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# Work-based learning models in engineering curricula: insight from the French experience

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## ABSTRACT

To favour an early exposure of students to professional practice, several engineering higher education institutions have implemented integrated curricula, as proposed in the international CDIO educational framework. In the 1990s, the French engineering education accreditation body introduced in its quality standards a compulsory internship period. Based on this national experience, this article sets out the various models of internships and apprenticeships in French engineering education and presents two curriculum integrations: one in a highly selective public graduate *Grande Ecole* and another in a private multisite engineering institution strongly linked to professional branches and national qualification framework. To provide some inputs and rationales to educational programme designers in other national contexts, this article proposes to extend the CDIO framework to systematically include work-based learning as integrated activities, to better match industry requirements and student competency expectations as future engineers.

## ARTICLE HISTORY

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## KEYWORDS

Work-based learning; CDIO framework; internship; apprenticeship; integrating skills; Work-integrated learning

## 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 (HEIs) and fields and it has a special resonance for the training of engineers. Even more, work-based learnings (WBLs) are strongly supported in the EHEA for the period 2011–2020; the ministries in charge of Higher Education considered WBL as major tools to meeting the twin goals of improving individuals' employability and increasing economic competitiveness (EU Bruges Communication 2011). Although there is now in European HEI a global agreement on these orientations and on the underlying competence approach, their concrete implementation – even in 2018 – is highly variable depending on the countries and the institutions (Remaud 2013). Competencies 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 (PjBL) methods exist. Industry partnerships are also often in place, as capstone PjBL experiences with external partners, as analysed in Einarson (2016) with learning outcomes (LOs) and assessment alignment. Various extra- and intra-curricular activities can also be in place, e.g. sponsoring of student activities, forums and seminars,

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lending equipment, teaching by company representatives and, particularly, internships in companies as part of the school curriculum.

Some countries or regions rely on WBL. WBL has been extensively analysed in the literature. Two decades ago, Brennan and Little (1996) showed that WBL is in the workplace, but, in certain conditions, it can also be in higher education. 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 higher education. But WBL relates to several models for engineering students. At variance with many 'co-op' programmes observed abroad (e.g. University of Waterloo which was the first school in Canada to introduce co-op in its engineering program in 1957), the French WBL models do not prolong the studies. In France, internships or experiential terms or semesters in companies are fully included into the curriculum (to some extent at the expense of the summer holidays). In this regard of WBL integration, the French experience appears as peculiar, as linked with the – 80 years old – organisation of engineering studies. French engineering education mainly relies on two WBL models at Master level: regular higher engineering education (HE) and vocational education and training for engineers (VET). In such a context, the focus of this article is to recall the two main models of internship (HE-based) and apprenticeship (VET-based) in French engineering education and their integrations in line with the CDIO framework reference models (Crawley et al. 2014): one in a highly selective public *Grande Ecole* and another in a private multisite engineering institution strongly linked to professional branches and to the national qualification framework. Both institutions are CDIO collaborators. The paper does not argue or give formal and scholar evidence that the outcomes of WBL for engineering students are better. The elements presented in the article are to 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. For such, this article proposes to extend the CDIO framework with a new reference model to systematically include WBL as integrated activities in educational programme.

## WBL in French engineering education

WBL, as a key aspect of VET, is directly linked to its goal of helping learners acquire knowledge, skills and competencies with direct relevance for the labour market (European Commission 2016). But 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? In an Australian University of technology context, Blicblau, Nelson, and Dini (2016) indicated that undergraduate students who spent time on work integrated learning in their penultimate year of their mechanical engineering course obtained better grades than those who did not undertake such a placement. Exploration on engineering students' perceptions of developing practical competencies as experienced in their industrial placements has been studied in a CDIO context (Kamaluddin 2015).

Recently, Europe has set up many recommendations and practices in WBL for Higher Education (European Commission 2013). Less recently, in 1934, the French Law tasked the national engineering accreditation body (CTI – *Commission des Titres d'Ingénieur*) with assessing the programmes of engineering education. From the CTI origins, French HEIs 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 1990s, 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 and 30 European Credit Transfer System (ECTS).

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). Since two decades, in France, the practice of WBL has been partially evaluated. In fact, many of WBL developments were supported by government-sponsored schemes the last years. In the context of engineering education, France has its particularities (Maury 2012); 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 1–5 of the European Qualifications Frameworks (EQF). They are much less in use for the levels 6 (Bachelor) and 7 (Master) in several countries.

### ***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 twentieth 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; and
- 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 an R&D profile may choose long internships in laboratories, they must anyway spend at least 14 weeks as interns in a company. More recently, the Entrepreneur internship is in place in some French engineering institutions, where students can create their own company thanks to incubators, like at IMT Atlantique<sup>1</sup> (formerly Telecom Bretagne).

### ***Apprenticeship WBL model in French engineers' curricula***

In 1992, a French law extended the possibility to deliver higher education degrees through apprenticeships. The apprenticeship contract is a work and study training programme, where students

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: learning 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 the 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 since 2002), the new paradigm of LOs allowing to prepare the same diploma by different tracks (i.e. the same set of LO but with different programmes or experience contents) (CTI 2011). Per the French law, apprentices are not students, they are VET professionals, and they have a work contract and get a salary (from 40% to 90% of the minimum legal salary). A formal contract 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..

## WBL examples in two French engineering institutions

To exemplify the French diversity of HEI in engineering, two models of WBL are described hereafter, 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 some ECTS are allocated to WBL as presented in Table 1 (180 ECTS in 3 years overall):

### IMT Atlantique figures

Public *Grandes Ecoles*, with their highly selective national admission *concours*, take root in the French Napoleonic Ecole Polytechnique (created in 1794). Close to the labour market, Engineering *Grandes Ecoles* are the main medium to create a tank of future high-skilled managers for large industries, in France and abroad (Power 2003). Their students graduate only at Master level (in three years, with 180 ECTS, after two years of *classes préparatoires* with 120 ECTS).

IMT Atlantique offers two degrees: (i) a medium size full-time generalist program (HE), which imparts a wide spectrum of knowledge, skills, and competencies. Graduates from this program often move into respected expert or managerial positions in national or international companies, or in the national hierarchy of the French civil service; (ii) a small size specialised apprenticeship program (VET), where graduates move to more technical expert positions in companies in the national area.

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

Institution/WBL model	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)

IMT Atlantique hosts 290 full-time academics with around 800 HE and VET students on the Brest campus. The two aforementioned programmes are accredited by CTI. They are also awarded the EUR-ACE label (2015) by ENAEE (European Network of Accreditation of Engineering Education). They thus comply with EHEA, in line with the Bologna process.

### ***CESI graduate school of engineering figures***

The CESI (*Centre d'Etudes Supérieures Industrielles*) was created in 1958 by five major French industrial companies wishing to promote their high-potential technicians and help them grow. As a private multisite engineering institution, it is strongly linked to professional branches and in line with the national qualification framework. For the last 30 years, the CESI group has started training future engineers through combined work-study VET programmes as well as under HE student status. Pioneer in the engineering program through apprenticeship back to the 1980s, the School remains leader in training future engineers through the combined programme: today, CESI Graduate School of Engineering graduates over 33% of the French apprentice engineers.

The whole group counts over 700 staff, around 7000 students in total. It is covering the whole national territory, with 25 centres of various sizes close to companies and major industrial areas. All its engineering programmes are accredited by CTI and also EUR-ACE-labelled.

### ***Classical integrated programme structure including internships for HE 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 LOs (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). Since 2003, each HE student of the Brest campus has to spend between 80 and 100 hours (36 ECTS) in team-based PjBL, 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-month-minimum internship is in place at the senior level. A compulsory 63-hour career preparation programme (21 hours per year) also supports the professional development (Rouvrais and Chelin 2010).

More than 40% of the HE students also take a gap year in industry after their second year of study. It is even possible to carry out the last year of engineering studies alternating with a company for 12 months (under salaried status).

### ***Apprenticeship programme structure for VET students***

At IMT Atlantique, since its creation in 2002 on the Brest campus, the apprenticeship programme relies, for the VET 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, Picart, and Fracasso 2007), where AP being the academic periods (114 ECTS overall) and CP being the company periods (66 ECTS overall) (Table 2).

The programme structure is similar at CESI; in-company times are punctuated by periods at school from 2 to 10 weeks over the 3 years. Besides, 5 weeks are dedicated to laboratory research and 12 weeks to a mission abroad.

**Table 2.** Distribution of study periods in company and at school (IMT).

		Number of weeks					Total
Year 1	Academic (AP)	4		5		13	22
	Company (CP)		6		12		30
Year 2	Academic (AP)	11		11			22
	Company (CP)		10		6 + 9	5	30
Year 3	Academic (AP)	15		6			21
	Company (CP)		2		28		30

## Return on experience on WBL in French engineering schools

Recent discussions (Vienna 2016) on the EQF showed that for most professional engineer representatives, academic training should not be compensable by professional experience, underlining the idea that learning on the jobsite has not the same value as the academic one. It raises the issue regarding the perception that WBL is an inferior form of learning. 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 and nomadic careers). By experience at CESI and IMT Atlantique, WBL HE and VET 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. Even if no formal evidence are given by professional branches to compare pure academic students and WBL students, this section presents some French modalities which may limit the biases of WBL and foster academic formal recognition of WBL 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 raise tensions, they 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 with an LO approach. In France, an HE or VET 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, with specified LOs. The academic tutor visits the company several times to meet the learner and his/her supervisor, participates in monitoring the learner development, facilitates the LO framing and fosters to put into perspective the training objectives and experiences. This learner/supervisor/tutor trio (Rouvrais, Picart, and Fracasso 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 LOs and proficiency levels required for a period). The curriculum logistic is thus very demanding, not only to organise the tutoring.

### *Skills and competencies 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. As strong motivational factors, WBLs 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, Picart, and Fracasso 2007). Engineering programmes are more and more oriented towards competencies, 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 competencies 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 competencies. By developing a corporate culture and sense of responsibility, WBL also requests 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).

At IMT Atlantique and CESI, the LOs referential is formalised for VET students, in line with targeted professional branches requirements. The 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.

At IMT Atlantique, 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 VET 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 VET 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. At both CESI and IMT Atlantique, apprenticeship accredited programmes for VET 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 ways they function at work, and the posture expected in more formal and 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 (academic periods), 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 (1976) or the Felder Index of learning styles (Felder and Spurlin 2005), 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.

## **Skill assessment of WBL and professionalisation**

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 the referenced educational syllabus of LOs.

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 article, CESI and IMT Atlantique provide guarantees on control and monitoring of skill development. They control LOs 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, and 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 exists. 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.

At CESI, the assessment system allows students to measure their progress both at work and at school. The assessment focuses not only on the performance of the various academic tests but also on the student's intellectual approach, his/her behaviour and activity in the company. The evaluation system is based on three modalities: (i) semi-annual business assessment, once a semester, the company tutor assesses the achievement of the previously set objectives: through the missions entrusted, it carries out a qualitative and quantitative assessment of the acquired knowledge, the intellectual approach and the behaviour of the student; (ii) knowledge assessments: verifying that the student has acquired the knowledge and methods taught at school. They give rise to written or oral tests; (iii) assessments of synthesis activities: to ensure that the student is able to put in context his/her knowledge, to combine it effectively in order to achieve a project and a realisation, based on report writing, presentations, individual and group project defence.

For the apprenticeship programme, at IMT Atlantique, each company period is associated with a specific summative assessment grid, including competencies to develop during each period, with proficiency levels. CP1 refers mainly to company integration, CP2 to company knowledge, CP3 to personal efficacy and technical aspects, CP4 and CP5 to engineering and project management, CP6 to overall skills and competencies, as for the generalist programme internship. Throughout the three years, the apprentice produces five reports and has some oral defence in front of a mixed jury (academic and industrial, benefiting from the presence of other apprentice supervisors and tutors). The corporate mission is the core of the report, but the way to describe it depends on the learning objectives of the period. The whole process, with its requirements, is described in a 12-page institutional document, shared with and recalled to the company supervisor throughout the periods.

Both programmes at IMT Atlantique use summative assessment all along the curriculum. As far as regular generalist programmes are concerned, internship offers are managed ahead of the student selection. Thanks to several years of compulsory WBL, the institution maintains a large pool of

industry contacts along with a grey list of companies or supervisors. All HE students are mentored by a specific academic career orientation service to help select internships with appropriate missions, learning contexts and outcomes, as well as transferable. Final-year engineering or project management internships with clearly specified missions in line with the required graduate outcomes are most likely to be validated, while debugging source codes with an obscure supervisor in an unknown company may not. Besides, a learner/supervisor/tutor trio is in place all along the internship at IMT Atlantique, but in a more flexible manner than in apprenticeship. The activities of the HE intern are regularly controlled, via oral exchanges and formal reporting (at least three), including risk analysis. Two final reports are produced by the student and (re)checked by both parties, one short executive summary and one long technical report. Both are assessed according to specific grids and a formal oral presentation closes the HE internship.

### **In 2018, what about the situation in France?**

Internship is inscribed in the genes of the French engineering education (Maury 2010) and its accreditation body (CTI 2011). For French HEI, there are now less and less CTI recommendations concerning the lack of compliance with the related criteria. 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 and learning in and out the campus, with detailed follow-up processes.

In France, CTI urges to make apprenticeship a success and not a second-hand path: precise definition of expected LOs, 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 ensures WBL integration and control on the pedagogical dimensions (Rouvrais, Picart, and Fracasso 2007). 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 5000 graduates over a total of 35,000 per year). 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.

### **Insights for an educational framework**

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. 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 12 CDIO reference models can be put to the test in order to draft opportunities of its reference models adaptation for more professionalisation purposes and, ultimately, improvement of the quality of engineering higher education from various stakeholders' viewpoints.

Taking inspiration from the 20 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 12 CDIO reference models. The CDIO Standard 3 recalls that an integrated curriculum includes learning experiences that lead to the acquisition of personal and interpersonal skills, and product, process, and system building skills (Standard 2), interwoven with the learning of disciplinary knowledge and its application in professional engineering ... by mapping the specified LOs to courses and co-curricular activities that make up the curriculum. Due to the numerous concerns of WBL as potential curricular activities and their vast echoes in an educational framework for engineering education, creating a specific reference model may perhaps be considered (Malmqvist, Edström, and Hugo 2017) in order to move forward institutional and policy implications, as e.g. a new 'Industry Partnership' dedicated CDIO reference model, aligned and consistent with the 12 existing ones. It could be defined as this:

- Optional New CDIO Standard. Industry Partnership: partnerships with various types of companies are in place in the institution and within the formal integrated curriculum. Adequate WBL and co-op models support authentic student competency development of product, process, system building, knowledge, personal and interpersonal skills, so as of workplace social contexts and related professional responsibilities.
  - Rationale: the curriculum and LOs are specified and designed with authentic and experiential pedagogical approaches, in the workplace, in and out of the formal curriculum. Students can develop their professional identity, recognise real professional engineers as role models during activities, instructing them in disciplinary knowledge, personal and interpersonal skills, product, process, and system building skills, in line with competency requirements of professional bodies. With WBL and/or co-op experiences in place for their students, faculties and academic instructors are more effective in contextualising their courses and better prepare their students to meet the demands of the engineering profession, so as to become lifelong professional learners.
  - Rubric (maturity scale):
    - There is no evidence of industry partnership, corporate involvement, nor of WBL in the programme;
    - Industry partnerships and WBL model plans have been benchmarked with respect to the integrated curriculum plan;
    - Industry partnerships and WBL plans with LOs and real professional workplace activities that integrate personal, interpersonal, conceiving, designing, implementing, and operating skills and competencies with disciplinary knowledge have been approved, in the professional and social contexts;
    - Student WBL experiences and formal industry/company implications are being implemented across the curriculum, according to the integrated curriculum plan;
    - There is evidence of the impact of the implementation of authentic WBL experiences and formal industry/company implications, according to the integrated curriculum plan;
    - 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.

## Discussion

Academia sometimes consider that WBL models have not the same standing as general education or academic formal education and relying programmes are often regarded as second-rate education. Nevertheless, WBL models are in place in several countries, as in France for engineering education, and since a long period of time. Many good practices are transferable, as already clarified in the literature (e.g. ASET 2009) or in European recommendations (European Commission 2016). In this article, the authors have recalled some strengths and weaknesses, including safeguards, of internship and apprenticeship models formally included in engineering education curricula through the lens of the French experience in two different institutions.

The main pros of integrated and mandatory 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, and (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. These pros and cons may provide some inputs to international engineering education collaborators investigating to include WBL as formally integrated activities in their programmes to better bridge some gaps with industry requirements and integrated programme skills.

## Insights

WBL is implemented in several countries, whether it is integrated or not in formal curricula. In the French higher education context, the engineering studies stand out for the integration of internships and apprenticeships in their curricula. But similar measures and organisational structures can also exist in other countries, as identified in European Commission (2016) and in line with key European challenges. Thus, in the specific context of this article, 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, LOs permit to realign profiles. In such an LO 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, and 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) comparing the French WBL models with the ones of other countries (e.g. accreditation standards of the Canadian Association for Co-operative Education) and transposing the French WBL experience 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.

Potential research questions (RQ) could be inferred:

- (RQ1) What are the WBL and 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 2018). 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 LOs is fixed by institutions in WBL models. A regular study is done by CTI and the French Association of Engineers (CTI and IESF 2016) with the young professional engineers (graduated either by apprenticeship or classically); they rate their training to the competencies needed in their professional life; the ratings are quite comparable between the two categories, with a slight better judgment from the apprentice graduates on the 'soft skills' outcomes. But 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 WBL pedagogical models in engineering education, how do they echo in learning cycles (Felder and Spurlin 2005)? 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 long article 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 of concrete experience, reflective observation, abstract conceptualisation, and active experimentation learning styles.

## Note

1. <https://incubateur.imt-atlantique.fr/>

## Disclosure statement

No potential conflict of interest was reported by the authors.

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