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Feedback on a cross-curricular health technology teaching for undergraduate students at the Bordeaux Institute of Technology

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Abstract: This paper introduces a new cross-disciplinary curriculum teaching in Health Technology (HT) for undergraduate students involved in five different disciplines, which are computer sciences, materials engineering, mechanics, electronics, and applied physics. The major insight is based on the integration of University Degrees (UDs) to educational programs of Bordeaux Institute of Technology (BIT) to empower students to customize their educational paths based on their individual projects and interests. To the best of authors knowledge, such personalized pathway opening up learning practices and breaking down preconceived stereotypes is unique in a French institute of technology. Focusing on the UD dedicated to HT, the new cross-curricular syllabus is introduced. Highlights are *i*) a project-based learning to promote student success and the development of soft and hard skills, and *ii*) the establishment of a partnership to bring together healthcare professionals and local authorities on identified needs in HT. Students' feedback, lessons learnt and on-going discussions finally conclude the paper.

Keywords: Engineering Education, Undergraduate Students, Project-Based Learning, Collaborative learning, Teaching curricula developments for control and other engineers.

1. INTRODUCTION

The president of the French institutes of technology, Martin Martial, made a strong statement in *Le Monde* on March 19; 2024: "We cannot pursue the reindustrialization without strong technological education". This announcement was based in part on a report by the so-called *Direction de l'Animation de la Recherche, des Études et des Statistiques* – which is the French research, studies and statistics direction –- in 2023, which highlighted that the number of open industrial jobs had tripled between 2017 and 2022, reaching around 60,000. If there are several alternatives for remedying this situation, one of them is to tailor students' training pathways to the right level of qualification and to focus on the jobs that have been identified as being in demand. To fulfill our role in French society, Bordeaux Institute of Technology (BIT) is innovating by adding University Degrees (UDs) to its range of educational programs, to train the new generation of technicians and intermediate technical managers capable of working at the interface between operators and engineers.

From the first two years of higher education, the initiative at BIT aims to raise students' awareness of major societal issues in order to anticipate the needs of the regional and national industrial sector (SMEs, ETIs, etc.). This initiative uses the levers of the University of Bordeaux's institutional projects, such as the NewDEAL program for experimenting with inclusive and open pathways. NewDEAL has been proposed in response to the call for projects "New Curricula at the University (NCU)", funded by the French future investment program (PIA). These resources are intended to allow the university to transform itself to improve the academic and educational success of first-cycle students. To achieve this ambition, NewDEAL is based on three pillars: *i*) the creation of open, flexible, and diversified courses in terms of content, formats, and pace; *ii*) the implementation of programs connected to the world of research, socio-economic, industrial, and associative spheres; and *iii*) autonomous students who are actors in their own success. By integrating such objectives into its educational offerings, BIT seeks to address the challenges and opportunities identified by the university's strategic plan and contribute to the broader goals of regional economic development and job creation. In this context, the Activities of Opening and Personalization (AOP) proposed at BIT are proposed to empower students to customize their educational paths based on their individual projects and interests.

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Among the societal issues targeted at BIT, there is a UD program dedicated to health technologies (HT). This initiative is supported by a pedagogical team comprised of lecturers with established research expertise in health and biomedical engineering fields. These include blood glucose regulation (Olçomendy *et al*., 2022, Franco *et al*. 2021), smart sensors for environmental and medical applications (Hallil & Heidari, 2020*)*, air quality monitoring sensor design (Ngoune *et al*., 2024), neuromorphic-based neuroprostheses (Beaubois *et al*., 2024, Chiappalone *et al.*, 2022), fluid mechanics of cardiovascular system (Drochon *et al*., 2022), remote control of respiratory neural network (Le Gal *et al*., 2014), virtual reality for immersive learning (Ristor *et al*., 2023) and artificial intelligence for emergency medicine (Chenais *et al*., 2023) to name a few. To address the evolving skill needs, the UD in HT is enhancing its curriculum by integrating insights from healthcare professionals. As part of this initiative, BIT has entered into an agreement with the University Hospital Center (CHU) of Bordeaux, allowing students to carry out practical work session related to medical device (MD) maintenance within a hospital environment.

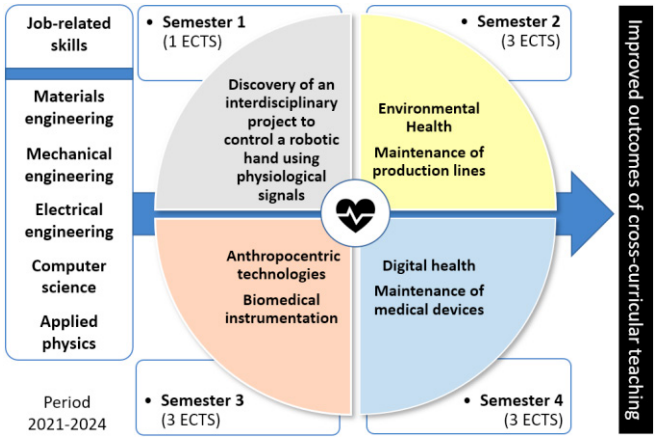

Fig. 1. Outline sketch of the cross-curricular teaching module

This cross-disciplinary approach to HT education is open to students from various technical disciplines, including computer sciences, materials, mechanics, electronics and applied physics. The curriculum emphasizes the development of soft skills alongside technical expertise. The teaching module, as described in Fig. 1, is designed to respond to environmental challenges, shift towards preventative healthcare, and support societal transitions associated with chronic diseases and increased life expectancy. The UD program in HT focuses on four main themes:

i) Anthropocentric technologies. This theme prioritizes ergonomics in innovation, including the study of exoskeletons and the augmented human capabilities to mitigate strenuous work and monitor worker health;
ii) Digital health. The module explores digital solutions such as simulators that reproduce the physiological behavior of patients with various pathologies. It emphasizes the creation of digital platforms, like virtual reality for emergency medicine, to test the efficacy of technological solutions and accelerate innovation;
iii) Environmental health. The curriculum emphasizes the development of smart technologies for real-time monitoring of pollutants in the air. Additionally, these devices are also discussed to introduce their use for diagnosing and monitoring other non-communicable diseases resulting from these effects, among others. This approach, which promotes sustainable development, contributes to improve public health.
iv) System maintenance. The module covers preventive and corrective maintenance of biomedical equipment and automated production line. With the rise of intelligent technologies, technicians need to be equipped with skills for maintenance, enhancing production efficiency, and suggesting improvements to the production process.

The paper is organised as follows. Section 2 introduces the organization of the cross-curricular module. Section 3 provides expected skills and discusses of secondary benefit. Section 4 presents student feedback and lessons learned.

2. ORGANISATION AND LEARNING STYLES

This teaching module aims to maintain a learning-by-doing approach to promote student success and well-being. The four following subsections will introduce the topic, timeline and learning styles of each semester in a project-oriented way.

2.1 Semester 1: Robotic hand control with physiological signal

After highlighting the need of health technology, the module initiates practical learning by providing students with an Arduino starter kit. This allows them to develop basic coding skills necessary for the project. In addition, two sessions are dedicated to acquiring electrical signals from an electromyogram (EMG) sensor. Concurrently, students attend computer-aided design (CAD) classes to model the fingers of the robotic hand. These models are then produced at BIT's Coh@bit platform (https://cohabit.fr) using additive technologies. Finally, all solutions are integrated during a Hackathon. The syllabus of semester 1 (1 ECTS) is as follows:

i) Introduction: context and issues in HT (1-hour lecture)
ii) Coding using the Arduino starter kit (5 hours)
iii) Modeling fingers of the robotic hand by using CATIA, *i.e.* a CAD software for 3D modelling (3 sessions of 2 hours)
iv) Integrating biomedical measurement in an Arduino code (2 sessions of 2 hours each)
v) Production of fingers using a laser cutter at BIT's Coh@bit platform (2 hours)
vi) Integration of previous results during 10-hours Hackathon to present personalized functional solutions (10 hours)

Additionally, students explore the use of physiological signals to control the robotic hand, further enhancing their understanding of biomedical engineering concepts.

2.2 Semester 2: Transitioning from design to production of health environmental monitoring boxes

The objective of this teaching unit (3 ECTS) is to train students from various departments of the BIT, to the use of sensors and their instrumentation, as well as data acquisition for measuring parameters influencing environmental health. Additionally, the concepts of industrial automation and mechanical design of packaging boxes for the developed systems are introduced. This is distributed as follows:

i) Tutorials on transducers and acquisition system (12 hours);
ii) Hands-on projects and personalized projects on sensor

manipulation for measuring parameters such as CO_2, temperature, and volatile organic compounds (20 hours);
iii) For students engaged in electronics and industrial computing diploma, lectures and practical work on a CAD software (CATIA) in order to design the packaging boxes integrating smart sensors for monitoring (18 hours);
iv) For students engaged in computer sciences, materials, mechanics and applied physics diplomas, lectures, tutorials and practical work on automation. Focus is put on sequential function chart (SFC) language by using STEP 7 (TIA-Portal) software, SIEMENS (18 hours);
v) Production of boxes using additive technology (3D printer) at BIT's Coh@bit platform (4 hours)
vi) Hackathon: This challenge involves dividing students into competing teams (3 students / group) to propose an original solution for environmental parameter monitoring in the context of environmental health. (10 hours).

It can be noticed that the differentiated learning in iii) and iv) comes from already mastered skill in automation, for students engaged in electronics and industrial computing diploma. Such organization enables an extra cross-disciplinary skill to be developed, *i.e* CAD skills for students engaged in electronics, and automation ones for others. Finally, this innovative teaching is also punctuated by participation in some local events to enhance cross-curricular students' skills, *e.g* a) the NeuroTruck initiative proposed by the health science college of University of Bordeaux, providing students with hands-on experience on MDs, and b) cross-disciplinary workshops organized by BIT and other colleges (political science, etc.) addressing societal issues, *e.g*. energy, agronomy, HT, etc.

2.3 Semester 3: Design of an embedded device to highlight the benefits of a medical device (the exoskeleton)

This module (3 ECTS) focuses on the benefit of health innovations, especially the ones dedicated on anthropocentric solutions. After an introduction of passive commercial exoskeletons by a healthcare professional, a basic teaching of human physiology is delivered, with discussions to promote ergonomics of medical device. Expected outcome of this semester consists of developing a portable device bringing together physiological information such as electrocardiogram (ECG), EMG and blood oxygen saturation (SO2). This system will make it possible to compare this physiological information depending on the use (or not) of an exoskeleton. The syllabus of semester 3 is as follows:
i) Introduction of commercial exoskeletons by a healthcare professional: market and ethics issues (4 hours);
ii) Lectures of human electrophysiology (10 hours);
iii) Mechanical kinetics of passive exoskeleton device, with 3D modelling in CATIA software (14 hours);
iv) Ergonomics for exoskeleton context (4 hours);
v) Testing and implementing ECG, EMG and SO2 sensors. Design of custom-made ECG sensors. (14 hours)
vi) Integration in an embedded portable device (14 hours)

In addition, students have to visit the facilities of a private hospital (GBNA Health center) for a full immersion in the job of a biomedical technician.

2.4 Semester 4: From digital health to medical devices

To bridge the gap between coding skills and expected ones for MD maintenance, the module (3 ECTS) involves a learning for repairing MDs. Next, these MDs are imported into a virtual reality (VR) environment for digital health training. After an introduction of emergency medicine service by a health practitioner, students follow a module whose main aim is to develop a VR application simulating the sedation of a patient. Core digital elements come from the benchmark introduced in (Ionescu *et al.*, 2021). The module opens with an introduction to the Unity3d framework and basics of programming for VR. Each of following sessions of 4 hours is devoted to one key point of the application separately. The communication with the real external simulator is finally established and all developed parts are glued together. Students can polish their application in a final unsupervised session. To highlight cross-disciplinary benefit, notions of fluid mechanics in relation with the injection-perfusion protocol are given and the students have to carry out a practical work session in the maintenance department of the CHU of Bordeaux, to maintain the operational efficiency of MDs (syringe pump, etc.). It is organized as follows:

i) Introduction of emergency medicine issues (3 hours);
ii) Tutorials and hands-on project on VR following this organization: platform development introduction, handling the interaction with the infusion pump, drawing ECG and bispectral index (BIS) on a screen, sending inputs to a faked embedded server and receiving its outputs, communicating to the real external server which computes the BIS of patient in response to drug infusion. (32 hours);
iii) Lectures and tutorials in fluid mechanics (10 hours)
iv) Practical session of MD maintenance (syringe pump, etc.) at CHU of Bordeaux (6 hours)
v) Oral presentation on a biomedical device to study technological, ethical and regulatory aspects (10 hours).

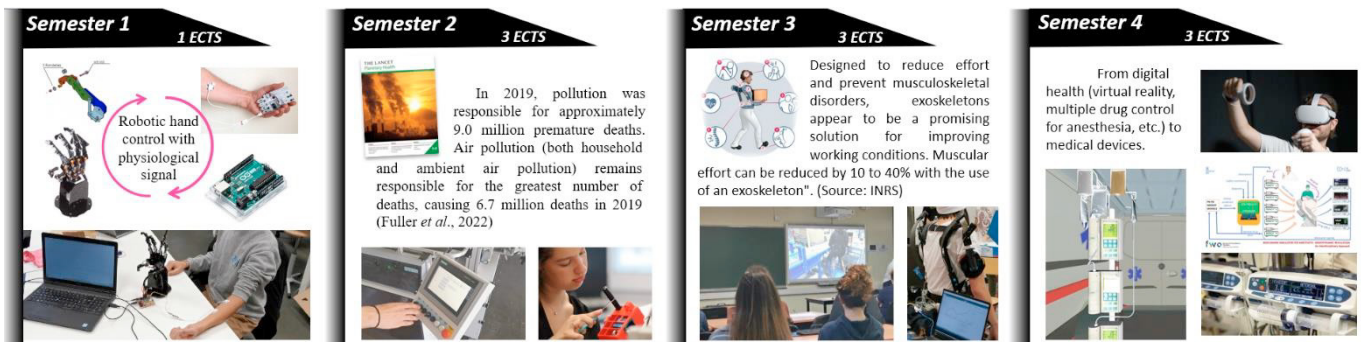

Fig. 2 : Highlights of baseline tools and some realization with respect to the time-line of this cross-curricular module.

Remark: It is assumed that students do not have any experience in developing any 3D environment. The module has emphasis on quickly acquiring programming competences, that are not restricted to the studied case.

3. ASSESSMENT

In this cross-curricular initiative, there is an alignment between teaching activities, learning outcomes and student assessment. Both skills and knowledge are assessed. Individual written exam account for 40%, followed by evaluation of written reports during practical work (30%) and hands-on project with deliverables (30%) made as a group.

3.1 Expected skills

Based on the cross-curricular organization and learning styles, expected skills combine soft and hard skills. Hard skills are known as technical abilities which are relevant to the job for which you are applying, *e.g.* a mechatronics technician must be able to design a mechanical piece in 3D by using a CAD software. Soft skills are the ones that enable you to provide an added value in the workplace. After completion of the UD in HT, the students improve their skill levels on:

Semester 1, 2 skills
- *Hard-skill 1.1:* Design and build hands-on robotic systems driven by biomedical measures with electronics, mechanics and basic computer coding;
- *Soft-Skill 1.2:* Team-building. Working as part of a team with students from different backgrounds to enhance collaborative skills, crucial in cross-disciplinary field.

Semester 2, 4 skills
- *Hard-skill 2.1:* Study a problem as an overall environmental health issue, *i.e.* identifying suitable sensors, acquiring signals and coding electronics card to monitor precursor parameters;
- *Hard-skill 2.2:* Design appropriate 3D boxes with a CAD software, choosing the right scale to integrate all necessary sensors for targeted environmental health problem;
- *Hard-skill 2.3:* Develop the code to control a Programmable Logic Controller (PLC) using a simple language and check its action on a processing unit;
- *Soft-skill 2.4:* Problem-solving. Through hands-on projects and the Hackathon, students enhance their ability to identify and solve complex problems.

Semester 3, 4 skills
- *Hard-skill 3.1:* Identify, formulate and analyze a problem in its human, ergonomic and technological dimensions;
- *Hard-skill 3.2:* Analysis and design of a mechanical part of a passive exoskeleton, under 3D CAD environment;
- *Hard-skill 3.3:* Solve a problem by means of biomedical sensor integration, test, verification and experiments;
- *Soft-skill 3.4:* Creativity. It involves the ability to think outside the standard training. Needless to say, it requires an inquisitive mindset and a willingness to address ethical and ergonomic issues in health innovations.

Semester 4, 4 skills
- *Hard-skill 4.1:* Design and integrate a 3D application with networked black box simulation, 3D models of medical device and able to handle interactions through VR;
- *Hard-skill 4.2:* Use appropriate biomechanical models and choose the relevant simplifying assumptions to deal with a tractable problem of fluid mechanics;
- *Hard-skill 4.3:* Analysis and maintenance of MDs (syringe pumps, etc.) in a regulatory and hospital context;
- *Soft-skill 4.4:* Work ethic. Through a practical session in a regulatory and clinical environment, students have to raise their level of discipline and reliability, which enhance their credibility in biomedical workplace.

3.2 Secondary benefits

Although this cross-curricular initiative does not provide a complete training for a specified job, an open mindset is observed in the final semesters. For instance, students are not confident with control theory at the end of the second year. However, students following the UD in HT showed a good aptitude to work in transfer function framework. Hence, they were capable, with a half-year in advance, to design their first single input / single output (SISO) controller by means of frequency approach during a project-based learning. Verification and discussion against human physiological variability has even enabled us to understand the concept of robustness (Cassany *et al*., 2021). UD in HT definitively helps to achieve student success.

4. ANALYSIS

This section illustrates some insights of the implementation of this AOP in HT, together with some feedback of students and colleagues. In lessons learnt subsection, some on-going discussions are introduced.

After 3 years (3 promotions, and 2 classes graduated), this cross-disciplinary initiative involves the management around 48 students (until 26 for semester 1, and 24 for other semesters) per university year, supervised by a cross-disciplinary pedagogic team of 18 professionals (teacher, teacher-researcher, CNRS researcher, healthcare professional, PhD students, non-teaching staff). Since initiative is opened for 5 diplomas with different job-related skills (see Fig. 1 and 3), around 460 students can choose the AOP in HT. From the first three years, this AOP received a great interest with 7.6%, 16.5% and 14.5% of the eligible student's which apply for semester 1 in 2021, 2022 and 2023 respectively. That represents a pressure rate (number of applications divided by number of available positions) of 1.34, 2.92 and 2.53 respectively. Highlights of HT is thus of interest for students.

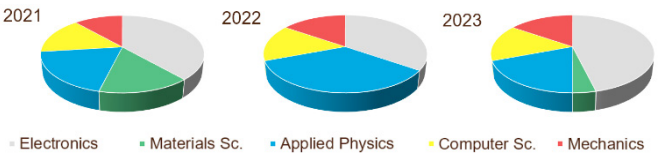

Fig. 3. Student distribution by speciality (Semester 1)

4.1 Feedback of students

For each semester, a feedback on the cross-curricular UD in HT is proposed to analyze and improve the organization, relevance and progress of the module. For instance, the Table 1 gives the results of students' assessment for the semester 4 dedicated to digital health and medical devices, see subsection

2.4 to have all details of this semester. The assessment rate has to be understood as follows: 0 = no skill has been acquired, 3 = the student has a basic understanding of a concept at a user level, 5 = the student has a perfect grasp of the problem, without needing any supervision.

Table 1. Results of students' assessment in semester 4

Semester 4	**2023**		**2024**	
Number of students: 13 in 2023, 15 in 2024	Yes	No	Yes	No
Q1. Do you already studied virtual reality?	11,10%	88,90%	27,30%	72,70%
-> Students' assessment of skill level after training	3,33		3,45	
Q2. Do you already studied fluid mechanics?	55,60%	44,40%	63,60%	36,40%
-> Students' assessment of skill level after training	3,55		2,81	
Q3. Do you already studied medical devices?	11,10%	88,90%	63,60%	36,40%
-> Students' assessment of skill level after training	3,77		3,18	
Q4. Is it of interest to be trained by healthcare professionnal?	-		**4,18**	

From Table 1, results of Q1 highlight a major aspect of the personalisation of the pathway which, in addition to having institutional recognition leading to a double degree, makes it possible to add unique skills to a student enrolled in the UD in HT, *i.e.* they enable to stand out extra skills in his or her CV compared to students enrolled in a usual pathway. According to Table 1, the hard skill 4.1 appears to be new for their training path since a mean of 80.8% of students has never studied VR.

The difference in fluid mechanics assessment over the 2 years comes from a change in the module organisation, *i.e.* the practical session on the MD at the CHU of Bordeaux in 2024 have been proposed too late compared to 2023. Hence, we are close to a standard pathway with lectures, tutorials and practical work at the end, which seems to be not compliant with students' expectations. This organisation will be corrected in 2025. With 63.6% of students having already "studied" MDs for 2024, there is here a direct impact of the NeuroTruck initiative with hands-on experience on MDs. This playful learning experiment in semester 2 captures the interest of students, but the integration of the regulatory aspects of MDs made the students aware of the need to progress in this field in order to be able to work as biomedical maintenance technician position, see the rate of 3.18 obtained in 2024.

Finally, the item Q4 was added in 2024 in response to the initial students' feedback in the "open comment area" in 2023, in which almost 80% of them stressed the importance of developing skills in collaboration with healthcare professionals. The score of 4.18 on a scale of 5 obtained in 2024 definitely supports this key message.

4.2 Lessons learnt

UD is an agile tool for promoting inter- and intra-component teaching innovations (Neurotruck initiative, cross-disciplinary workshops, etc.), *i.e.* it enables HT initiative to be structured within a higher education establishment composed of several colleges, while at the same time promoting it for the benefit of the industrial sector and local authorities. Although the integration of UDs in a personalized pathway is, to the best of authors knowledge, currently unique in a French institute of technology, it is important to remain vigilant to hold on to its long-term position. For that purpose, lessons learnt will be structured in three parts in the following, and each part will lead to on-going discussions.

Lesson 1: *Securing the position of UDs in the personalized pathway spirit*. This warning point comes from the transition between semester 1 and semester 2. The enrolment to HT activity in semester 1 is only valid for one semester, in order to allow the student to choose his or her opening 2 times in the first year. To obtain a double degree (UDs in HT and an undergraduate level degree), students have to complete the cross-curricular modules over 3 semesters. In this context of openness, such constraint is detrimental to recruitment (enrolment in semesters 2, 3 and 4) in the UD of HT. This statement is based on an average pressure rate of 1 at the semester 2 and can be explained as follows:

- To empower students to customize their educational paths, BIT has to propose several opening activities (sport, theatre, entrepreneurship, etc.) to cover the number of 4'000 students. In this context, the number of AOP module has significantly growth since 2023;
- UDs must be compatible with the schedules of 5 different degree courses. Unfortunately, this number rises to 10 when the timetables of students under apprenticeship contracts are included. With the exception of students enrolled in the electronics degree program, students under apprenticeship contracts are currently not eligible to UD to begin the program in HT;
- European (EU) label for undergraduate level degree at BIT is also a personalized training. To facilitate the deployment of cross-disciplinary initiative as UDs, students enrolled in EU label are currently not eligible to apply in UD.

On-going discussions: If a trade-off has to be found between the number of AOP and the number of students, some short-term actions for improvement should be also considered as *i*) a re-introduction of UD program to students enrolled in the 5 specialities before the end of semester 1, and *ii*) a launch of the recruitment process (for semester 2) earlier to prioritise cross-disciplinary module, rather than monodisciplinary opening activities. If we integrate the following results (15% in 2023 and 40% in 2024 of the UD class in HT has completed an internship abroad), there is a great opportunity here to open up the EU label to these students in the medium term, and contribute to reinforcing the BIT's reputation abroad.

Lesson 2: *Current profile of students who choose the UD in HT*. The students enrolled at BIT are mainly those with a general baccalaureate (more scientific), than a technological one (more practical). To be compliant with the French government's requirements, BIT needs to recruit 40% of its students from the technology branch, to encourage training at a right level of qualification, and aim for a rate of 50% of all students to enter in the job market (graduating with a professional license), as technicians and intermediate technical managers able of working at the interface between operators and engineers. If the objectives are met at BIT (43.7% in 2021-2022, 42.7% in 2022-2023 and 42.2% in 2023-2024), an analysis of the students' profile graduating from the UD in HT shows that the scientific opening seems to be more attractive to students with a scientific profile, than those with a technical one (see Fig. 4).

On-going discussions: We intend to put more focus on project-based learning when the UD program in HT will be introduced, in order to better emphasize a continuity in learning methods with technological baccalaureate. The aim is to guarantee students' success. In addition, the idea of opening up to Master

and research for the most outstanding profiles could provide further perspectives for the mid-term.

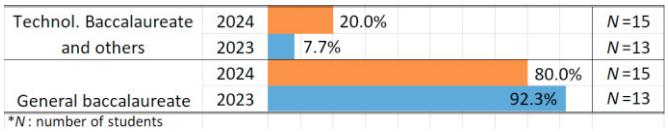

Fig. 4. Distribution of student profile enrolled in the UD of HT

Lesson 3: *Local and regional positioning of the HT action*. The Nouvelle-Aquitaine region is the largest in France. It extends over 84,000 km2 and has a population of over 6 million. By reaching out to healthcare professionals for the UD in HT, they alerted the BIT to the need of a training program in the region, with respect to hard and soft skills related to the job of biomedical technician. So, there is a real opportunity here to develop a new educational initiative that will promote the BIT's reputation, while at the same time fulfilling its role as a higher education establishment for industry and territorial authorities need.

On-going discussions: We currently intend to capture the expected hard and soft skills from healthcare professional. Next step will be the design of a new syllabus to reach expected skills. From this syllabus, a study will be made to define a sustainable economic model, including lifelong learning by proposing a training module for professionals who need to upgrade their skills due to the new technologies involved in MDs. Frankly speaking, BIT works to meet challenges of environmental (maintenance of MDs to extend sustainability) and societal (new training program for a job identified as being in demand in 2030) transitions.

5. CONCLUSION

This paper highlighted the new cross-curricular syllabus in Health Technology (HT) for undergraduate students enrolled at the BIT. If national curriculars of French Institutes of Technology have be thought for suitable development of job-related skills, integration of UDs inside educational programs give the possibility to have extra skills, centered on the students' individual projects and interests. It is an original training offer which seems to be useful to be more agile and anticipate the skill needs in the world of tomorrow.

Expected future work will come to well capture the need of healthcare professionals on the maintenance issue of medical devices in order to open discussion for the creation of a new sustainable curricular learning, which can be also open for lifelong training manifold.

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