WORK-BASED LEARNING MODELS IN FRENCH ENGINEERING CURRICULA

Siegfried Rouvrais[1], Bernard Remaud[2], and Morgan Saveuse[3]

1. IMT Atlantique, Télécom Bretagne School of engineering, France
2. Consultant on Higher Education, France
3. CESI Group, eXia School of Computer Science, France

ABSTRACT

In the 90s, the French engineering education accreditation body introduced in its quality standards a compulsory internship period. Based on this national experience, this paper presents an in-depth background and description of the use of internships and apprenticeships models in French engineering education. The elements of analysis presented may provide some inputs to programme designers in other contexts. Thus, this paper proposes to extend the CDIO framework to systematically include Work-based Learning as integrated activities in educational programme, to better match industry requirements and student competency expectations as future engineers.

KEYWORDS

Work-based learning, Work-integrated learning, Internship, Apprenticeship, Curriculum Design, Integrating Skills, Industry partnerships, CDIO Standards 1, 3, 5, 6, 7, and 8.

INTRODUCTION

From 2012 to 2015, the European Ministers of the European Higher Education Area (EHEA) gave as a priority for working “to improve employability, learning throughout life, the ability to problem solving, entrepreneurial skills, through enhanced cooperation with employers, especially for the development of training programs” [EU Bucharest Communiqué, 2012]. This formal recommendation applies to all Higher Educational Institutions (HEI) and fields and it has a special resonance for the training of engineers. Even more, Work-Based Learnings (WBL) are strongly supported in the EHEA for the period 2011-2020. The ministries in charge of Higher Education (HE) considered WBL as major tools to meeting the twin goals of improving individuals' employability and increasing economic competitiveness [EU Bruges Communiqué, 2011]. Although there is now in European HE a global agreement on these orientations and on the underlying competence approach, their concrete implementation -even in 2016- is highly variable depending on the countries and the institutions [Remaud, 2013]. In particular, because they sometimes conflict with the view of university professors on their missions. In the formal academic environment, it is acknowledged that the tension between real-practice skills and engineering disciplinary knowledge is hard to manage in curricula [Rouvrais, 2012]. Competences are context-dependent and should be developed in a technical environment, especially for future engineers. In traditional in-school engineering programmes, where integrated curricula supported by project-based learning methods (PjBL) may exist, industry partnerships are often in place, which may result in various intra- and extra-curricular activities, e.g. sponsoring of student activities, forums and seminars, lending equipment, teaching by company representatives, and particularly, internships in companies as part of the school curriculum. WBL relates to several models. Internships in research labs of the academic institution or capstone PjBL experiences with industrial partners are some examples, as analysed in [Einarson, 2016] with learning outcomes and assessment alignment.

In this regard of WBL integration, the French experience appears as peculiar, as linked with the -80 years-old- organisation of engineering studies. In 1934, the French Law tasked the national engineering accreditation body (CTI - *Commission des Titres d'Ingénieur*) with assessing the programmes of engineering education[1]. The "*titre d'ingénieur diplômé*" (a Master's degree in Engineering Science) is then awarded to students by the institutions accredited by CTI. CTI's board membership comprises 50% of employers and professional engineers' representatives and 50% of academia. It has a wide autonomy -without governmental interference- to define new standards and to enforce them in HE. From the CTI origins, French HE have been rather sensitive to the cooperation of employers and academia as a key factor for the training of engineers. But during the last three decades, many relationships have been developed between graduate engineering schools and companies, aiming at adapting the programmes to the needs of the job market. In the 90s, CTI introduced in its accreditation standards a compulsory internship period for all engineering programmes. Nowadays, a student cannot graduate if he/she has not validated his/her internship. At the time of writing, an internship in French engineering education, as a semester in a company during the curriculum, is valued between 24 credits to 30 ECTS (European Credit Transfer System).

French engineering education mainly relies on two WBL models: regular higher engineering education (HEE) at Master level and vocational education and training for engineers (VETE). In such a context, the focus of this paper is to recall the two main models of internship (HE-based) and apprenticeship (VET-based) in French engineering education in line with the CDIO framework reference models [Crawley et al., 2014]. The elements of analysis presented in the paper may thus provide some inputs to international CDIO collaborators or newcomers investigating to include WBL as integrated activities in their programmes so as to better bridge some gaps with industry requirements and CDIO skills. This analysis also provides some rationale to better meet intended outcomes for students. From then, the existing twelve CDIO reference models are put to the test in order to draft opportunities of reference model adaptation and ultimately improvement of the quality of HEE from various stakeholders' viewpoints.

[1] Initially, only the private institutions were concerned, CTI mission was then extended to all institutions.

WORK-BASED LEARNING IN FRENCH ENGINEERING EDUCATION

WBL, as a key aspect of VET, is directly linked to its goal of helping learners acquire knowledge, skills and competences with direct relevance for the labour market [European Commission, 2016]. WBL has been extensively analysed in the literature. Two decades ago, Brennan and Little [Brennan and Little, 1996] showed that WBL is in the workplace, but, in certain conditions, it can also be in HE. They questioned the roles and responsibilities of individual employers and higher education in the continuing education and training of adults, and identified corresponding risks and problems. They produced a substantial literature review of progress made and issues raised in the field of WBL in HE. More recently, exploration on engineering students' perceptions of developing practical competencies as experienced in their industrial placements has been studied in a CDIO context [Kamaluddin, 2015]. Nevertheless, there is still a widely-shared opinion among academia that WBL models would not have the same standing as general education or academic education and are often regarded as second-rate education, is that judging over?

Since two decades the situation has evolved in France and practice of WBL curriculum integration has been partially evaluated. In fact, many of WBL developments were supported by government-sponsored schemes the last years. More recently, Europe has set up many recommendations and practices in WBL for HE [European Commission, 2013]. In the context of engineering education, France has its particularities [Maury, 2012]. As recalled by Maury from the CEFI (*Centre d'études sur les formations et l'emploi des ingénieurs*) during an international CDIO meeting in France [Maury, 2012], among the five cultural keys which permit to understand French HE is "in France we love complexity and variety". Industry partnerships and WBL models are French cultural keys, as in the following models of WBL:

- Internships for HE engineering students, which are "on-the-job training periods in companies (…) that are incorporated as a compulsory or optional element of programmes leading to formal qualifications" [European Commission, 2016];
- Apprenticeship for VET engineering students, which "formally combines and alternates company-based training with school-based education, and leads to nationally recognised qualification upon successful completion. (…) There is a contractual relationship between the employer and the apprentice, with the apprentice being paid for his/her work" [European Commission, 2016].

Internships and apprenticeships are usually considered and highly praised in the context of VET. Although the situation is very diverse in European countries, these WBL models are widely used for the levels 1 to 5 of the European Qualifications Frameworks (EQF). They are much less in use for the levels 6 (Bachelor) and 7 (Master) in several countries.

In France, full accredited engineering programmes are developed in traditional and highly selective *Grandes Ecoles* (distinct from universities and supervised by Technical ministries, 25% of the engineering students, e.g. as at Mines Paris, IMT Atlantique), in private *Grandes Ecole*s (25%, e.g. as at ECAM, ICAM, ESTP), in universities of technology (18%, e.g. as at UTC, UTT, INSA), and in university components (23%, e.g. as at Polytech), the other 9% being for professional and vocational education (e.g. as at CNAM, CESI) [Maury, 2012]. To exemplify the French diversity, two models of WBL are described in this paper, in two different institutional contexts, i.e. in a public *Grande Ecole* (IMT Atlantique) and in a private Graduate School of Engineering (CESI), both institutions where ECTS are allocated to WBL as presented in Table 1:

Table 1. ECTS WBL credit ratio at an IMT Atlantique campus and CESI group for their two types of Master level programmes.

Institution / WBL model at Master level	Last year internship (HE students in 3 years)	Apprenticeship over 3 years (VET students in 3 years)
IMT Atlantique (Telecom Bretagne campus)	24 / 180 ECTS (215 students per year)	66 / 180 ECTS (40 students per year)
CESI Graduate	20 / 180 ECTS (250 students per year)	63 / 180 ECTS (1250 students per year)

Internship WBL model in French Engineers' curricula

Far in the past (i.e. 1990), CTI considered and approved alternate study periods of engineering students in companies. At the turn of the XXth century, CTI introduced mandatory internships in all Master's Degrees ("*Ingénieur diplômé*"). In the 2001 revised version of its frameworks standards, CTI considered 20 weeks of cumulated duration of internships as a minimum. In the 2016 version of its standards [CTI 2016], CTI states that "the aim of the training courses in the workplace for engineering students is to acquire technical, organizational and human skills". A minimum of 26 weeks of internship is now required for all students during their 300 ECTS Engineer curriculum at Master level. This total duration can include [Remaud et al., 2010]:

- Operative internships: ("*Stage ouvrier"*) usually placed at the beginning of the engineering studies, for a short duration (less than one month). In these internships, the HE students need to perform a low-level (usually manual) operative work;
- Company internships: ("*Stage en entreprise"*) the HE student is placed in a real working situation; ideally, he or she will be in charge of a real working assignment;
- Research internships: ("*Stage de recherche*) intended to develop innovation skills, they are recommended to the HE students who want to proceed to doctoral studies;
- Final engineering projects ("*Stage de fin d'études"*) frequently performed in a company or in a research laboratory, they often constitute an additional internship period.

In France, all these internships in companies or laboratories can be organised abroad, which adds an opportunity to "develop students' ability to work in an international environment". Graduate engineers who look for a R&D profile may choose long internships in laboratories, they must anyway spend at least 14 weeks as interns in a company. At variance with many "coop" programmes observed abroad, the French internships model for HE students do not prolong the studies but are included into them (to some extent at the expense of the summer holidays).

Classical Integrated Programme Structure Including Internships for HEE Students

In Europe, despite a deeply rooted liberal art style in some countries, “there is no consensus in structuring engineering education, but rather a constructive diversity in programme design” [Murphy et al. 2016]. Syllabus of learning outcomes [Crawley et al., 2007] can however be pivotal to align the programme structure and contents with the requirements of competency development. For such, as CDIO collaborators, both IMT Atlantique and CESI have followed such methods for continuous constructive alignments of their educational programmes.

At IMT Atlantique, economics, entrepreneurship, business, humanities and social sciences subjects are full constituents of engineering programmes, via sometimes classical lecture models but more and more since 2003 via transdisciplinary approaches based on problem- and project-based learning (PBL and PjBL). The classical integrated model at IMT Atlantique ensures that each HE student receives the intellectual guidance and experiences necessary to prepare them for vibrant engineering careers in a wide range of industrial, business and government settings. Since 2003, each HE student in the gerneralist programme of the Brest campus has to spend between 80 to 100 hours in team-based PjBL each of the five semesters (36 ECTS overall in the 3 years, inc. for the five semesters: 8 (S1), 6 (S2), 6 (S3), 10 (S4), and 6 (S5) credits), one day per week, under the regular supervision of methodological and domain tutors and with industrial partners [Rouvrais et al., 2006]. Aside, in its integrated curriculum, minors and majors include several mini-projects and PBL sessions. Each HE student carries out a minimum of 8 months of training in a company. A compulsory 6 months-minimum internship is in place at senior level. A compulsory 63-hours career preparation programme (21 hours per year) also supports the professional development [Rouvrais & Chelin 2010]. The periods of company “immersion” are important for the acquisition of skills, competency development and the affirmation of the professional and personal project. More than 40% of the generalist HE students also take a gap year in industry after their second year of study. An international stay of at least 9 weeks is also compulsory (e.g. via an academic semester or an internship abroad). It is even possible to carry out the last year of engineering studies alternating with a company for 12 months (under salaried status).

Apprenticeship WBL model in French Engineers’ curricula

In France, there is a continuous growth in the apprentices’ number in the engineering studies [CDEFI, 2015]. In 2014, about 130 HEIs offer 240 apprenticeship programmes. The apprentices now account for more than 14% of the total number of engineering students. While in 2014, 11% of the graduate engineers were apprentices, very soon this ratio will reach 15% (more than 5,000 graduates over a total of 35,000). In 1992, a French law extended the possibility to deliver higher education degrees through apprenticeships. The apprenticeship contract is a work & study training programme, where students (aged between 16 and 25) combine periods of work in a company and periods of study at the Training Centre to acquire skills and professional experience while preparing a diploma. The purpose of the apprenticeship is to enable students to undergo general, theoretical and practical training in order to obtain a vocational qualification attested by a diploma. Apprenticeship training has a positive effect on the occupational integration of young people: teaching them a job with practical experience makes them attractive in the labour market and offers them quick access to employment. In France, there were overall 365,000 apprenticeship students in 2015. Last but not least, the apprenticeship takes the form of a special contract between the student, the company and the school.

In the following years of the 1992 French law, CTI accredited a few institutions to award the "*titre d'ingénieur diplômé*" by apprenticeship to VET students. It remained for years a matter of relatively specialised institutions, like the CESI Graduate School of Engineering. In 1985, the situation changed because on one hand, the Government took incentive decisions for the companies which hired apprentices. On the other hand, the French engineering schools were searching ways of increasing and diversifying their student's recruitment to VET students. CTI accredited more and more "classical" engineering schools to develop curricula by apprenticeship (as at IMT Atlantique, Telecom Bretagne School of Engineering, since 2002), the new paradigm of learning outcomes (LO) allowing to prepare the same diploma by different tracks (i.e. the same set of LO but with different programme contents) [CTI, 2011]. Per the French law, apprentices are not students, they are VET professionals, they have a work contract and get a salary (from 40% to 90% of the minimum legal salary). A formal contract (3 or 2 years) between the company and the HEI states the educational objectives, the respective responsibilities of the company and the school, the schedule of the work and school experiences, etc.). Usually, the VET apprentices spend about 40% of their working time in the company, the rest at school; with an equivalent share of ECTS credits.

A follow-up of VET apprentice graduates shows that their professional trajectory is as good as the "classical" HE graduates; they are not confined to pure production jobs, although they are less employed in R&D departments of large companies. A still better indicator is the increasing number of applicants with top records who choose the apprenticeship track.

Apprenticeship Programme Structure for VETE Students

At IMT Atlantique, since its creation in 2002 on the Brest campus, the apprenticeship programme relies, for the VETE students, on a progressive alternation between the institution and the company, including, for apprentices enrolled in 2016, an international stay of at least 9 weeks. The WBL model is organised as follows [Rouvrais et al., 2007], where AP being the academic periods (114 ECTS overall) and CP being the company periods (66 ECTS overall):

- year 1: 4 weeks AP1, 6 weeks CP1 (4 ECTS), 5 weeks AP2, 12 weeks CP2 (8 ECTS), 13 weeks AP3, and 12 weeks CP3 (6 ECTS);
- year 2: 11 weeks AP4, 11 weeks CP4 (8 ECTS), 13 weeks AP5, and 11 weeks CP5 (8 ECTS);
- year 3: 15 weeks AP6, 9 weeks CP6 (8 ECTS), 6 weeks AP7, 29 weeks final CP7 (24 ECTS).

Engineering training at CESI is a 3-year curriculum that students can embrace after a Diploma of Higher Education. Throughout these three years, in-company times are punctuated by periods at school from 2 to 10 weeks for a total of 54 weeks over the 3 years. Besides, 5 weeks are dedicated to laboratory research and 12 weeks to a mission abroad. Taking advantage of its syllabus review, the engineering school has developed a pedagogical method that combines PjBL and PBL. This method is based on iterative loops to get closer to the operations of in-company engineers. Internally called "A2P2", for Active Apprenticeship by Projects and Problems, it was implemented in 2015-2016. The project topic is close to a real problem that could be experienced in companies, with multidisciplinary content. To solve the various problems that appear, students must acquire disciplinary knowledge, which is then applied to the project. It is an ideal opportunity to integrate knowledge, methods and tools from different disciplines of the curriculum and to make connections between subjects that are often learned separately. This project is divided into three main phases. First of all, (i) a launching phase, during which the students must define their roles (facilitator, scribe, secretary, manager), (ii) a second phase where the working group is to read the project statement, discuss the need, and rephrase it. The group also receives the project synoptic and must identify all the deliverables requested at the end of the project. Then, (iii) during the realisation phase, students carry out a succession of PDCA iterations (ie. Plan, Do, Check, Act), which gradually lead to targeted learning outcomes and final products. This phase can last from 1 to 5 weeks.

RETURN ON EXPERIENCE ON WBL IN FRENCH ENGINEERING SCHOOLS

Recent discussions (Vienna 2016) on the European Qualifications Frameworks showed that for most professional engineer representatives, academic training should not be compensable by professional experience, underlining the idea that learning on the job-site has not the same value as the academic one. In the French engineering community, the opinion is different: the real professional situations encountered in internship and apprenticeship WBL models reinforce the proactive role of the learner in acquiring the knowledge necessary for the execution of his/her mission, thus promoting the autonomy development, the ability to adapt to some unexpected situations, and to evolve towards new technologies and a priori unknown situations (e.g. career kaleidoscope, nomadic careers). By experience at CESI and IMT Atlantique, WBL HEE and VETE students are more in line with the needs of recruiters in terms of attributes and skills once graduated, have a foot in the door, and are more operational once hired. This section presents some French modalities which may limit the biases of WBL and foster academic formal recognition of work-based learning more formally in an integrated curriculum.

The learner/supervisor/tutor trio

Specific pedagogical methods are required for WBL models. Logics of knowledge transmission in the academic side and logics of operation, performance, efficiency, and productivity in the company side must coexist and enrich each other, with synergies. It is difficult to define uniformly the content of each of the corporate missions in WBL due to the diversity of the hosting companies (e.g. large industry groups, operators, equipment manufacturers, IT services companies, banks, or insurance companies), the diversity of occupations or missions and the diversity of organisations encountered. However, to promote the learning effectiveness and alignments of the proposed missions with the activities during school training, a substantial effort is to be made in order to increase the formalisation of the core skills and competencies. In

France, a HEE or VETE WBL student in engineering is continuously supervised by a company senior engineer in the related field of training and by a pedagogical tutor for the academic side. The academic tutor visits the company several times to meet the learner and his/her supervisor, participates in monitoring the learner development, facilitates the learning outcome framing and fosters to put into perspective the training objectives and experiences. This learner/supervisor/tutor trio [Rouvrais, 2007] is an essential triangular consortium in which the interactions are regular, improve follow-up, and promote reflexivity. As an example, the trio sets the missions and learning objectives before each WBL period, and communicates them to the academic services for validation (e.g. alignment with the learning outcomes and proficiency levels required for a period). The curriculum logistic is thus very demanding, not only to organize the tutoring.

Skills and competences developed during WBL company placement

Although universities and engineering schools include in their pedagogical styles learning situations close to the reality of the engineering practice, many professional skills remain difficult to instantiate realistically in pure academic environments. Most often, the situations are simulated, thus with several biases, where students have their own perception of the corporate world (or even sometimes academics) and may develop misconceptions and stereotypes, having difficulty to accept the theoretical learning objectives fixed by the teaching staff. Impacts of WBL and work placements on the development of students' skills have been extensively studied in the literature, even in engineering education [Saunders, 1995; Ahmed, 2009; Onof, 2010]. As strong motivational factors, WBL in companies for engineers are experiences to be exploited regularly in the formal curriculum, in line with the autonomy required for future operational engineers [Rouvrais, 2007]. Engineering programmes are more and more oriented towards competences, with a view to training in relation to real professional situations. Apprenticeship WBL models, with their school/company transitions, are modalities that respond particularly well to the skills and competences orientation, via contextual working occupations. WBL Logics of knowledge transmission in the academic corner and logics of operation, performance, efficiency, and productivity in the company corner coexist and enrich each other. WBL classically permits students to mobilise their formal knowledge and skills in real contexts, in non-simulated environments, and thus develop real professional competences. By developing a corporate culture and sense of responsibility, WBL also request interpersonal skills, team integration and operation skills, professional behaviour, and corporate cultures, strategies and goals. Not least, WBL models permit HE or VET students to regularly echo lived experiences in their formal curricula and thus put knowledge and skills to acquire into perspective, not only for personal development, but also for peer learners and academic staff, who may not be aware of all the most recent engineering practices (i.e. non familiarity with all current practices and technologies in the engineering sector).

CTI urges to make apprenticeship a success and not a second-hand path: precise definition of expected learning outcomes, role and training of the apprentice's tutors (in the company and at school), innovative pedagogy adapted to new profiles of students, etc. For accredited apprenticeship programmes, quality assurance and enhancement procedures are in place which ensure WBL integration and control on the pedagogical dimensions [Rouvrais et al., 2007]. At IMT Atlantique, the learning outcomes referential is formalised in the apprenticeship programme for VET students, in line with targeted professional branches requirements. The seven company periods (CPi) permit to cover all these outcomes, including proficiency levels on a continuous basis. The companies do not fix alone the mission given to an apprentice for a period. It is managed by the academic institution (i.e. a specific service including programme leaders and career orientation managers) and the trio apprentice/supervisor/tutor. For each period, a constructive negotiation is instituted ahead of "day one", to be signed by each party. This negotiation permits to legitimate the learning and competency development objectives of the academic side to the company specific environment, in order to strongly limit the "most of student working" effect for the only benefit of the company. In this negotiation is recalled what has been acquired in terms of knowledge and skills by the VETE student in the previous academic periods. An apprentice student is formatively assessed several times throughout the periods, including self-perception on proficiency development.

WBL student exigencies in the formal curricula

A classical main pitfall of apprenticeship is to consider this WBL model as just a way for the VETE students to get a salary and as a less quality-demanding curriculum. In the French VET engineering education, the students' workloads are very heavy, their vacations are much shorter than those of "classical" HE students, i.e. they are employees. Both at CESI and IMT Atlantique, apprenticeship accredited programmes for VETE students were set up on demand of companies that have expressed the need to hire operational engineers, endowed with technical and managerial skills, a good culture, and already possessing a potential for autonomy, adaptation and evolution. In the general context of apprenticeship, apprentices may experience difficulties to return to school, because they notice a gap between the way they function at work, and the posture expected in transmissive pedagogy. Thanks to the CESI and IMT Atlantique long-term experience of WBL, students back in the academic environment after a company working period prove to be more demanding with regard to the courses they attend, what points their ability to take a critical step back from the learning objectives and contents of the various courses. Under the influence of their experiences in companies, their analyses involve criteria of performance, potential re-use and transfer of knowledge. They thus become more active actors of their own training. But they can also become censors: a theoretical course targeting high-level cognitive skills may be under pressure due to their non-direct applicability. In line with the Kolb inventory of learning styles [Kolb, 1976], concrete experience may refrain abstract conceptualisation for pragmatists and activists, as often experienced with VET students. On the academic side, such critical student feedback is exploitable by the teacher via an exchange and open discussion with the peer learners, whose critical opinions may be reframed to the extent that perception of the performance of a teaching activity is not always temporally localised with the skill and competence development.

INSIGHTS FOR AN EDUCATIONAL FRAMEWORK

It was shown by Edvardsson Stiwne and Jungert (2010) that many engineering students argued that generic skills and cultural values are best learned in extracurricular activities and in work contexts, and that doing a thesis project in a firm was the best learning experience. In order to include an early exposure of engineering students to professional practice, integrated curricula in line with latest programme outcomes (i.e. ABET graduate attributes at Master level or ENAEE areas of programmes outcomes [EUR-ACE, 2015]) are in place in several engineering HEI. Among them, industry partnership is to be considered as rational for most of the reference models and maturity levels, even more with the growing importance of international internships. Nevertheless, a profound reengineering of engineering education [Borri and Maffioli, 2007] may not be so necessary, knowing that some frameworks clarify many good practices to meet such requirements. For engineering programmes, as promoted by the CDIO framework, the association of several stakeholders in the quality enhancement processes is recognised. The existing twelve CDIO reference models can be put to the test in order to draft opportunities of its reference models adaptation for professionalisation purposes and, ultimately, improvement of the quality of engineering higher education from various stakeholders' viewpoints.

Taking inspiration from the twenty guiding principles for apprenticeships and WBL [European Commission, 2016] proposed by the Education & Training 2020 working group in EU and the accreditation criteria and guidelines of the French CTI [CTI, 2016], to sustain industry-University partnerships (e.g. as argued in [Morell, 2014]), some extensions may be suggested to the twelve CDIO reference models. Due to the numerous concerns of WBL and their vast echoes in an educational framework for engineering education, creating a specific reference model may perhaps be considered in order to move forward institutional and policy implications, as e.g. a new thirteen "Industry Partnership" dedicated CDIO reference model, aligned and consistent with the twelve existing ones. It could be defined as this:

(13) <u>Industry Partnership</u>: partnerships with various types of companies (regionally, nationally and internationally) are in place in the institution and within the formal integrated curriculum. Adequate models of WBL support student competency development of product, process, system building, knowledge, personal and interpersonal skills, so as of company social contexts and related professional responsibilities.

a. <u>Rationale</u>: the curriculum and learning outcomes can only be designed if there are corresponding authentic pedagogical approaches, in and out of the formal curriculum. Students recognise professional engineers as role models, instructing them in disciplinary knowledge, personal and interpersonal skills, and product, process, and system building skills, in line with competency requirements of professional bodies. With WBL experiences in place for their students, faculties can also be more effective in contextualising their courses and better prepare their students to meet the demands of the engineering profession and to become lifelong learners.
b. <u>Rubric (maturity scale)</u>:
   0. There is no evidence of industry partnership nor of WBL in the programme;
   1. Industry partnerships and WBL model plans have been benchmarked with respect to the integrated curriculum plan;

2. Industry partnerships and WBL plans with learning outcomes and real professional activities that integrate personal, interpersonal, conceiving, designing, implementing, and operating skills and competencies with disciplinary knowledge have been approved, in the enterprise and social contexts;
3. Student WBL experiences and formal industry implications are being implemented across the curriculum according to the integrated curriculum plan;
4. There is evidence of the impact of the implementation of WBL experiences and formal industry implications according to the integrated curriculum plan;
5. Formal industry implications and student WBL experiences are regularly monitored, evaluated, and revised regarding their curriculum integration and the impact of these professional experiences.

To sharpen the conceptualisation of WBL curriculum integration, 30 years of good practices recorded from the French experience may be generalised and transferred in such a new reference model to capitalise and share experience at European and international levels.

CONCLUSIONS

Internship is inscribed in the genes of the French engineering education [Maury, 2010] and [CTI, 2011]. For French HEI, there are now less and less CTI recommendations concerning the lack of compliance with the related criteria. A recent survey showed that internships represent 23.5% of the training duration and that 18% of graduates underwent an internship abroad (only the engineer cycle is considered here, i.e. the last 6 semesters for Master level graduation). The main pros of integrated internships are (i) opening of the engineering studies to students with different skills, for whom the inductive pedagogy (from experience to theory) is more efficient than the classical deductive one, (ii) better understanding of academia and employers of their mutual constraints and objectives, (iii) enhancement of HEI to adapt their curricula to the employers and society needs. The main cons of integrated internships are (i) the risk that employers consider apprentices as mere employees and let the company constraints overrun the training project, (ii) companies must be aware and academia must watch carefully that the objective is not the training of ready-to-use engineers but the training of young people for several tens of years of professional career in an evolving environment. This analysis may provide some inputs to international engineering education collaborators investigating to include WBL as integrated activities in their programmes to better bridge some gaps with industry requirements and integrated programme skills.

As pointed in [Rouvrais, 2012], adults, as students, have an active role in their own learning and training. Non-formal and informal education, e.g. out of the formal academic environment, is the cornerstone for lifelong learning and career development. But related knowledge and skills are sometimes hardly recognised in the formal education arena. Candidates for a diploma or certification derived from professional experience or continuous vocational, have to confront more or less to referenced educational syllabus of learning outcomes. In French engineering education, according to the CTI standards, about 30% of the ECTS credits must be assessed in the workplace by a joint team of supervisors (inc. academic professors and tutors, and professional mentors). In the WBL internship and apprenticeship models presented in this paper, CESI and IMT Atlantique provide guarantees on control and monitoring of skill development. They control learning outcomes during and at the end of the working periods thanks to the trio learner/supervisor/tutor follow-up. Regular formative and summative assessments, self-assessments, restitutions to the learner by a competency and career expert, are in place. Capitalisation on peer experiences via collaborative student workshops, specific training sessions for supervisors in the academic environment, also exist. For example, on-site visit certificates of the academic tutor in the apprentice company, formally required by the professional branches supporting apprenticeship models in France, are to be signed at least once a year with the parties and HR managers.

Although the practice of internships has overrun all French degrees, companies praise the engineer internships, because they offer them a return. Additionally, the company might be able to promote itself among students, get a better knowledge of the profile of young professionals that will soon come to the job market, incidentally appreciate the quality of an intern and offer him/her a job when he/she ends his/her studies. The risk from both the company and HEI sides is that internship would be considered just as an accumulation of working periods in companies, where the students are not on campus. As a guardrail, CTI requires precise coordination between the teaching in and out the campus, with detailed follow-up processes. Academia sometimes consider that WBL models have not the same standing as general education or academic formal education, relying programmes are often regarded as second-rate education. Nevertheless, as in France for engineering education, WBL models are in place in several countries and since a long period of time. Many good practices are transferable, as already clarified in the literature (e.g. [ASTE, 2009]) or in European recommendations [European Commission, 2016]. In this paper, the authors have thus suggested the establishment of a 13th CDIO Standard, concerning Industry Partnership.

Policy implications of WBL are to be considered. A statistical study [Kailis and Spyridon Pilos, 2005] showed in 2005 that about half of the 25-64 years old in the European Union have an active role in their own learning. In several EU member states, knowledge and skills acquired and developed thanks to informal and non-formal learning can already be certified. As such, some higher educational institutions can award their diploma on the basis of a recognition of prior learning and work experience (RPL), based on professional and life experience [European Commission, 2012]. In France, since its formal inscription in the Law in 2007, it is an obligation for HEI, even in engineering. French RPL allows professionals (e.g., technicians with several years of experience in engineering), whose profile, i.e. the knowledge and skills acquired, matches the graduate outcomes formally defined by the degree programme and national qualification framework (called RNCP in France), to obtain the engineering degree from an authorised and accredited School of engineering [Rouvrais, 2012]. There often remains a distance between the competencies repositories of the professional world and those of the formal curricula, more knowledge- and skill-oriented. Indeed, the position of France in RPL of engineering skills remains original in the European landscape. In a 2016 academic leaders meeting on ECTS, several participants remain reluctant to the approach.

Insights

In the specific context of this paper analysis, opportunities for further innovations (Innovation of Practice, e.g. IP) in engineering education approaches can be suggested:

- (IP1) creating a full reference model of WBL to be integrated in educational frameworks for engineers, supported by constructive alignment principles and good practices per maturity levels for institutional application;
- (IP2) defining a unified framework bridging several pedagogical modalities for similar degrees. In the EUR-ACE language, learning outcomes permit to realign profiles. In such a Learning Outcomes approach, programmes are defined by their expected outcomes not by the way to achieve them [EUR-ACE 2015], which allows to deliver the same degree to students following different tracks (academic curricula, apprenticeships, continuing education, validation of professional experience). In France, the legal regulations, implemented by the CTI requirements, have given HEI a strong experience to bridge the various training modes in the engineering graduation.
- (IP3) transposing the French WBL models to other countries, e.g. by including legal context and framework, so as fostering industrial lobbying and collaborations. It should be noted that several requirements must be fulfilled to develop WBL: a large industrial basis offering the whole spectrum of engineering activities; a legal frame for the students while they are on the worksite including salaries and social security issues, employers ready to dedicate human resources for the tutoring of HE interns or VET apprentices, academia ready to involve all stakeholders -particularly employers- in the training design and assessment, teachers willing to contribute to the on-site tutoring of the students. The idea that there may be an external industrial council that can give advice on educational programmes, pedagogical styles and contents can boil in some HEI environments.

Thanks to this paper's elements of analysis, new potential research questions (RQ) could then be inferred:

- (RQ1) What are the career decision making factors and processes of engineering students and how do they impact them? A recent qualitative study in the IMT Atlantique context has analysed first job preferences and expectations of the school's HE students before their first internship [Gerwel, Chelin, and Rouvrais, 2017]. It showed some motivational factors echoed in students' course choices, students' WBL situation choices, and first job choices. These are to be analysed further, e.g. qualitatively and quantitatively, and maybe to be correlated to clarify student decision-making processes for WBL and career choices;
- (RQ2) How to measure the true quality and benefits of WBL at a systemic level for objective quality assurance? Some academics like to say that internships ("stages" in French) are just a way for companies to rip young students off and make the most of student labour with low salary and taxes. It might be true when no control loop aligned with learning outcomes is fixed by institutions in WBL models. Specific quality assurance procedures and objective analysis via longitudinal methods may be more deeply investigated to corroborate or not;

- (RQ3) What are the correlations between learning styles and pedagogical models in engineering education, how do they echo in learning cycles? In WBL, logics of knowledge transmission in the academic side and logics of performance, efficiency, and productivity in the company side must coexist. It was shown in this paper that students may become censors in the academic environment, especially when high-level cognitive skills are faced by pragmatist and activist students in the Kolb sense [Kolb, 1976]. Learning loops including WBL, PBL, PjBL and more classical courses may be analysed in light e.g. Kolb theory (even if contested) of concrete experience, reflective observation, abstract conceptualisation, and active experimentation learning styles (and maybe also the Learning Styles of [Felder and Silverman, 1988]).

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BIOGRAPHICAL INFORMATION

Prof. Bernard Remaud is professor emeritus at the University of Nantes. From 1995, his main activities were oriented towards the management of higher education institutions, the quality assurance and the assessment of engineering education. He developed the Polytech network which includes 13 French engineering colleges. In 2004, he was appointed at the CTI (French Committee for Engineering Programmes Accreditation), and served as an executive director until 2012. In 2014, he became president of ENAEE.

Dr. Siegfried Rouvrais is Associate Professor at the CS Department of IMT Atlantique (formerly Télécom Bretagne). His current scholarly interests are in quality enhancement in line with accreditation requirements, and in methods and processes for Higher Education changes. He organized the international CDIO 2012 Fall meeting and was elected to the board of CDIO international council member in 2013. He co-leads the French TREE research group on Engineering Education Research & Development (http://recherche.telecom-bretagne.eu/tree). IMT Atlantique - Telecom Bretagne is the first French CDIO collaborator, joined in 2008.

Morgan Saveuse is Dean of studies for CESI Graduate School of Engineering. Since 2013, he has implemented PjBL in Industrial and Civil engineering curricula at ei.CESI School. eXia@CESI is the second French CDIO collaborator, joined in 2016.

Corresponding author

Dr. Siegfried Rouvrais
IMT Atlantique, School of Engineering
Technopôle Brest-Iroise, CS 83818
Brest, France