# Common learning resources for academia & industry
## The case of digital provision in engineering

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## INTRODUCTION

In knowledge societies, University-Business Collaboration (UBC) in engineering is seen as crucial for the provision of high quality education and qualifications, for innovation[1] and growth. Indeed, initial and continuing engineering education is a strategic asset to foster knowledge production, knowledge transfer and creativity. As a consequence, the educational sector can evolve towards local[2] integration, involving regional public and private players, for the provision of customized solutions. The benefits wouldn't come primarily from the scale effects but rather from a fine targeting of comprehensive educational needs and from a rationale learning provision system.

In this respect, Higher Education Institutions (HEIs) and companies can collaborate for the design and provision of digital learning resources. In doing so, they would benefit from "operational" collaboration and from cross-boundaries blended learning solutions while implementing an original lean[3] learning provision system. This study is based on a traditional literature review, whose material stands at the junction of education, engineering and technology-enhanced learning. In engineering education, we analyze the reasons for academia-industry collaboration, we draw a comparison between the respective practices, and we propose a possible approach to investigate the methods for the co-development of learning resources.

## 1 WHY WOULD HEI AND CORPORATIONS COLLABORATE ?

According to Lord Dearing's National Committee of Inquiry into Higher Education, the role of higher education in a learning society is to inspire and enable individuals to

[1] Innovation = Conception + Invention + Exploitation, Rosenfeld and Servo cited in [1].
[2] Here, "local" suggests geographical, organizational, business and/or subject-matter proximity.
[3] Here, "lean" is used as cost effective or exempt of superfluous.

develop their capabilities to the highest level, to increase knowledge and understanding, to serve the needs of the economy and to shape a democratic and civilized society [2]. In companies, training focuses on the acquisition of skills that are expected to bring about intended changes in an employee's performance and to make valued contributions to the organization [3] [4]. In this general context, Boisclair [5] is wondering how we can imagine "the bridges between the places of research production and theoretical knowledge, and the world of emergence of practical and action knowledge", namely academia and industry.

### 1.1 The existing university-business collaboration models

*Table 1.* Examples of partnerships between universities and companies. Built from partial information [6] [7] [8] [9] [10].

| What? | Type | How? | Who? | Benefits |
|---|---|---|---|---|
| Research activity[4] | Strategic[5] Transactional | Consortia, joint program, graduate program. | Undergraduate, graduate students, graduate thesis, faculty consultancy, managers, researchers. | Students (U): educational value, scientific research method, occupational guidance, Faculty (U): tacit knowledge production, knowledge body expansion in one discipline, new teaching content, HR (B): talent search, Specialists (B): allow new technical capabilities, Managers (B): product/service improvement, All: solutions for social and global challenges. |
| Student mobility | Transactional | Internship and cooperative education ("co-op" programs, apprenticeships, trainee programs). | Undergraduate, graduate students, managers. | Students (U): work experience, financial support, occupational guidance, Managers (B): inexpensive student labour, social contribution. |
| Teaching collaboration | Transactional Operational | Accredited university degree-granting programs, special courses, industrial affiliates programs, multidisciplinary degree programs, facilited work based learning (FWBL)[6]. | Faculty, industry specialists. | Faculty (U) & specialists (B): new topics introduction, modernize teaching and learning. |
| Student design projects | Transactional Operational | Industry relevant challenges | Undergraduate, graduate students, faculty, professionals. | Student (U): work experience, occupational guidance, HR (B): talent search, Managers (B): inexpensive student labour. |
| Discrete activities | Transactional | Visiting speakers, industrial tours | Teachers, professionals. | UB relationship |

[4] Only 40% of the projects with major research outcomes were exploited in ways that led to major impact, defined as an observable and generally agreed-upon positive effect on the company's competitiveness or productivity [11].
[5] Audi built the Ingolstadt Research Institute in collaboration with the Technical University of Munich. This UBC went beyond transactional research projects, focusing mainly on technology and innovation for direct application on Audi's cars and on pool of future talents [10].
[6] The "Lonely Wolf" case: facilitated work based learning [12].

According to the Hippo Study [6] two third of HEIs undertake UBC activities, and technology and engineering have the highest level of UBC. There are eight different ways in which HEIs and business cooperate, ordered from the most usual to the less common: collaboration in R&D, mobility of students, commercialization of R&D results, lifelong learning, curriculum development and delivery, entrepreneurship, governance, mobility of academics (see the main UBC in Table 1).

It has been found that the main drivers for collaboration are the motivation of people and their relationship based on mutual trust, on understanding, on commitment, and on shared goal [6] [10], the university's need for external funding [7] [10] and the interest for Intellectual Property (IP) [7].

The main barriers to productive UBC are the funding and bureaucracy within the HEIs [6], the inflexible approach to IP [10], the use of poor metrics such as the number of papers published or patent applications filed instead of quality [10], the lack of academics with deep understanding of industry and business experience [10], and, in addition, the difficulty to devise mechanisms in order to share accountability [10].

We acknowledge the fact that most partnerships involve students within initial education. Only one collaborative frame, that we discuss hereafter, supports employees' learning for continuing educational purposes : the so called “Lonely Wolf” project, a Facilitated Working Based Learning (FWBL) solution for Engineers in Small and Medium Enterprises (SMEs) [12]. FWBL can be defined as a lifelong learning method based on a partnership between university and enterprise with the purpose of research based knowledge transfer as an integral part of daily business [13]. Scientific staff from the university is facilitating a tailor-made course of learning to the individual employee or to a team of employees. The “Lonely Wolf” project involved engineers from 75 enterprises in order to develop cost effective continuous training for geographically distributed SMEs. This programme included a mix of standard classes from university programmes, reading and problem solving, academic researcher review and meetings.

### 1.2 University and business value proposition for UBC

The contribution of each organization is defined against its service capacity. From the previous section, we saw that in the general UBC frame, HEIs bring their theoretical and research knowledge of the discipline, along with their experience in instruction. In turn, companies bring real life challenges, both technical and human. As far as we can judge, with the exception of FWBL, we didn't help Boisclair solving his problem. From our understanding, research projects are transactional activities embedded in the academic environment. It doesn't necessarily expose students to situational challenges that current employees face at work. Internships do. Conversely, we will argue that intern students are isolated in a corporate context where academia doesn't challenge the common practice. Either students stand at university or within the industry.

We believe common learning resources design and provision is an effective way to initiate and sustain “operational” UBC. The incorporation of real life material in the academic programs and the transmission of modernized theoretical knowledge in corporate training would be beneficial. It assumes greater flexibility of university teaching around industry related activities and cooperation between faculty and corporate specialists.

### 1.3 Cost : a driver for collaboration

The Learnovation Delphi survey [14] predicted that the decreasing of public funding, especially true in Europe[7], will push public-private partnerships forwards. In this part, we consider the cost of technology-enhanced learning.

*Table 2.* Type of cost versus time for blended learning. Adapted from “Figure 3 : Spending for blended corporate training”, [15]. “FC” and “VC” mean Fixed Cost and Variable Cost respectively.

<table>
<tr><th colspan="2"></th><th>Initial cost</th><th>Class delivery</th></tr>
<tr><td rowspan="5">Blended learning</td><td rowspan="2">e-learning</td><td>Content design & development: multimedia material (FC)</td><td rowspan="2">Support, scaffolding (VC)<br>LMS maintenance (VC)</td></tr>
<tr><td>Infrastructure:<br>hardware, networks, LMS (FC)</td></tr>
<tr><td rowspan="3">Traditional class</td><td>Traditional class material:<br>hardcopies, print (VC)</td><td>In corporation:<br>- tuition fees, travels (VC)<br>- production loss (short-term) (VC)</td></tr>
<tr><td rowspan="2">Class preparation:<br>time (FC)</td><td>Teacher:<br>salary (VC)</td></tr>
<tr><td>Running costs:<br>facilities, administration (FC + VC)</td></tr>
</table>

Information and Communications Technology (ICT) development and especially custom e-learning is known to be expensive due to the technology utilization, to further project management activities and to extra training activities for design strategies, tools, processes, and standards [4] (see Table 2 for the cost structure of blended learning).

In the context of UBC, cost reduction will be achieved by sharing the initial cost between few local[8] partners. Cost effectiveness will follow an arithmetic rule depending on the number of partnering organizations[9]. As said before, the benefits would come primarily from a fine targeting of comprehensive educational needs and from a rationale learning provision system.

## 2 THE EDUCATIONAL SETTINGS

Education is an activity “undertaken or initiated by one or more agents that is designed to effect changes in the knowledge, skill, and attitudes of individuals, groups, or communities” [16]. Most theorists categorize kinds of learning in three domains : cognitive, affective, and motor. In this paper, we are concerned with cognitive learning. Cognitive education is “composed of the set of instructional methods that assist students in learning knowledge to be recalled or recognized, as well as developing students’ understandings and intellectual abilities and skills” [17].

### 2.1 The academic and corporate learning resources

In universities, it has been found that six main barriers prevent teachers to share their learning resources : the lack of collaborative culture at university, a possible loss of

[7] The recent data on the changes in budgets between 2010-2011 for tertiary and adult education show that nearly half of the twenty eight countries reduced their budgets. As regards with higher education, in Spain as well as in the United Kingdom tuition fees have been or are in the process of being increased in 2012-2013 [18].

[8] Here, “local” suggests geographical, organizational, business and/or subject-matter proximity.

[9] A special attention should be given to the extra effort asked to each partner in order to successfully collaborate. The sum of these efforts shouldn’t exceed the expected gains.

time, instructors' self-esteem and fear of judgment, preference to informal learning, need to avoid plagiarism, and the effort to work the layout [19]. Besides, in science, as stated by Hennesy [20], teachers' motivation to use ICT in the classroom is limited by a number of factors such as : lack of time to implement technology, limited access to reliable resources, a curriculum overloaded with content, no need to use technology for assessment, and a lack of guidance for using ICT to support learning.

In the European industry[10], blended learning is establishing itself as the benchmark training method with 76% of respondents of the European survey organized by CrossKnowledge and 47% of companies decided to expand its use in the short term [21]. Although companies claim they use blended learning, there are typically two parallel but different delivery forms : a classroom with an instructor or an e-learning environment without an instructor [22]. In corporations, technology application is seen as an opportunity to shorten the classroom session by expanding the work-based activities outside the classroom [23].

An UBC for the development of digital learning resources would benefit from industry financial capacities and technology leverage.

The principles of learning that apply in traditional education will of course apply equally to the design of technology-enhanced learning [1] [4]. That is the reason why, from now on, we use the didactic triangle in order to organize our discourse on engineering education in HEIs and corporations (see Fig. 1).

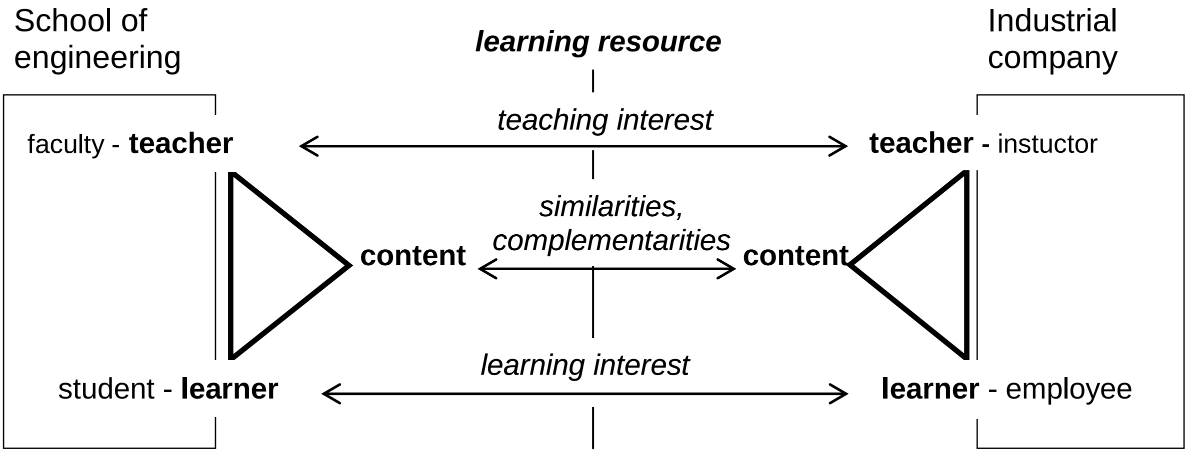


*Fig. 1*. The didactic triangle in the context of the study. The arrows symbolize the main factors that promote cross-organizational construction.

## 2.2 Engineering: the discipline knowledge

In the *Encyclopedia Britannica*, engineering is defined as "the application of science to the optimum conversion of the resources of nature to the uses of humankind". For Goldberg [24], engineering is "the social practice of conceiving, designing, implementing, producing, and sustaining complex technological artefacts, processes, or systems". In a global and knowledge-driven economy, it is considered that the transformation of knowledge into products, processes, and services is critical to competitiveness, long-term productivity growth, and the generation of wealth [25].

In academic engineering it is argued by some teachers that the separation of a curriculum into distinct applied science categories prevents students from developing

[10] Western Europe is the second market for self-paced e-learning with $6.1 billion reached in 2011 [26].

solving capabilities of open-ended problems [1]. Applied to design, it means that they can't cope with ambiguous and complex situations [1]. Consequently, throughout higher education, there is an on-going emphasis towards the development of problem-solving capabilities, meta-cognitive skills, critical thinking [22], together with an apprenticeship into a community of professionals (Sfard as cited in [22]).

### 2.3 The academic and corporate learners

Knowles developed a model of assumptions about adult learning [16]. Among the six principles of the model, three might not apply to university students for the following reasons. The first principle is the self-concept of the learner. According to Perry's post-Piagetian theory, development continues into adulthood and university should prepare them for self-directing and lifelong learning (Beston, Fellows, and Culver cited in [1]). The second principle is prior experience. Students lack of prior experience, both theoretical and practical, in the discipline subject-matter. The third principle is the motivation to learn. Intrinsic motivation, and the need for relevance, is important to deep learning. Here, prior experience acts as "climbing holds" would do for a "mountain climber". Flammer advocated the use of case studies in order to give students "a flavour of the reality of engineering" [1]. In addition to motivational implication for university students, the use of real-life and authentic situations is also beneficial for adult learning [16].

Mixing students and employees in learning communities would challenge and involve students in learning. It would promote a climate where the need to know is exposed before instruction, where students have active roles in methods and resources selection, and where they share responsibility for evaluating their learning [16]. It would also help to avoid silo thinking. As IDBM professor Mikko Koria said about multidisciplinary and cross-cultural projects, "students have to understand and appreciate differences in how others think" [10].

### 2.4 The teachers and the instructors

The first model of university[11] is the model of liberal education where the knowledge acquisition makes people free from handwork. In this model, the university departments tend to be relatively closed, with a hierarchical ordering of status, with fairly rigorous structures for the provision of curriculum, and it is made up of specialists who are unused to work in teams [1]. Therefore, in this scenario, the teachers have full responsibility for making all decisions about the content, the methods, and the sequence and assessment of learning [16] [22], Tardif & Lessard as cited in [19]. In the second model, the research model, universities organize their research and knowledge production according to the structures of disciplinary sciences [13] ; the teachers integrate their current research results into courses and the learning resources are their intellectual property [13] [19] [22]. The last model is the service university. In that model, HEIs serve the social advances and utilitarian knowledge ; faculty develop, maintain and cultivate professional relationships with their target industries [27].

Regarding companies, a large part of learning, around 80% according to Tough's and Cross' studies, is informal [28] [29]. Considering formal training, the course offer addresses business change and human resources development needs identified through competence-gap analyses [22]. Resources for in-house training are corporate property and they can be shared internally [22]. Technical training is often delivered by company's specialists themselves. It might happen that specialists don't have the necessary resources (time, budget), nor the knowledge or organizational

[11] Three university models have been described by Boisclair, Bourdoncle and Lessard's [5].

support to develop didactics approaches and to design instruction. As a result of unsuitable formal instruction, bad training delivery conditions might affect both trainers and students' motivation to learn [30].

Through Community of Practice (CoP) [31], by working jointly, faculty and instructors would learn from "teachers professional craft knowledge"[12], would expand their perception of the body of knowledge and of its application, and would open themselves to outside perspectives (professional associations, events, seminars…).

# 3 FUTURE DIRECTIONS: THE DESIGN-BASED RESEARCH

In this section we describe the constructivist approach in didactics and the design-based research that will serve for the next investigation phase of our research program.

## 3.1 Didactics and constructivism

According to Astolfi [33] the didactics approach considers the teaching contents as objects of study. Didactics identifies the main concepts used as references in the discipline, analyses their relations and relies on situational analysis to understand the construction of students' representations, the mental models used, the modes of reasoning, and how students decrypt teachers' expectations [33] (see Fig. 2).

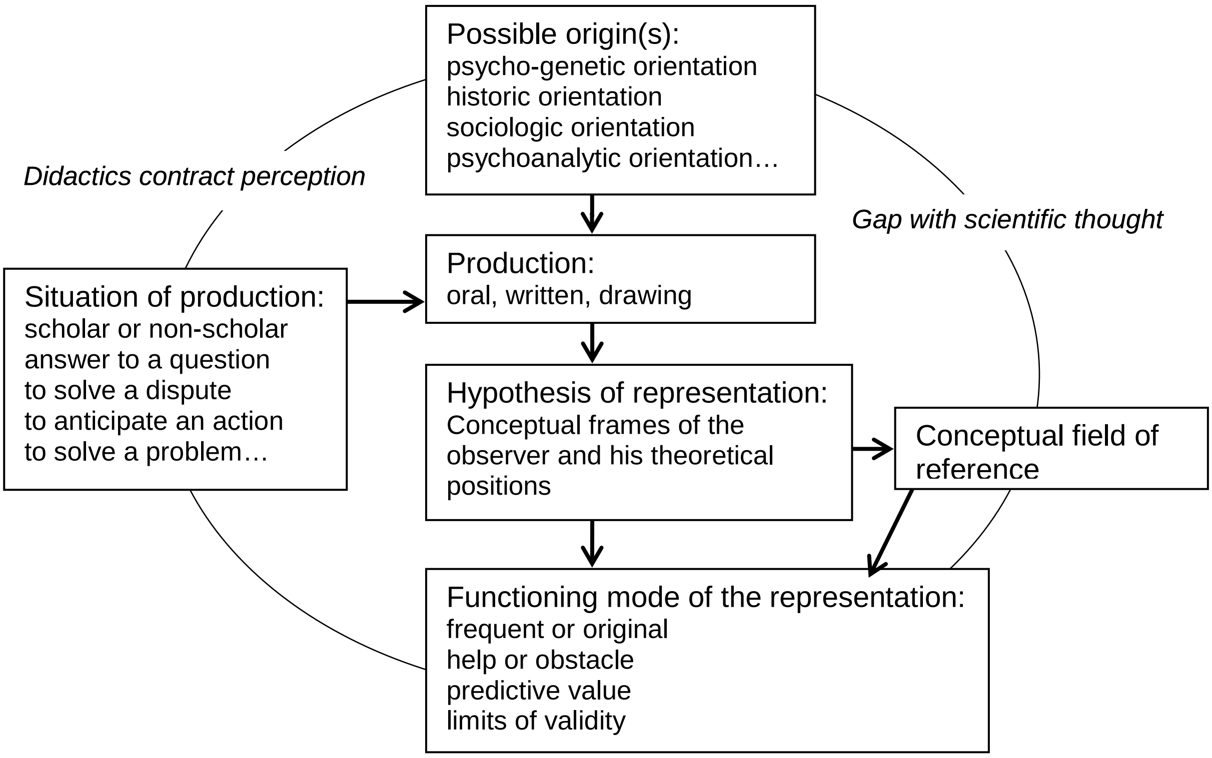


*Fig. 2.* Functioning modes of representations. Adapted from "Tableau II – Mode de fonctionnement des représentations" in [33][13].

[12] Brown and McIntyre developed a model based on the assumption that over a period of time experienced teachers have acquired substantial practical knowledge about teaching, and that they have 'craft knowledge' which is accessible to others [32].

[13] According to Houssaye, the concept of the "contrat didactique" [didactics contract], initiated by G. Brousseau in the early 1980s, concerns all the specific behaviour of the teacher which is expected of him/her by the pupil, and all the behaviour of the pupil which is expected of him/her by the teacher [32].

Constructivist approaches assume that all knowledge is constructed from the learner's previous knowledge [34], might it be true or false [33]. A constructive approach views instruction as a process to facilitate students' learning through a meaningful, contextualized, and active experience.

Significant studies are available on the effectiveness of using external static, dynamic or interactive representations in scientific learning. These results have to guide the development of technology-enhanced resources in engineering education. They analyse the impact of diverse computer-based representations on learners strategies [35], the cognitive foundations for designing interactive and multimodal learning environments [36], for designing multimedia instruction [37] [38], for understanding scientific graphs [39] and for choosing between static / dynamic representations [40].

### 3.2 Design-based research

Instructional design theory "offers explicit guidance on how to better help people learn and develop" in specific situations and it is design oriented [41]. In accordance with the constructivist didactics approach, deemed adapted for complex cognitive skills development in engineering, we plan to investigate the methods for the co-development of learning resources in the case of UBC. Design-based research will be used. Design based research is "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" (Wang & Hannafin cited in [42]).

In real world context, we plan to develop digital learning resources for a blended learning application in one engineering college and in one industrial company. This work will require collaboration among teachers, trainers and domain specialists ; it will use a mix of research methods and will test the instructional material [4] directly with the learners.

## 4 SUMMARY

In this paper, we used an international and multi-domain literature review in order to understand the ways academia and industry collaborate. We particularly considered why HEIs and corporations would benefit from joint learning resources development in engineering education. A conceptual frame, based on the didactic triangle, allowed a direct comparison between teaching and learning in both organisations.

The purpose of this study is not to draw conclusions from existing references in the educational sector, but rather to identify the main practices and opportunities before entering the investigation phase of our research program. Actually, we plan to use design-based research to further prospect, in real context, the main factors that support and prevent such UBC for digital learning provision in engineering. If necessary, a specific constructivist instructional design theory will result from this work.

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