The paper has only summarized the results obtained in 3 modules dealing with: 3D Design-Simulation-Prototyping, Smart Systems Engineering and Multidisciplinary, and Sustainable and Responsible Engineering. The original aim to provide a hybrid learning model in the COVID19 pandemic context has finally evolved into a set of physical classrooms, autonomous learning, practical work to prototype a scooter, to program and test smart systems, and some serious games in sustainable design to learn by doing. A large number of students from all levels of the bachelor's degree and also first year of master's were trained. Provided feedback have helped to plan improvements of the developed modules.

For future work, the next series of experiments will have to be performed on a larger number of student basis. The dissemination of the teaching contents and all the educational supports should be enlarged to all universities and academic institutions candidates. Currently, the modules which deals with systems engineering and sustainable design are available in English. A collaborative, shared and contributively model like wikipedia should be defined for proactive educational developments of additional teaching contents, new case studies, etc.

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