Framework for the evolution of acquiring knowledge modules to integrate the acquisition of high-level cognitive skills and professional competencies: principles and case studies

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ABSTRACT
The changing profile of students, the expectations of business and the capabilities offered by Information and Communication Technologies (ICT) makes it necessary to change teaching practices, particularly in higher education. This paper proposes a methodological framework destined to force disciplinary course modules to evolve in order to integrate high-level cognitive skills and professional competencies. In this paper, we examine this framework in terms of the primary currents in educational psychology: behaviourism, cognitivism, constructivism and social constructivism. We present and analyse three case studies showing the evolution of three disciplinary course modules. We show that the lessons taught in these three modules are more motivating and more efficient, producing results that are closer to what employers are asking of their employees.

Keywords
Improving classroom teaching, Teaching strategies, Learning strategies, Collaborative learning, Pedagogical issues

1. Introduction

1.1. Diverse teaching difficulties

During our many years of university teaching in the three-year undergraduate program and the two-year Master's program in science and technology, we have noted that certain educational goals have been hard to reach, especially since the students' involvement in the traditional types of courses (e.g., lectures and seminars) has declined over the last several years (Eastman & Reisenwitz, 2006; Cole, 2009). For example, educational goals are hard to attain when teaching students about conceptual knowledge, which includes a lot of theoretical definitions and models. Many students refuse to learn this theoretical knowledge. In fact, this kind of knowledge makes it difficult to set up technical learning activities, and it often does not have any immediate practical applications

Finally, based on our university teaching experience, another difficulty, especially in technology, is the underestimation of the importance of acquiring and practising interpersonal skills and teamwork, which are nonetheless required by companies (Gunasekaran, McNeil& Shaul, 2002). This is particularly detrimental in software development, in which teams are the foundation of the organization due to the increasing complexity of software development projects, which makes these projects unachievable for a single individual (Sancho-Thomas, Fuentes-Fernández & Fernández-Manjón, 2009). Companies prefer engineers with acceptable technical skills, who know how to "connect" with the activities, processes and people in the company, rather than technical specialists with no people skills, who are often isolated and out of touch with the reality and the objectives of the company. Students rarely practice and acquire such high-level competencies, especially in the numerous computer training programs, in which both the teachers and students feel the priority should be technical skills. Abet (Abet, 2000) lists these competencies as the fourth out of eleven outcome criteria for engineering: "*An ability to function on multi-disciplinary teams*"; he divides these criteria into four behavioural dimensions: *collaboration*, *communication*, *conflict management* and *self-management* (Besterfield-Sacre, Shuman, Wolfe & Atman, 2000a; 2000b).

1.2. Discipline versus competencies

The above phenomena have intensified recently. In fact, until the 1980s, companies specified their recruiting needs in terms of functions to perform, which they then divided into tasks and skills (Raynal & Rieunier, 2001, p110). This corresponded to the definitions of university programs, structured according to discipline. However, this structured system found itself at odds with reality because the work in companies has become more open (Curricula-Vitae, http) and is now expressed in terms of complex requirements (Pisa, 2005). Thus, individuals have had to cope with the need to better manage their interdependences, to have a greater responsiveness to the company's needs, and to manage a variety of missions (Pisa, 2005).

Nowadays, many companies think in terms of competencies, which have generated a proliferation of heterogeneous definitions (Mc Clelland, 1973; Katz, 1974; Pisa, 2005; Le Boterf, 2006). We will retain the one formulated by Perrenoud (Perrenoud, 1999): "*the ability to act efficiently when confronted with a family of situations that are controllable because people have the knowledge, know-how and social skills and the ability to use them effectively, in time to identify and resolve genuine problems*", particularly in a job or profession. The lack of involvement of our students in our course modules can be explained by the gap between the education supplied, expressed in terms of *discipline*, and the expectations of students and professionals, expressed in terms of *competencies*.

To meet these new challenges, we propose in this paper a framework that will allow us to make our knowledge acquisition modules evolve, by adding disciplinary competencies in order to provide the most appropriate modules to students, companies and educational policy. These additions integrate professional, methodological and meta-cognitive competencies and can be an opportunity for teachers to lead students to think about their relationship with their courses. Although the curricula are accurate in terms of the knowledge that has to be acquired, they are less forthcoming about the competencies and attitudes to be acquired, about the nature and techniques of learning, and about the value and use of the acquired knowledge. Integrating these competencies will allow us to develop our courses to meet the challenge of changing profiles of students who are less and less traditional (Miller & Miller, 1999; Cole, 2009).

This paper is organized as follows. In Section 2, we position our approach in terms of the primary currents in educational psychology. In Section 3, we describe our practical framework, which should allow teachers to make their courses evolve according to 7 principles. In Section 4, we introduce three case studies for course modules in which our framework was implemented, and we show the main changes brought about on the modules compared to the way that they were originally taught. In Section 5, we examine how the 7 principles influenced the case studies presented, and we report the educational benefits. In Section 6, we offer our conclusions and perspectives for future research.

2. Our approach in relation to the primary currents in educational psychology

In this section, we briefly review the four main currents of educational theory and situate their principles in relation to our approach.

2.1. Behaviourism

In French universities, pedagogy is historically based on a behaviourist approach. (Thorndike, 1911) introduced this approach in the early twentieth century.

Watson (Watson, 1913) also encouraged the use of this approach; he was inspired by the 1904 Nobel Prize winner Ivan Pavlov's work on respondent conditioning (Pavlov, 1927). Between 1930 and 1950, Skinner continued on with this behaviourist approach, introducing operant conditioning (Skinner, 1935) and programmed instruction (Skinner, 1968). This approach is still dominant in the field of education, thus insuring knowledge of behaviorism and its founding documents are well known (Green, 2009; Raynal & Rieunier, 2001; SEP, 2006).

From the teacher's operational perspective, it is possible to reduce this approach to a few principles:

1) Knowledge is an objective reality and the teacher determines it completely.
2) This knowledge is divided into elementary knowledge units, which are expressed in content to be known and ability to solve problems directly related to that content.
3) Learning is done by learning the elementary knowledge, thus insuring the educational objectives are achieved.
4) Assessment is done according to the teacher's model, and therefore is objective. It is quantifiable, individual and most often written.
5) Learning is conducted by the presentation of the teacher's knowledge.
6) The learner learns by listening and reading, then trial and error followed by reinforcement.

This form of pedagogy is teacher-centered and necessitates individual work from the learner. It is appropriate for mass education, although it inherently does not provide any response to the question of high-level competencies. Although this pedagogy still remains valuable, even essential, for many situations, we want to propose a conceptual framework that allows it to evolve.

2.2. Cognitivism

While the subject of behaviourism is behaviour, that of cognitivism is to be able to model and explain the mental activities that generate a behaviour. Part of cognitive science, cognitivism postulates that the human mind is like a machine for processing information. One stream of knowledge, called *computo-symbolic*, is based on the sequential operation of computers and distinguishes short-term memory from transient memory and from long-term memory. Appearing at the same time as the first but acknowledged later, another stream, called *connectionism*, likens the brain to a neural network with the possibility of parallel computation.

From the pedagogical standpoint, cognitivism assumes that the learner interprets the environment according to its mental schemes to internalize new knowledge. Gagne's nine events of instructions can serve as a guideline to a constructivist pedagogy (Gagne, 1965): 1) gain the learner's attention, 2) inform learners of the objectives, 3) stimulate recall of previous learning, 4) present the content, 5) provide for learning guidance, 6) elicit performance, 7) provide feedback, 8) assess performance, and 9) enhance retention and transfer to the job. From a practical standpoint (Kruse, 2009), this approach suggests that the teacher begin lessons with a provocative question or an original fact, present first the objectives and the lesson content, connect the new knowledge to previous knowledge, encourage learners to organize the knowledge, and present the content in different forms and different paths, for example. Even though our approach can follow in the same path as cognitivism, it also privileges action and constructivism.

2.3. Constructivism

In our approach, we enriched the cognitivist approach by using constructivism, established on a theoretical level since the 1930s, in particular by Bruner (Bruner, 1960), Piaget (Piaget, 1970) and Vytgotsky (Vytgotsky, 1978). The constructivist approach considers that learning results from the interaction between learners and their environment and thus is not only a result of the influence of the environment. It gives priority to the knowledge that depends on the person, to the knowledge that is codified and fixed by a social group.

In our framework, we consider students as active organisms that seek meaning and significance. This active knowledge processing system interprets information and the outside world based on its personal representation. The students learn best when they can contextualize what they learn for immediate application, which allows them to acquire personal meaning. Thus, we promote active non-directive learning, recommending giving priority to a real learning context and a *supportive* teaching style rather than an *interventionist* teaching style. We give priority to guided discovery, to collaborative learning and to a project approach. The teacher's task is to offer students a rich and stimulating learning environment. The teacher becomes a facilitator and a mediator more than a knowledge supplier, and the competencies are addressed holistically rather than by cutting them into smaller goals.

2.4. Socio-constructivism

Our framework also incorporates some of the principles of socio-constructivism (Vytgotsky, 1978). We recommend using social interaction to help construct knowledge and mediation tools, particularly Information Processing and Communication (ICT) tools (e.g., wikis, blogs, forums), to mediate the learning processes. Thus, in our classes, we encourage the collaborative learning skills that are the key to finding future jobs (Looi, Cheng & Ng, 2010). The success of such an ambition does not come all by itself (Cole, 2009).

Obviously, a pedagogy that is totally active and non-directive, or conversely totally passive and directive, is an illusion. First, there is evidence that progress only occurs by integrating different currents within a single pedagogical style: behaviourism, cognitivism, constructivism (Hoic-Bozic, Mornar & Boticki, 2009) and socio-constructivism. Second, it is necessary to deal with applying these diverse currents in an ecological situation, or, in other words, in a real situation. In the next section, we propose our framework for developing learning modules that can meet those two conditions.

3. Our framework for the evolution of course modules

The problem of educational change is twofold. It is necessary to improve the quality of student learning. It is also necessary to consider the realities and offer teachers an approach that allows them to take into account the learning situations they encounter. The purpose of the proposed approach is to offer, for an university context, a response to the crisis in education, providing a framework for the evolution of existing courses. This framework is based on seven basic principles, as shown in Figure 1. In this section, we explain in detail the seven founding principles this framework is based on.

1. Redefine the roles of teachers and students
2. Introduce pedagogical mini-projects guided by cooperative learning
3. Alternate individual work and group work
4. Foster a shared understanding of the activities proposed to students
5. Use ICT to support teaching
6. Evaluate the knowledge acquired by students regularly
7 Analyze the teaching process

Fig. 1 – Seven basic principles

Starting from a "traditional" course module, the seven basic principles are used to make the traditional module evolve towards a final module. In addition to acquiring the disciplinary knowledge referred initially, this final module will also help the students to acquire high-level cognitive skills and professional competences (Figure 2).

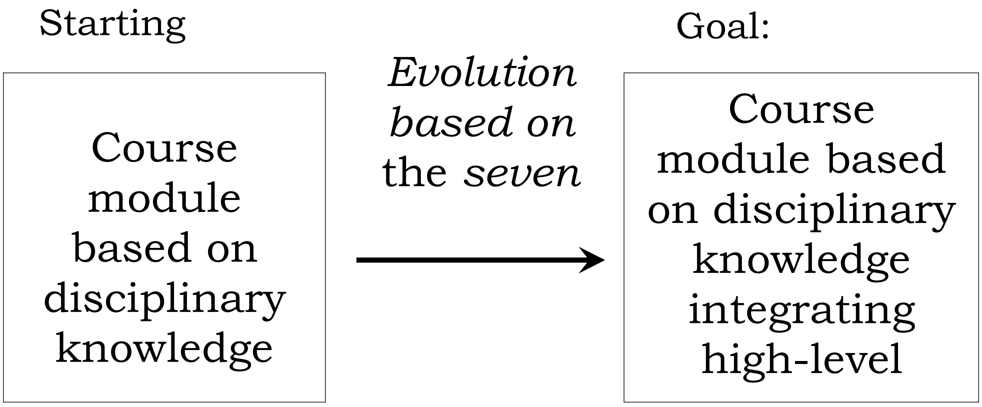


Fig. 2 – Context of instructional evolution

Another of our objectives is to improve student motivation, learning quality and the teacher's role diversity. Changes may take into account all these principles or only some of them. Similarly, depending on the context, the degree of influence of a principle can vary. Our approach allows an implementation that is simpler, more gradual and more adaptable to the context.

In the rest of this section, we summarize and explain the seven principles presented in Figure 1. Each of the seven principles is applied to a traditional module to make it evolve.

Principle 1: Redefine the roles of teachers and students

Although the two main roles — teacher and student — are still recognizable, they have evolved. Teachers still have the traditional roles of evaluator and knowledge provider, but now they must be completed by other roles. Now, teachers must also assume the role of project conductor (Dillenbourg & Tchounikine, 2007). Teachers should establish structured scenarios that will facilitate group organization and allow them to satisfy the objectives of one or more mini-projects (see principle 2) incorporated into a given module. For this reason, teachers must play many roles: (1) *facilitator*, who helps the students make choices; (2) *manager*, who encourages the group to be productive; and (3) *organizer*, who helps the students break down the tasks. In turn, the teacher's responsibility as a knowledge provider evolves. Although teachers remain the guarantor that the knowledge is relevant, students can intervene before or during project to bring new pieces of knowledge. Teachers may thus feel undermined by the student productions or, on the contrary, may feel their authority has been consolidated via their explanations of any gaps in any knowledge that the students have brought. These changing roles make it necessary for teachers to have a more sophisticated pedagogical process, while at the same time maintaining their role as academic referee.

Meanwhile, students must be aware of their place and their active and cooperative role in this new teaching style. Although collective learning allows the development of ideas that are difficult to attain through individual thought, collective learning does not happen on its own. It may be necessary to present a certain number of proven principles to students, such as the necessity of positive interdependence and the recognition that collective success depends on individual achievements (Johnson & Johnson, 1980; Gillies, 2004). The students may learn their new role separately, as part of another lesson, or during the first sessions. This new student awareness helps the students to situate themselves in the new system, to align their future efforts, and to coordinate themselves with the rest of the group, team or class.

Principle 2: Introduce pedagogical mini-projects guided by cooperative learning

Our framework is structured in a context of active learning supported by a mini-project. It is, of course, a special kind of project in which the main objective is knowledge acquisition; content production is also often directly related to this objective. The nature of the production can be varied: produce a slide show that will then be presented to an audience, develop a thematic report, make a mock-up, and so on.

Specifically, the project aspects considered are:

1) joint production of an object,
2) sharing tasks and responsibilities,
3) respecting deadlines, the teaching sessions are quite limited in terms of time, and
4) analysing the activities carried out and the knowledge acquired, both as a group and as an individual.

The project objective is knowledge acquisition. We recommend a collaborative learning process, in which the students are responsible for their learning, as well as the learning of others (Gokhale, 1995). One of the techniques used is to ask students producing games for the other students, using such software as found on the *Hot Potatoes* site (Hot Potatoes, http) to create multiple-choice questions or fill-in-the-blank texts, to name but a few of the possibilities. The goal of the games is that the other class members learn course content. There is a double learning effect. First, the students learn a first time when designing the game; then, when playing games designed by their classmates, students learn a second time. If circumstances permit it, especially if there is enough classtime spread out over time (e.g., thirty hours spread over several months), it may be interesting for students to complete a project, including all the project life cycle phases (i.e., initiation, planning, control, construction and closing) (PMBOK, 2008), resulting in traditional deliverables: project demand, framework memorandum, reports and balance sheets. Inspired by *team-based learning*, this principle requires classtime spread out over several months (Michaelsen, Fink & Knight, 2002; Gomez, Wu & Passerini 2010).

Principle 3: Alternate individual work and group work

Inherited from the Greek civilization, the pedagogy used in our universities is historically based on a behaviorist approach, which inherently results in individual work (Dumont, 1992). We recommend introducing group work as part of an alternating pattern: individual work – group work. This alternating pattern is found in many cooperative learning methods, including JigSaw (Aronson, Blaney, Stephan, Sikes & Snapp, 1978), JigSaw II (Slavin, 1980) or Team Accelerated Instruction (Slavin, Leavey & Madden, 1986).

This alternation allows different roles to be assigned to group members and empower them with respect to themselves and with respect to the group (Martinez, Herrero & Santiago de Pablo, 2010). It also provides an opportunity for the teacher to establish interdependence between students (Aronson et al. 1978) as a support for cooperative learning (Johnson et

Johnson, 1980). The sessions devoted to individual work can provide opportunities to develop a differentiated pedagogy or to upgrade individual skills (Slavin et al. 1986). This alternation seems effective at increasing motivation (Gomez et al. 2010) and promote interaction between students, the teacher and the knowledge targeted (Martinez et al. 2010). In addition, if the alternation is connected to production of individual and collective texts, the contributions of each group member can then be discussed and thus be a factor in the individual evaluations, which are known to have an impact on the success of collective work (Davis, 1993). In general, the alternation can also offset the disadvantages of collective work, including its slowness (Cooper, Prescott, Cook, Smith, Mueck & Cuseo 1990; Eastman & Reisenwitz, 2006) or the fatigue it generates. Students may need the calm of the individual work to better focus. This alternation may lead to inter-group competition, with all its expected risks (Slavin, 1977).

Principle 4: Foster a shared understanding of the activities proposed to students

Collective work gives rise to contradictions and tensions between the different stakeholders. These tensions and contradictions can interfere with work because they can cause the worsening of the activity dynamics: coordination, cooperation and co-construction (Bardam, 1998). We recommend that part of the class be devoted to ensuring that students understand the requested individual and collective learning activities. Introducing and understanding the rules of the game helps to creates a need and motivates students to perform the activities proposed (Kruse, 2009) according to Gagne's pedagogical practices (Gagne, 1965). For example, if a teaching method is proposed to students, the teachers must insure that it is understood, at least its broad outlines, before being put into practice. Sometimes, it is necessary to provide a preliminary educational activity to explain a new teaching method.

This shared understanding should focus on both goals and the means used and can be developed in various ways. It can be developed through individual work on the procedures to carry out or through constructing a collective representation of the teaching method. A key element of success seems to be providing students with examples similar to deliverables required by the second principle (e.g., framework memorandum, meeting minutes, reference slide shows).

Principle 5: Use ICT to support teaching

Through its capacities for storing, disseminating and processing information, ICT allows educational attractive activities to be implemented. These activities can be done inside the classroom or, using the Internet, outside the classroom: at home, at a company… in fact, anywhere. They also help establish new partnerships and roles (e.g., the group, the outsider, the community) and provide these new roles with the means to communicate. Different types of communication become possible: teacher-student, student-student, student-community, student-content, and so on. Many benefits (Wagner, 1997) can be expected concerning participation, feedback, knowledge retention and development, student evaluation support, student self-regulation, motivation, negotiated understanding and team building. Through its application storage capacity, ICT allow the reuse of student products.

There are different levels of technology available. For example, basic **and** easy-to-implement tools, such as the existing commercial websites on which analysis can be conducted; tools for prototyping human-machine interfaces; and/or tools for editing text and layouts can sometimes be preferable to technologically advanced e-learning tools. These advanced tools are known to be cumbersome to implement and require good level of coordination of responsibilities (Wagner, Hassanein & Head, 2008) and are sometimes little used (Holbert & Karady, 2008).

Nevertheless, it remains true that the e-learning wave (CCCEP**,** 2001), as well as the various programs designed to provide all educational communities concerned by Learning Management Systems (LMS) and open source applications, leave no doubt about the availability and importance of ICT and e-learning in courses and university life in general. Let us mention the three best-known systems: *Sakai* (Sakai, http) (created by four American universities: MIT, Indiana University, University of Michigan, Stanford University), *Moodle* (Moodle, http) and *Claroline* (Claroline, http) (used at the Open University of Louvain-la-Neuve in Belgium).

Principle 6: Evaluate the knowledge acquired by students regularly

In addition to its strategic nature (Gravestock & Mason, 2004), evaluating learning is an important, even essential, part of the educational process (Sander-Regier, Mehry & McColl, 2007). Evaluation should be a focal point in all teaching methods, but unfortunately, there is not enough knowledge about it (Shepard, 2000). Many questions arise: Is it a way to evaluate learning or a way to control the number of students? How to integrate acquisitions with natures as different as knowledge, skills and attitude? What should be evaluated? When should these things be evaluated? This sixth principle requires a more regular work by the teacher, who must promptly correct the evaluations. It also requires increased quantities of correction and good organization but provides a feeling of professionalism.

Our regular interaction with students and their replies to educational questionnaires at the end of end of modules show that students ask for regular evaluations on limited subjects. They support formative assessment prior to summative assessment. These evaluations provide regular feedback to students to allow them to better situate themselves in relation to what they are learning in the module. In addition, the results of these evaluations are also an opportunity for dialogue between students and the teacher, leading to mutual understanding of the difficulties. The fact that the subjects are limited permits students to gradually understand their learning strengths and weaknesses. Remedial measures can be undertaken easily and quickly and thus efficiently. Clearly, this is what is recommended by *Mastery Learning* (Carroll, 1963; Bloom, 1971; Carroll, Bloom & Hunter 1987). This remediation may even be undertaken as part of a specific external remedial program, thus allowing a real differentiated instruction.

The clear announcement — if possible, in writing — of the things that students are expected to learn and how they will be evaluated (including a range of marks) has many advantages. In addition, if the content is discussed with the students, this will lead to a better understanding and mutual trust. Such a system allows clear, enforceable and negotiable rules to be set with other stakeholders (e.g., university, employers, ministries). The system then provides a way to avoid the "*constante macabre*" (Antibi, 2003), which underlines that, in order to remain credible, any evaluation has its share of bad marks.

We recommend a student evaluation that addresses the three types of learning identified by Prime (Prime, 1998) and integrates them into a single evaluation. In this context, we recommend that one part of the evaluation take into account the student's use of the proposed teaching method. Evaluations should be multifaceted. They can be individual or collective, written or oral, and/or concern product behavior or product quality. For group activities, the evaluation should not only be collective but also individual, evaluating the attitude during the mini-projects, the quality of individual written texts required, and the behavior of everyone in public presentation of the work, for example.

Principle 7: Analyze the teaching process

The previous principles provide a framework for creating learning scenarios. However, the teacher still assesses whether or not the educational goals have been attained. Feed-back from the other stakeholders is necessary, especially with the students, for example, using questionnaires and semi-structured interviews. These techniques allow the teacher to introduce the concept of participatory educational design and its process.

There are protocols designed to insure that these techniques are effective (Sander-Regier et al. 2007). For example, these techniques have to follow well-tested rules. It is not a question of allowing students to freely criticize the teachers or lessons. In addition, if they are announced early to the students in the course module, these feedback techniques strengthen the feeling among students that the teacher is particularly interested in what they say. Such practices are known to improve the student performance (Mayo, 1945; Olson, Verley & Santos, 2004). Then a feed-back is also necessary with the other stakeholders (i.e., the university management, the business world, future employers).

In the next section, we present the tests of our framework. We provide three case studies that are representative of university teaching modules and are significantly different in terms of their initial objectives. We show how they evolve after applying the seven basic principles.

4. Case Studies

In this section, we describe three case studies in which we implemented our framework, according to the mindset shown in Figure 3. For each case study, we begin by describing the context of the specific module and then specify how we used the seven principles explained above in the module. Finally, we provide details about how we constructed the final teaching scenario.

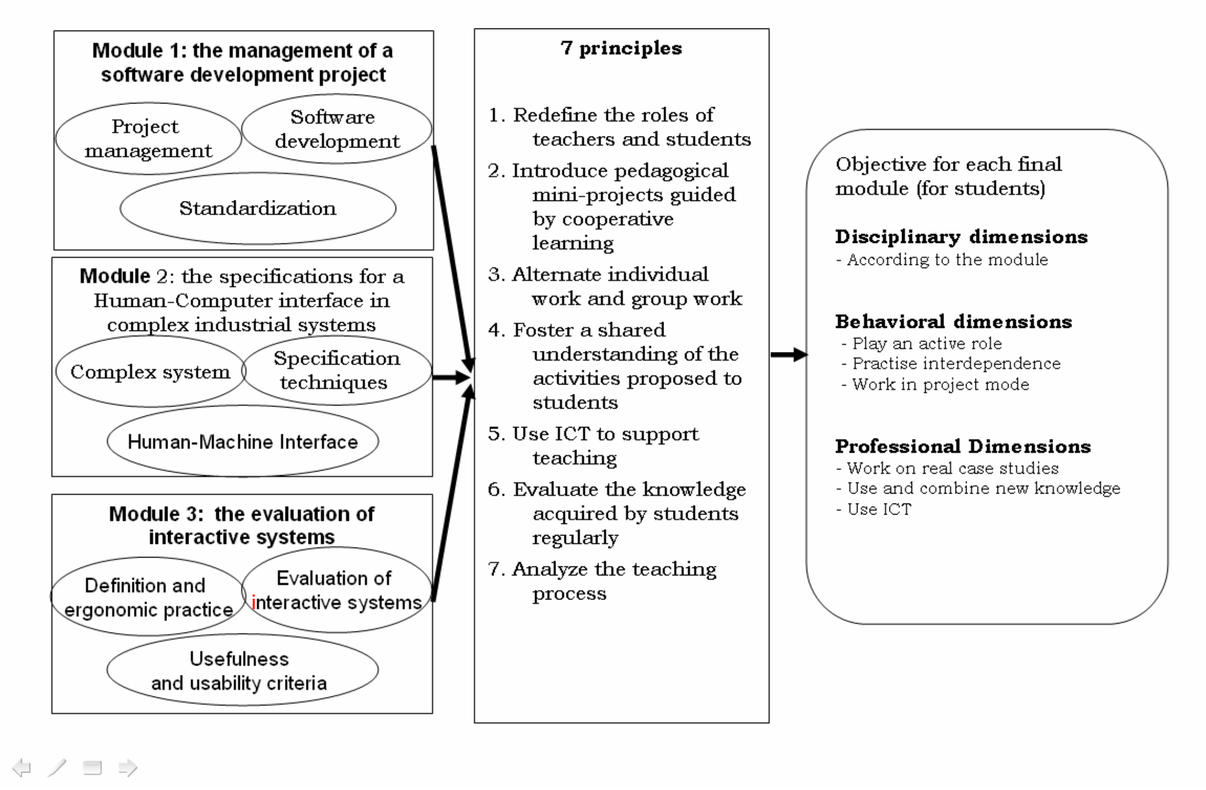


Fig. 3 – Case studies

4.1. Module 1: the management of a software development project

4.1.1. Context

The first case study concerns a project management module intended for students in the final year of the Bachelor's degree course. One objective of this module is to make them learn about a number of conceptual models, such as a software quality model (ISO/IEC 25000, 2005), a software engineering model (SWEBOK, 2004) or project management model (PMBOK, 2008). They have to assimilate the state of the art of some conceptual schemes established by the international engineering community.

This module was made necessary by the complexity of network development projects, the rapid evolution in this domain and the interconnection of the fundamental problems in computer science and project management. These "high-level" models allow students to better understand the issues of network projects. This knowledge makes students more independent and more able to fit into a team; these are essential qualities often required by companies (Gunasekaran, McNeil & Shaul, 2002). The sessions, which are held in a computer room, include twenty students. Each student has a recent computer with Internet access.

4.1.2. Module specifications based on the 7 basic principles

We immediately rejected an approach that would make the students study these standards directly. We made this choice not only for cost reasons — most standards have considerable financial costs — but also for obvious pedagogical reasons. We also rejected the behaviourist approach that we had chosen for another degree a few years previous. For this degree, we had used lectures. Although we and our colleagues had tried to make our slide shows attractive, this attempt was disappointing both in terms of examination results and student attention in the small group sessions. In addition, teachers felt devalued and discouraged by this situation. In order not to reproduce this situation, we decided to implement a new teaching style. The seven principles described in section 3 were set up and applied to the module. The module's specifications are shown in Table 1.

Table 1 – Specifications for the module, "Software development project management"

Principle	**Set up for module 1**
Principle 1: Redefine the roles of teachers and students	- The teacher proposes a pedagogy based on a group project. Each concept to be explored (e.g., software quality) is the subject of a mini-project. The teacher's role is to supervise, motivate and assist students in completing their mini-projects. These mini-projects take 75% of the face-to-face time. In the last quarter of the time, the teacher resumes the traditional role of knowledge provider and evaluator and gives a traditional lecture of thirty minutes. - Students must find, criticize and present the knowledge required by the teacher. They have to organize themselves in teams, respecting the teaching style dictated by the pedagogical strategy (see Figure 4). The students can participate in defining the evaluation criteria for some work, and, in an advisory capacity, evaluate some of the work of other teams.
Principle 2: Introduce pedagogical mini-projects guided by cooperative learning	- Completing the mini-projects is part of the knowledge acquisition process. To complete them, a basic project management method is proposed. These mini-projects are worked on during the group sessions (groups of two to five students) and, if needed, completed at home. At the end of the project, one or two teams show their project results to the rest of the group. - The pedagogical rules set by the teacher explicitly mention cooperative learning. Although this learning style did not count towards the final mark, the students are regularly encouraged to put it into practice.
Principle 3: Alternate individual work and group work	- Every phase of collective work is preceded by a phase of individual work (see Figure 4). Students must submit their individual work on an e-learning platform (i.e., Moodle). - For these group projects, the individual marks are composed of a mark assigned to the group and a mark based on the attitude of the individual student and his/her personal work. These marks are subsequently incorporated into each student's individual mark.
Principle 4: Foster a shared understanding of the activities proposed to students	- In a document of several pages, the teacher proposes the rules of the new pedagogy. The beginning of the course module is devoted to studying this new pedagogy. Each student has to reformulate the explanation of the pedagogy given in the form of a graphic model of his/her choice using his/her choice of tool (e.g., Freemind). - The models thus made are put on the e-learning platform. Students are then asked to assess strengths and weaknesses of models of their colleagues. - The students are regularly asked about how the meetings were conducted and the appropriateness of the controls and evaluations.
Principle 5: Use ICT to support teaching	- The Internet is used to conduct the research for the mini-projects. The students regularly propose new knowledge, which is validated by the teacher or not.

	- Some of the mini-projects result in deliverables (e.g., slideshows, posters, electronic quizzes, reports), produced using ICT, (e.g., such tools as PowerPoint, Word, Hot Potatoes and/or FreeMind). - The group sessions, the mini-project products, and the use of the teaching resources are monitored using the Internet. At any time, anyone can file or access a report, for example, on the e-learning platform Moodle (Moodle, http), which is especially rich in tools (e.g., filing documents, handing in assignments, wikis, blogs, databases, glossaries).
Principle 6: Evaluate the knowledge acquired by students regularly	- At the end of the mini-project, students are required to present their work publicly. These presentations are evaluated both individually and collectively. - Each mini-project ends with a written exam. On average, four hours of face-to-face time resulted in a 30-mn exam. - The students' attitude during the sessions is evaluated. It should be noted that, in practice, this evaluation is not included in the final mark. - In each session, students are asked to submit their work and their reflections on their behaviour. This work can serve as the basis for an evaluation discussion between the student and the teacher.
Principle 7: Analyze the teaching process	- Students are regularly asked how the meetings were conducted and the appropriateness of the controls and evaluations. - At the end of the module, the students complete a questionnaire on how the meetings were conducted and pedagogical style. - The students' feelings about their learning and the pedagogical style are gathered through informal discussions.

4.1.3. Final teaching scenario for module 1

By applying the basic principles, we were able to propose a scenario based on mini-projects completed by teams of two to five students. There were 6 main learning phases: a) distribution of the subject and a 3-page document explaining the pedagogy to be followed; b) group analysis of the pedagogy; c) completion of a mini-project by team of two to five students, using information on the Internet and/or any books available; d) public group presentation of a slideshow summarizing the group's research; e) a traditional 30-minute lecture by the teacher that serves as a reference for the exam; and f) written exam as a test of the individual's knowledge. In addition, each team member had to produce a number of texts on the work he had done individually, which was included in the final mark.

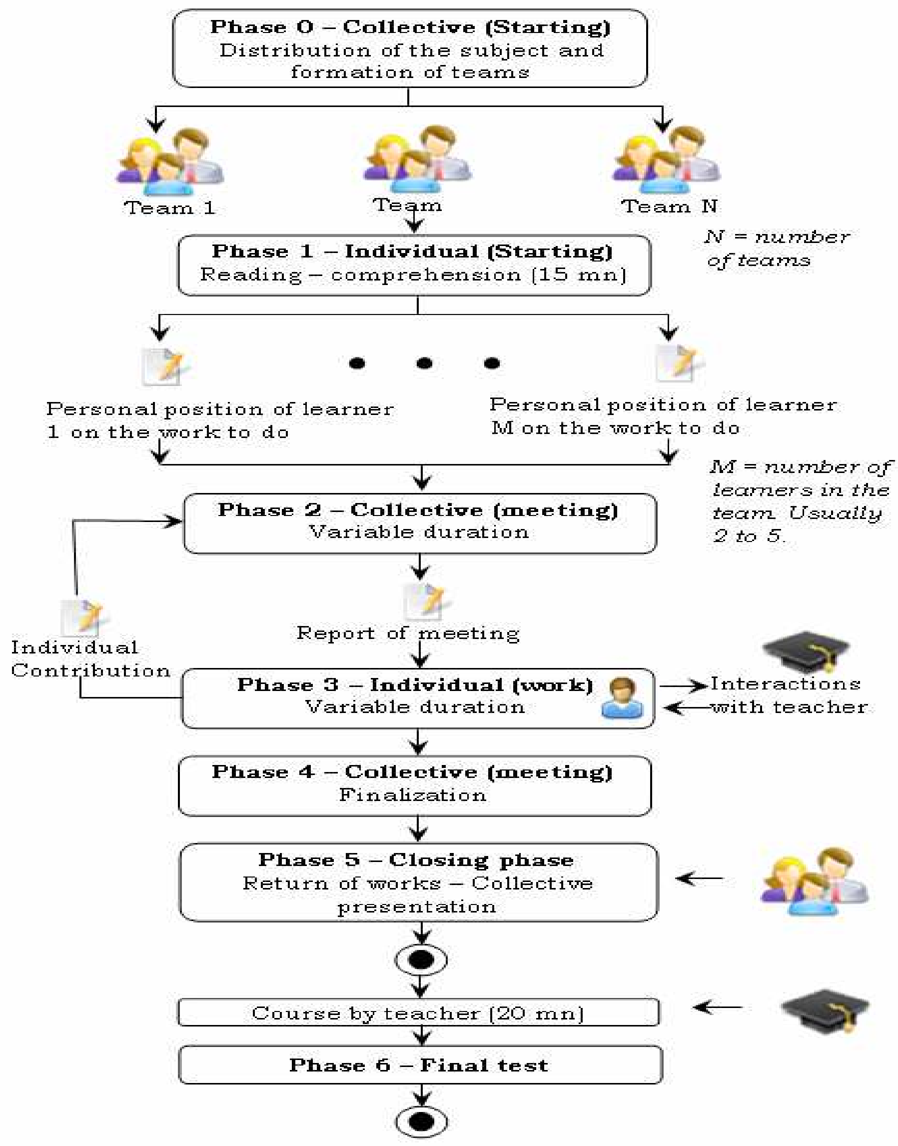


Fig. 4 – Scenario for module 1 based on the basic principles

Figure 4 shows the broad outlines of this scenario. Students were graded on the individual written tests (50%) and on their interactions and their individual and collective production during the sessions (50%).

4.2. Module 2: Human-Computer Interfaces for Supervision

4.2.1 Context

This second case study concerns a module about the specification of Human-Computer Interfaces for industrial system supervision. This module is intended for post-graduate students in the field of Automation. The Human-Computer Interfaces must be used in specialized control rooms by human operators, who have to monitor, diagnose and intervene in industrial systems. The interface design must integrate the state of the art in information presentation modes and the ergonomic knowledge from the field of Human-Computer Interface (HCI) design for industrial systems (Rasmussen 1986; Kolski, 1997).

This module is necessary for students because the needs in this area are very important since most industrial systems are equipped with control rooms. The projects dedicated to designing human-computer interfaces for supervision are most often done by a team, who should consider various ergonomic, safety and productivity criteria. In this module, the sessions take place in groups of about twenty students, who meet face to face.

4.2.2. Module specifications based on the 7 basic principles

We rejected the traditional approach that focuses primarily on acquiring knowledge about this vast and complex domain. It would have been possible to start with a theoretical description of current knowledge and offer students a set of exercises to permit them to explore this knowledge in more depth. This approach was judged insufficiently effective on our first attempts. We therefore decided to establish a pedagogy that was more attractive for both teachers and students. The seven principles described in section 3 were thus established and applied to the module. The module's specifications are shown in Table 2.

Table 2 – Specifications for the module, "Human-Computer Interfaces for Supervision"

Principle	**Set up for module 2**
Principle 1: Redefine the roles of teachers and students	- The teacher proposes an educational project integrating a simulation with role-playing. During the first sessions, the teacher has the traditional role of knowledge provider, explaining the knowledge essential to the field of HCI design. Then, the students are asked to meet in groups of 3 to 5 students to work on a real complex case study. Following a simulated call for tenders, these groups compete with one another to win the tender. During these sessions, the teacher plays the role of a human operator available to answer the groups' questions as to the needs the human operator with regard to the human-computer interfaces in the control room of a plant. The teacher also plays the role of the evaluator during the final session. - Students must exploit the knowledge available to produce the HCI design specifications. They also have to organize themselves in order to analyze the complex case, produce the HCI design specifications, and present them orally to the teacher and the other groups. Consequently, each group member also plays the role of evaluator during the final session.
Principle 2: Introduce pedagogical mini-projects guided by cooperative learning	- The focal point of the module is a mini-project that is part of the knowledge acquisition process. This mini-project has to be conducted over three sessions and completed outside the session by the groups of 3 to 5 students. At the end of the mini-project, each group presents the HCI design specifications in front of the teacher and the other groups. - The teacher establishes the pedagogical rules, explicitly mentioning cooperative learning.
Principle 3: Alternate individual work and group work	- Each student must first focus individually on the domain knowledge. - During the mini-project, even though the teacher primarily plays the role of the human operator available to the groups, he nonetheless also insures that each student participates actively in the group's work. - During the group's oral presentation of the specifications, each group member must play an active role in the presentation. During the evaluation phase, each student is asked to speak individually. - Each group is marked as a group, with a ranking among the groups, in order to focus on the group's shared responsibility.
Principle 4: Foster a shared understanding of the activities proposed to students	- The rules are explained orally at the beginning of the module to all students. - Early in the mini-project, each student is given a detailed description of the industrial process for which each group is asked to provide a HCI design. - Then, at each mini-project session, the teacher insures that the work is going in the right direction through a rapid but regular examination of the progress made on the HCI design specifications. The teacher also insures that the students understand all the objectives and the oral and written output expected.
Principle 5: Use ICT to support teaching	- Students are asked to use their choice of an HCI generator, whether or not it is specific to the field of industrial supervision. In fact, the goal is to produce a professional quality report, written with a professional text editor, containing representative snapshoot screens of the HCI graphics. - All the oral presentations are supposed to be made using a professional presentation editor (e.g., PowerPoint, OpenOffice editor).

Principle 6: Evaluate the knowledge acquired by students regularly	- During the mini-project, the group's progress is regularly evaluated by the teacher, which leads essentially to oral recommendations. - At the end of the mini-project, students are required to present their HCI design specifications in public. - The students are marked on both the HCI design specifications and the oral presentation. - At the end of the module, there is also an exam. The mini-project counts for 20% of the final mark.
Principle 7: Analyze the teaching process	- Interviews are used to gather the students' feelings. Observations: - The students were unanimous in their assertion of the effectiveness and interest of such a learning process. - The absentee rate was almost equal to zero during the nine years during which the module was taught, which was not the case for the other modules taught in this degree program. - An in-depth analysis of 64 reports produced over these nine years was conducted, which overall demonstrated the very satisfactory quality of the reports from the students (Kolski, Sagar & Loslever, 2004a; 2004b; Kolski, Loslever & Sagar, to appear).

4.2.3. Final teaching scenario for module 2

By applying the basic principles, we were able to propose a scenario based on mini-projects completed by groups of 3 to 5 students. Each group was competing to respond to a simulated call for tenders issued by a fictitious company. There were 5 main learning phases: a) description of the module and the pedagogy used and lecture presenting the domain knowledge, b) mini-project, including role-playing, with the objective of generating HCI specifications; c) group presentation of the specifications themselves, with a collective evaluation; d) results presentation, with an examination of the strengths and weaknesses of each group, and ranking of the groups, and e) final examination on the information presented in the module. Figure 5 represents a flow chart of this scenario. The mini-project counted for 20% of the final mark.

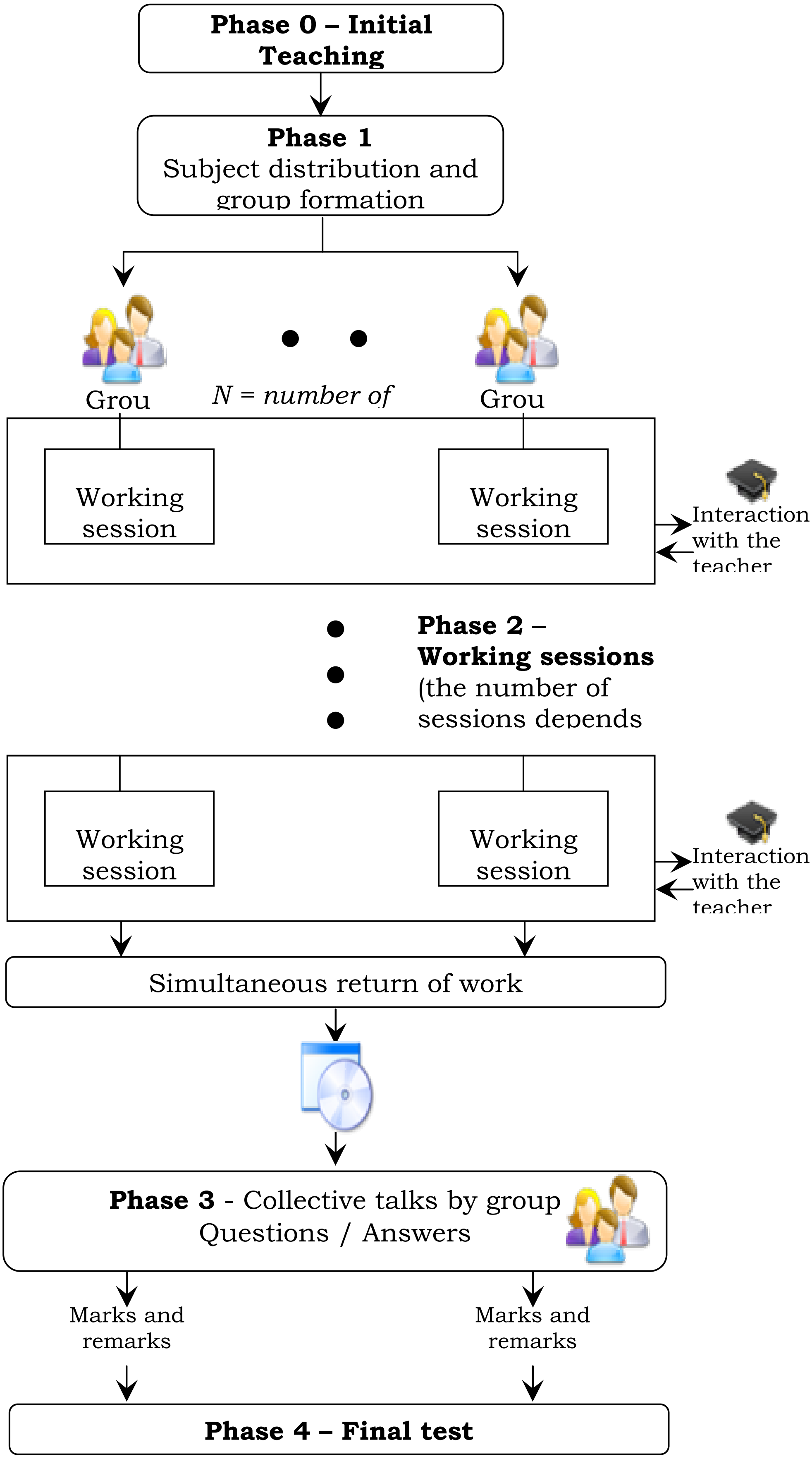


Fig. 5 – Scenario for module 2 based on the basic principles

4.3. Module 3: the evaluation of interactive systems

4.3.1. Context

This third case study concerns a module for evaluating interactive systems intended for students of Master level in Communication Sciences & Multimedia domain. The educational objective is to teach future engineers to evaluate websites and multimedia products and to suggest possible ergonomic adjustments to improve them. Ergonomics for human-computer interfaces (HCI) uses different evaluation methods to highlight the specificities of HCI as well as the prospects for ergonomically transforming HCI.

Among these methods, Cognitive Walkthrough (CW) evaluates the ease with which a user who has a minimum knowledge of the system performs a task (Polson & Lewis, 1992). This evaluation method uses the learning-by-exploring model (Polson & Lewis, 1990), which was inspired by Norman's theory of action (Norman, 1986). CW is a widely recognized method in both the industrial and academic worlds (Huart, Kolski & Sagar, 2004; Mahatody, Sagar & Kolski, 2007; 2010). It explores the HCI to see how easy it is to learn to use it. Students are asked to criticize the CW method in order to propose improvements to make it more effective at ergonomic evaluation. In this module, sessions take place both in the classroom and in the practical work room.

4.3.2. Module specifications based on the 7 basic principles

Knowing that design is an interaction between understanding and creation, and that it is a very complex activity, for this "Design and evaluation of interactive systems" module, we ruled out the traditional approach that focuses primarily on teaching the standards. In fact, we have observed that students have difficulties when facing problems that are both “simple and complex" or both "specific and general". Ergonomic standards and guides often focus on user characteristics and limitations. Certainly, these standards and guides only deal with targeted areas: workspace, dimensions, controls, and the physical environment. So, they are just interested in limits, and are not interested in everything that is complex or specific (e.g., cognitive activity and reasoning of users).

The knowledge in this field is vast and complex, and acquiring this knowledge cannot be limited to theory. Tutorials focusing on questionnaires and checklists have many limitations and thus prevent students from examining this knowledge in depth. Therefore, we decided to implement a more active pedagogy, showing first the limitations of the questionnaires and checklists, and then placing students directly into a role-playing game that focuses on their future job as an evaluator and a supervisor. Thus, the seven principles described in section 3 were applied to the module. The module's specifications are shown in Table 3.

Table 3 – Specifications for the module, "Specifications of man-machine interface in complex systems"

Principle	**Set up for module 3**
Principle 1: Redefine the roles of teachers and students	- The teacher proposes a pedagogy based initially on the use of ergonomic questionnaires and checklists to show their limitations and their subjectivity in terms of ergonomic recommendations. Then, the teacher proposes a role-playing game using the more objective Cognitive Walkthrough method for a more reliable ergonomic evaluation. - The teacher has a traditional role of knowledge provider. He explains the essential knowledge for the first phase, as well as for the second. In the first phase, he intervenes rarely, to surmount a critical situation, for example. Similarly, during the second phase, he lets the students play their roles as supervisor and evaluator fully, and only intervenes when problems arose. - Student 1, who plays the designer "supervisor" role, first breaks down the task in order to accomplish the goal he/she has set. This goal is supposed to be representative of website use. Student 1 then fills out the first card, "Preparing the

	Evaluation" (Figure 7), including the sequence of actions, which he/she submits, action by action, to the evaluator. Student 1 oversees the work of the evaluator. If necessary, the teacher answers questions and potentially intervenes in cases of deadlock. - Student 2 plays the role of the user and thus assumes the evaluation task. He/she applies the sequence of actions sent by the supervisor, filling out the second card, "Evaluation" for each action (Figure 7). Once the first action has been evaluated, the evaluator moves on to the second and so on. For each action requested by the supervisor, student 2 must note the requested task (e.g., "book a train ticket"). He/she must also note the action (e.g., action 1: "key in voyage-sncf.com") and then evaluate it, using the following three obligatory steps: (1) before the action, the student must imagine his/her goal and note it on the second card; (2) during the action, the student consults the website page and replies to questions on the card; (3) after the action, the student answers the last questions on the evaluation card. Thus, student 2 fills out as many cards as actions proposed by the supervisor. For every action, he/she answers questions proposed by the CW method on the evaluation card. When he/she encounters a problem, the student must fill out a third card, "Problem description", which is supposed to provide the solution in terms of ergonomic design. - The pair of students writes the report, offering their perspective on the use of the CW method. The teacher reads the report and critiques the use of the method.
Principle 2: Introduce pedagogical mini-projects guided by cooperative learning	- The focal point of the module is a mini-project that is part of the knowledge acquisition process and is supposed to simulate the stakeholder roles within the design process. This mini-project should be run by a pair of students in two 4-hour sessions. Next, each pair spends the following week working to prepare the ergonomic evaluation report and critique the methodology used. - The teacher establishes the pedagogical rules at the beginning of the module, explicitly mentioning cooperative learning.
Principle 3: Alternate individual work and group work	- Each student must first focus individually on the domain knowledge. - Then, in a four-hour session, each student has to evaluate an interface using standard ergonomic checklists and questionnaires and provide an evaluation report to the teacher. The objective of this session is to identify the limitations of these checklists and questionnaires, which are primarily interested in implementing the norms and standards. - Finally, each student in turn has to play the role of supervisor and evaluator, using the CW method and performing the same task on two different websites. The students must work cooperatively. - Each pair is marked as a group in order to focus on the group's shared responsibility in using these methods.
Principle 4: Foster a shared understanding of the activities proposed to students	- The handouts giving a detailed description of the methods used and the procedure to follow are provided to each member of the group early in the mini-project. Similarly, all the evaluation forms and problems are made available to all group members. - The rules are explained to all students orally at the beginning of the module. - The teacher insures that the work is going in the right direction and that the students understand all the objectives and the production expected.
Principle 5: Use ICT to support teaching	- The Internet serves as a support to complete the work. Other tools are used for written reports, proposal presentations and ergonomic adjustments (e.g., drawings, screen shots, pictures). - To monitor student progress, the University's Digital Work Space (DWS) is used for communication between the students and the teacher and to hand in reports.
Principle 6: Evaluate the knowledge acquired by students regularly	- During the mini-project, student progress is regularly evaluated by the teacher, which leads essentially to oral recommendations. - One week after each session, students are asked to hand in a report. This report is evaluated by the teacher. - At the end of the module, there is also an exam. The mini-project counts for 30% of the final mark.
Principle 7: Analyze the teaching process	- In the report, the students are asked to criticize the teaching approach used (i.e., the pros and cons) in order to improve this approach

	- At the end of module, the students are asked to provide feedback about their experience.

4.3.3. Final teaching scenario for module 3

By applying the basic principles, we were able to propose a scenario based on mini-projects for the module, “Design and evaluation of interactive systems". Figure 6 gives the broad outlines of this scenario. This module was completed by student pairs using two complementary methods: 1) questionnaires and checklists and 2) Cognitive Walkthrough (CW) method. For the latter, the students employed a role-playing game to simulate the roles used in the CW method (i.e., supervisor & evaluator). There were 4 main learning phases: a) description of the module and the pedagogy used; b) theoretical lesson presenting the domain knowledge; c) mini-project that used both methods to conduct an ergonomic evaluation, with the objective of producing a HCI specification report and critique of each method; and d) final exam on the module.

The CW method was designed to simulate the user's cognitive path during interaction with a web interface. This method involves two phases. During the preparation phase, for each task, the evaluator describes the initial state of the interface, the sequence of actions used to perform the task, and the original goals of the user. During the evaluation phase, the evaluator performs an in-depth analysis of the user-interface interaction. The questions on the form completed by the evaluator should allow any potential errors in the exploration operating model to be identified.

Even though this simulation approach has some problems (e.g., task breakdown, putting oneself in a representative user's shoes, evaluation time variability, bias due to the evaluator being monitored by the supervisor), it allows students to realize (1) the importance of evaluating and improving interactive systems available to users in work situations, (2) the difficulty of implementing evaluation methods to obtain results that are both meaningful and useful, and (3) the value of exercising and thereby developing knowledge and skills inherent to an evaluation activity and thus step away from the methods that only apply the standards.

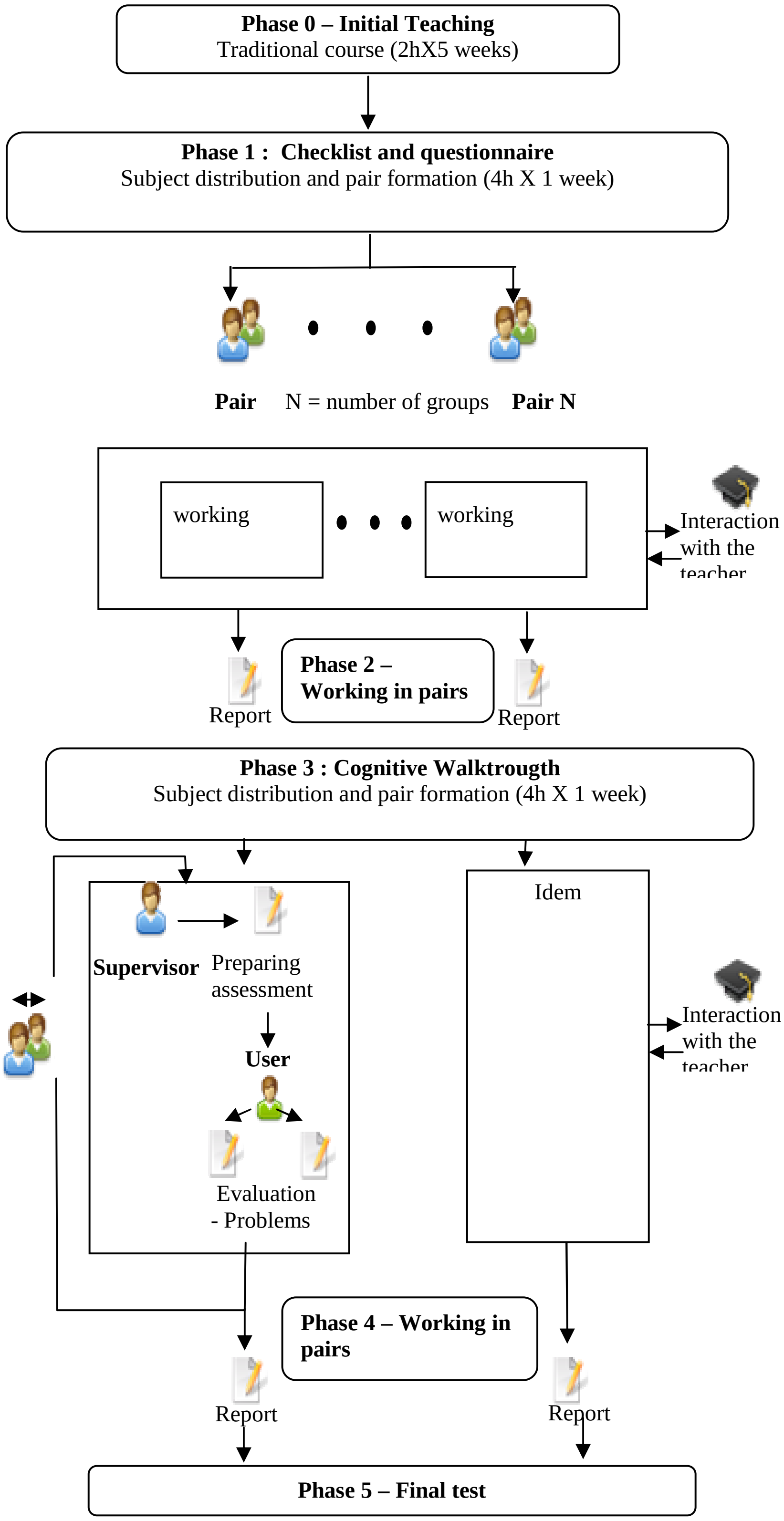


Fig. 6 - Scenario for module 3 based on the basic principles

Figure 7 shows the three forms used for evaluation. Please note that the mini-project counts for 30% of the final mark.

Card 1: Preparing the evaluation	**Card 2: Evaluation**	**Card 3: Problem description**
Product: **Task:** **Evaluator:** **Data:** **Product description:** **Sequence of actions:** **1. Click on …** **2. Give the value of …** **etc.**	**Task:** **Action:** **1. Before the action (goal to reach)** 1.1 What action has to be done? (What is the appropriate goal?). **2. During the action** 2.1 Is the action to be done obvious? 2.2 Are there visible propositions that, in your opinion, allow and/or suggest this action? 2.3. Are the labels or descriptions associated to the action explicit? **3. After the action** 3.1. Considering that the correct action has been done, what is the system's response? 3.2. Do you notice a progression towards the asked-for action? What indicates this progression? 3.3. If the action does not appear to be accomplished, what are the signals that indicate this state of affairs? 3.4. Does the system response contain a word or an indication that suggests that new actions are beginning? If so, describe these actions.	**Problem:** **Kind of problem:** 1. Brief description of the problem 2. How did you find this problem? 3. Have users encountered this problem? Rarely, Often, Very often, Always. 4. How do you evaluate gravity of the problem? Bearable, Moderate, Serious, Critical. 5. How have you evaluated the seriousness of the problem? 6. Make propositions for solving problem. (You can also write comments or suggestions).

Figure 7 – Evaluation cards

5. Assessment of the framework

In this section, we first present the research objectives. Next we look at how the seven principles have intersected the three case studies. Finally we show our findings in terms of improvements on student professional practices, needs for ICT and impact on student and teacher relations. We conclude by offering avenues for improvement. The definition of our framework has been gradual over ten years of practical lessons. For this assessment, we rely on the most successful results, those of the academic year 2009-2010. The first case study involved 17 students for a module of 25 hours of lessons, the second 21 students for a module of 18 hours of lessons and the last 13 students for a module of 18 hours of lessons. These observations were established empirically during meetings, informal student interviews and questionnaires, as well as examination results and realization work done by students. For ethical reasons we could not use a control group. Nearly ten years of study had shown the relevance of the proposed framework intuitively. Students who were taught without the application of the framework would have been at a disadvantage. When we draw comparisons with the teaching, it is therefore done with estimates based on other courses taught by the same teachers.

5.1. Research objectives

In the previous section we presented the application of our framework in three case studies. In this section we focus on evaluation. The first question concerns its consistency. Is it a set of independent recommendations or can it be applied as a whole, albeit at different levels, but in totality? The second issue concerns the achievement of the original objectives. Is it that the implementation of the framework promotes the professionalism of students? This applies especially in comparison of the courses without evolution of teaching. The third question concerns the impact of ICT. Is it that the implementation of the framework promotes the use of ICT? The use of ICT among students? The fourth question concerns the impact in comparison in teaching. The fifth question allows us to know whether the application of the framework has improved student interaction and learning outcomes.

5.2. Introduction of principles in the three case studies

The first principle (Redefine the roles) was strictly applied in the three case studies. In the three modules, 6 roles were implemented: the team, the student, the teacher-facilitator, the teacher-lecturer, the teacher-evaluator and the Internet community (primarily in case 1). The teacher-lecturer role evolved over the three modules. In the first module, the teacher took on this role at the end of module, representing 10% of the time. In the second and third modules, the teacher took on this role early in the module to initiate the process, representing 50% and 45% of the time respectively. One difficulty in the teacher's overall role is thus to be able to recognize what role they are playing in order to remain the knowledge provider and knowledge evaluator, while helping students to satisfy their roles, thus being the knowledge facilitator. Students played two roles: one individual, as a student; the other collective, as a member of a team. In modules 2 and 3, the individual role was not as explicit as it was in module 1. Thus, it was up to the teacher-facilitator to insure this role's existence.

The second principle (Introduce mini-projects with cooperative learning) was the basis of all 3 modules. It took many different forms depending on the module. Module 1 established a real project management for the mini-project. Module 2 was based on teamwork with a real individual component, whose intensity was fostered the teacher-facilitator in this person's interactions with students. Module 3 had the students working in pairs. This second principle was not easy to manage. Most teams recognized that the allocated time was insufficient. In fact, though teamwork makes learning accessible to a single individual, especially in terms of high-level skills, learning takes more time. Even in module 1, the strict "project” techniques were, in the end, little applied by some teams. These teams produced a collective work, but did not make it a priority to apply project techniques, such as verification, validation and planning. We think that this situation was brought about by the pedagogical choices made in implementing the principles. In other courses, we have implemented real project management with its traditional deliverables.

The third principle (Alternate individual work and group work) was properly applied. In the three modules, this alternation was done very differently. In module 1, it was explicitly programmed (see Figure 4). In module 2, the teacher guaranteed the alternation through his frequent interactions in the work sessions (Figure 5) and obviously in the final evaluation. In module 3, the alternation was directly related to technology implemented in Phase 2 (working in pairs) (Figure 6). In addition, between sessions, teachers encouraged working as a team (modules 1 and 2) or working individually (module 3). Students found this alternating pattern relevant. It gave them time to better understand both what was expected of them and the knowledge they were expected to acquire. In addition, it was, for them, a new learning mode.

The fourth principle (Foster shared understanding of activities) was applied in three complementary ways in the three modules. First, the exchanges between students in group work sessions promoted shared understanding of the domain knowledge (modules 1 and 2). Second, the distribution and study of handouts explaining the ins and outs of the teaching strategy fostered a better understanding of what they were trying to accomplish (modules 1 and 3). Third, the sustained interactions with the teacher supported a common understanding of what the teacher expected (modules 2 and 3). This principle is essential to avoid misunderstandings and pedagogical failure.

The fifth principle (Use ICT to support teaching) was naturally and thoroughly applied in the 3 modules (e.g., PowerPoint presentation editor, websites, educational games and professional tools for editing HCI). Since the three modules were in the domain of technological education, the application of this principle was facilitated, but it is not essential to be in this domain. The technological tools provided a common production framework and promoted team building (modules 1 and 2) and participation. They provided more opportunities for further exchanges between students and between students and teachers. Most often graphic, these tools helped by making certain aspects of knowledge to be acquired more concrete, thus making them more accessible. They also made possible the professional quality of the student productions. It should be noted that module 1 exploited a widely used e-learning platform (*Moodle*), whereas simple-to-implement tools (modules 2 and 3) would have been sufficient to support effective teaching.

The sixth principle (Evaluate knowledge regularly) was applied in all three modules through regular evaluation of student production, oral work presentations and the final exam as well as in a more informal manner through interactions between students and the teacher-facilitator (module 2). The limited disciplinary content in modules 1 and 3 allowed several mini-projects to be connected, each with a final evaluation. Thus, all modules were regularly evaluated.

The seventh principle (Analyse the teaching process) was encouraged by frequent interaction between the teacher and the students. In addition, informal interviews and/or questionnaires (modules 1 and 3) were used. This regular analysis of the teaching process seemed important to the teachers. Certainly, it introduces a bias in the evaluation of the proposed framework because of the well-known fact that students become more efficient if more attention is paid to them. But this analysis is difficult to avoid if our pedagogy is to be validated and our improvements, directed.

The above analysis shows that in the three case studies, the 7 principles were implemented. The proposed framework is complete. It allows us to take all facets of the 3 case studies into account and help to guide the development of scenarios.

5.3. Improvement of professional practices among students

We selected five professional practices. We noted their appearances during lessons. It is reasonable to think that they will tend to be replicated in the same way when working in a company:

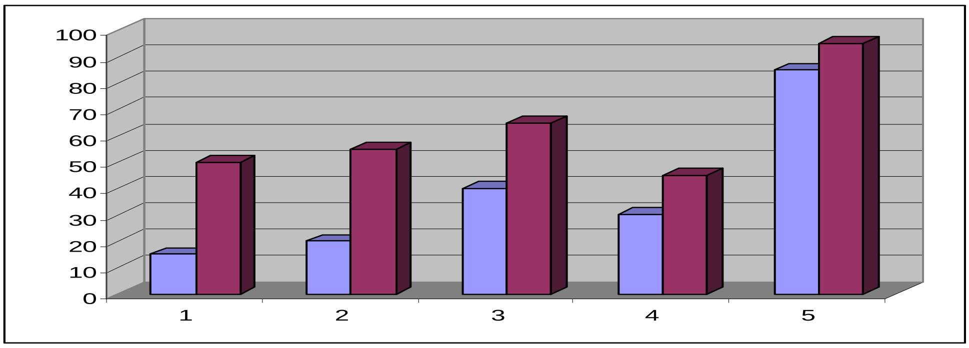
1. *Will the students produce more professional productions?* For each production requirement, a number of criteria were involved. These criteria could depend on the nature of production. If this were a study report, the criteria could include adherence to a professional documentary standard. If it was an exercise in reformulating concepts by producing a poster, criteria could include the legibility, aesthetics (color, shape: text-pattern-design-picture coherence), the visual efficiency, educational effectiveness of the poster. The scores are given out of 100.
2. *Will the students be more involved in teamwork*? This is the percentage of time spent in actual practice, sessions, group work.
3. *Will the students respect deadlines in their production of work?* Figures are expressed as a percentage of work submitted on time.
4. *Will the students respect the fixed rules and procedures (except non-timeliness)?* For example, do they prepare the seminar sessions when requested to do so? The scores are given out of 100.
5. *Will the students be more present (excluding excused absences such as illness)?* This is the attendance rate as a percentage.

The results are shown in Table 4.

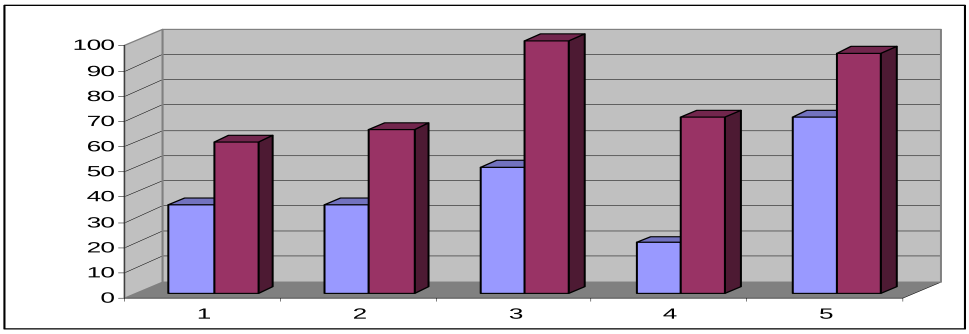
Table 4

Improvement of professional practices among students

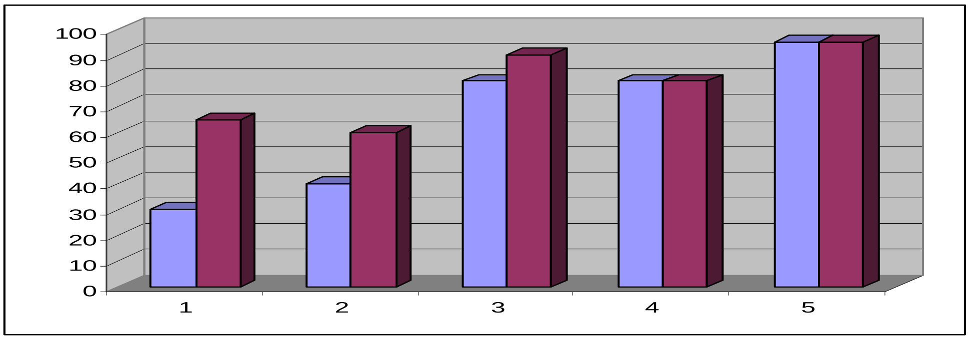
Case 1



Case 2



Case 3



1. Production of professional quality – 2. Team engagement - 3. Timeliness – 4. Compliance – 5. Presence.

This chart shows for each of the 5 professional practices listed above and then for each of the three case studies, changes in outcomes before and after application of the framework.

The three case studies show the positive impact of the implementation of the framework for each of the 5 practices observed. In particular, a net growth was observed in 3 case studies for the first 2 practices. The rendering professional production was increased from 15 to 50 points for case 1, 35 to 50 points for case 2 and 30 to 65 points for case 3. Involvement in teamwork was increased from 20 to 55 points for case 1, 35 to 65 points for case 2 and 40 to 60 points for case 3. Regarding the third criterion, there was a significant increase for the first two case studies which went from 40 to 65 and 50 to 100 and a moderate increase in case 3, which increased from only 80 to 90. Except the criterion 4 in case 2 which increased from 20 to 70, the last two criteria underwent less notable improvements. Case 3 even shows stability. This reflects the fact that the scores on these criteria were already high before the application of the framework. Finally, this study shows that the framework enabled a significant improvement of professional practices among students especially for the production of quality products and professional involvement in collective work.

5.4. Needs for ICT

In this section we focus on the impact of ICT in the framework application. ICT literacy is a prerequisite for employability. We try to evaluate the use of ICT and the dependence of the framework application in relation to ICT. Table 5 shows tools used and their evolution through the application of the framework. Moreover, these tools have been classified into two categories:

- *The optional tools*. For example, the dissemination of the teacher's instructions done by an electronic filing of documents can be also done by the distribution of course handouts on paper, certainly more expensive and less convenient, but fulfilling the intended function.
- *The mandatory tools in relation to educational* activities, whether individual or collective. For example, it is difficult to replace a professional design tool GUI or a database for sharing documents for collaborative work by a manual tool. The figures were calculated according to the scenarios developed.

The results are summarized in table 5.

Table 5
Evolution of the ICT use (in underlined the mandatory tools)

	Case study 1	Case study 2	Case study 3
ICT used before framework application	<u>1. Word processor</u> 2. A Web navigator 3. Moodle platform Three Moodle resources (Moodle, http): 4. Web link, 5. Web page and 6. Resource file. <u>7. A management project tool</u>	<u>1. Word processor</u> 2. Presentation program <u>3. Email</u>	<u>1. Word processor</u> <u>2. Spreadsheet application</u> 3. Graphics painting program <u>4. Professional software of ergonomics</u>
The application of the framework required some *additional* ICT tools	The three <u>Moodle</u> activities (Moodle, http): <u>8. Assignments</u>, <u>9. Databases</u> and <u>10. Wiki</u> <u>11. Presentation program</u> <u>12. The construction game program</u> (Hot Potatoes, http)	4. Spreadsheet application <u>5. Graphics painting program</u> 6. Image management program 7. A web navigator 8. The specific platform of the university <u>9. A professional supervision tool</u>	<u>5. A web navigator.</u> <u>6. The specific platform of the university</u> 7. Image management program 8. Email

Table 5 shows that using the framework led to an increase in the number of ICT tools used. The number of used tools is increased respectively for the three case studies from 7 to 12, from 3 to 9 and from 4 to 8 tools. However, the use of the framework has made teaching more dependent on technology. This finding can be made for the 3 cases. Certainly without the application of the framework, the three modules required ICT tools but in smaller numbers and only for the practical sessions, which represent about 30% of the course time. The use of the framework increased the needs of ICT for most face-to-face sessions and the mandatory tools increased respectively by 5, 6 and 4 tools for the 3 cases. Teachers noted that this increase was induced by the richness of scenarios and activities offered and not the result of a willingness to use ICT at all costs. This means that the tools are at the service of our pedagogy and not the opposite. In the 3 cases, all the students used every ICT tool available: about 75% of students did so as from the very first session, the others began no later than the third session. So the framework induced the use and mastery of ICT tools. The students and teachers explain this by the introduction of the pedagogical project guided by cooperative learning (principle 2) and by the regular assessment of knowledge (Principle 6).

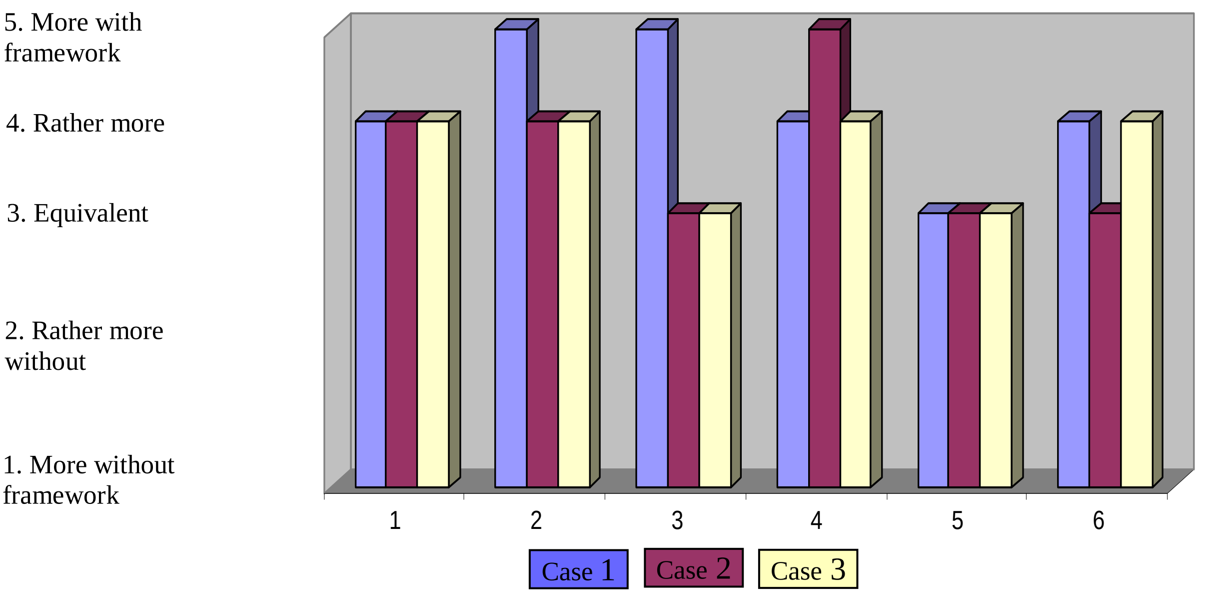
5.5. Impact on the teaching profession

In this section we study the impact of the implementation of the framework on the work of the teacher. Each of the six questions asked of teachers was answered using a Likert scale: 1. More with method 2. Rather more with method 3. Equivalent 4. Rather more without method 5. More without method. The questionnaire included the following six questions:

1. *Satisfaction from professional point of view.*
2. *Amount of work required to track students.*
3. *Need for greater regularity in the work.*
4. *Need for greater preparation work the first time.*
5. *Need for greater preparation work in subsequent years.*
6. *Opportunity for teachers to increase their knowledge.*

The results are summarized in the graph in table 6.

Table 6
Impact on the teaching profession



1. Professional satisfaction – 2. Work to monitor students - 3. Regularity in work – 4. Time preparation for the course the first time 5. Time preparation for the next time the course is given 6. Knowledge updating

This chart shows for each of the six questions posed to teachers and then for each of the 3 case studies: the evolution of teacher's work in terms of the Likert scale indicated on the left of the graph.

The three case studies show that implementation of the framework led to a significant change in the art of teaching. The teachers concerned agree in showing an increase in their satisfaction in professional terms. This positive development has a counterpart in the time spent tutoring students, regularity and preparation time at least when the course is taught for the first time. It should be noted that the use of the framework has also involved providing more opportunities for teachers to update their knowledge. Our analysis is that changes in the number of interactions between student and teacher and the results of student research are rewarding not only for students but also teachers.

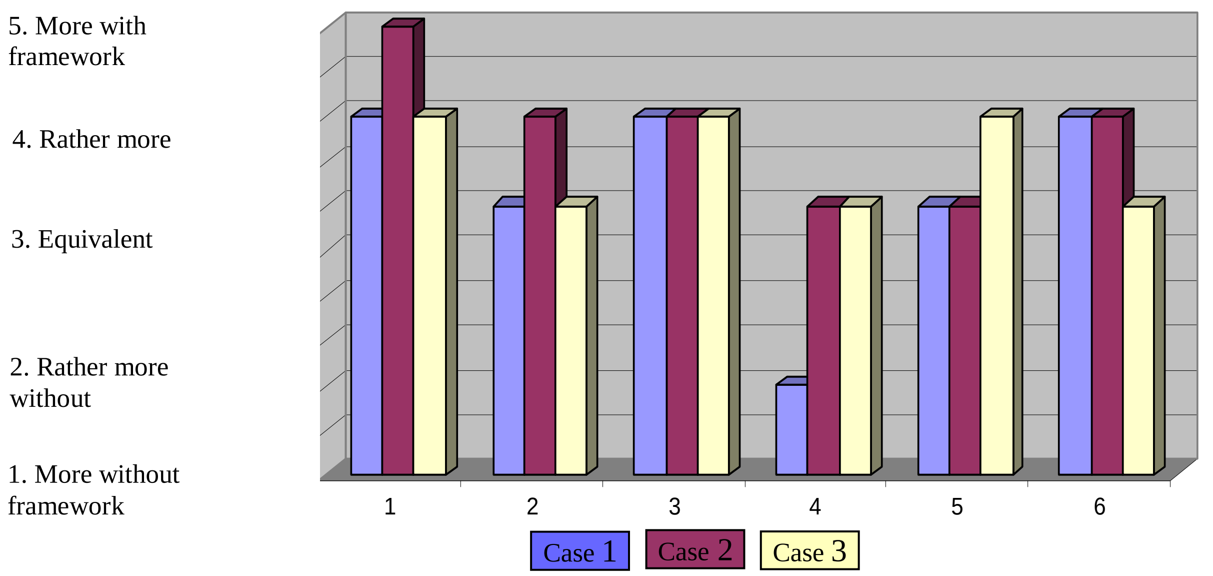
5.6. Study of student interactions and learning outcomes

In this section we study the impact of the framework on interactions in class and on outcomes of students. The teachers were asked six questions using the same Likert scale as previously: 1. More with method 2. Rather more with method 3. Equivalent 4. Rather more without method 5. More without method. The questionnaire included the following six questions:

1. *Student involvement*
2. *Detection of student problems*
3. *Interaction with students*
4. *Volume of knowledge transmitted*
5. *Importance of skills transmitted*
6. *Importance of attitude transmitted*

The results are summarized in the graph in table 7.

Table 7
Evolution of interactions and outcomes of students



1) Student involvement. 2) Detection of student problems 3) Interaction with students. 4) Volume knowledge transmitted. 5) Importance of skills transmitted. 6). Importance of attitude transmitted.

This chart shows for each of 6 questions and then for each of the 3 case studies: evolution of teacher's work in terms of the Likert scale indicated on the left of the graph

The use of the framework has shown improvements in student interactions, involvement and teacher / student relationship. We think that these improvements explain the better detection of pedagogical problems. Overall there is a stability in acquired knowledge and skills. There is an increase of acquired attitude. The lower level of acquired knowledge for case 1 is circumstantial; it was analyzed as a difficulty for the teacher to master some new specific content introduced into the course.

6. Discussion

Based on our study and our practices, there are several interesting points which can on the one hand encourage the application of our framework and on the other hand improve its educational efficiency. In this section, we consider how to help other teachers in higher education to improve their courses and also promote the effectiveness of their teaching. Then, we summarize the main educational benefits observed. This finding is based on the feelings of learners and teachers. It was established empirically, based on observations during meetings, informal interviews with students, examination results and various questionnaires completed by learners and teachers. We conclude with possible ideas of improvements.

6.1. Application of the evolutionary framework

The first reflection concerns the role played by ICT tools. Their introduction helps the realization of the first principle: "Redefine the roles of teachers and students". Through the opportunities they offer, the ICT can help to define new actors with their roles and tools for promoting the respect of defined rules for actors. They encourage the support of the project activities and may also improve the application of the other principles, through the possibility of communication that they offer.

The second reflection concerns the technical implementation of ICT tools. These tools do not need to be innovative: word processor, email, spreadsheet application , presentation program, blogs, etc. This makes the use of the framework available to many teacher profiles. More and more students have laptops and almost all universities offer wireless access to the Internet. It is increasingly possible and indeed required to develop new pedagogies. Our proposal, providing a flexible but comprehensive framework, will be a unifying aid in helping teachers to modify their teaching progressively. Of course the use of an e-learning platform such as Moodle, Blackboard, Claroline, etc., even if it requires a significant investment at the outset for the teachers, allows the use of richer scenarios and the teacher is discharged from the tedious tasks of student monitoring. Again all universities offer, or will offer, and provide training for their teachers for e-learning platforms.

The third reflection concerns the mini-projects. We found that when projects are too small, they can have a negative effect. On the one hand, students do not consider them as projects but more as exercises, and secondly they do not have time to deploy all scenarios and pedagogical outcomes are sometimes insufficient.

The fourth reflection concerns the mastery of knowledge by the teacher. It remains central. In case studies 2 and 3, where such knowledge was well mastered by teachers, there was equivalence (fig. 4) between teaching without or with use of the framework. In the case of Study 1, where an amount of new knowledge for teachers was introduced, there was less knowledge acquisition. Our analysis is that the teacher should have high level of knowledge control in order to guide students, this control cannot be left solely to activities or ICT resources made available.

6.2. Educational benefit

The analysis of these three case studies shows that applying seven principles provides a good model to explain the teaching scenarios produced. The application of these powerful scenarios was systematically evaluated by students. There was almost no absenteeism and involvement was strong over the years (table 4). The students acquired high-level skills (i.e., analysis, synthesis and argumentation) effectively (table 7). Students had to learn to work as a team and therefore communicate, negotiate and discuss their views. Students felt more responsible for their work, especially with respect to the team, and received reciprocal recognition from the team, which fostered their continued involvement and motivation.

Mutual aid between students was frequently observed, which allowed better learning. For example, some students had a comprehension block about an abstract problem. The team's help allowed these students to overcome the block, which in turn enabled them to participate more actively in the concrete aspects of the problem and has a positive effect on the learning of other students in this domain. The work produced was often quite professional (table 4).

The benefit of performing professional activities, such as writing reports, was found during the internships at the end of the degree program. Many former students, now in professional situations, have stressed the importance of supporting disciplinary knowledge by learning skills. In fact, disciplinary knowledge is often less important in a professional situation than at the university.

The evaluation method was almost universally appreciated for its form, its relevance to promoting learning, and its ability to reflect the students' knowledge acquisition level. Furthermore, the ongoing dialogue and the introduction of a part the work session allowed the students to better accept the marks on their exams. However, although it was widely appreciated, some of the students and teachers recognized that this evaluation method can become cumbersome. Even though it demanded a significant amount of work and availability, the teacher's role was more varied and more challenging. Teachers were able to use a personalized pedagogy that was flexible and tailored to the different student profiles.

We used Bloom's taxonomy (Bloom, Englehart, Furst, Hill & Krathwohl, 1956; Anderson & Krathwohl 2001) to analyze the contribution of our evolutionary framework. Indeed, table 7 shows that the use of the framework clearly preserves the first two levels of this taxonomy: *learning* and *understanding* (criterion 4). It strengthens the third level – *implementation (criterion 5)* – and improves knowledge acquisition on the fourth and fifth: *analysis*, *synthesis*. The feelings of teachers and especially their findings on the achievements produced by the students (table 7), show that increasing the acquisitions of the last level, creation, is sensitive. It thus leads us to think that our evolutionary framework supports skill acquisition, as defined in detail in introduction, and responds to the fundamental problems of companies and learning professional skills. This is confirmed by feedback from our students, either during their internships or during future professional interaction.

6.3. Suggestions for improvement

Two suggestions for improvement were picked from among all those are planned. The proposed framework has been applied individually to several modules with different students. This teaching style was new to students. Thus, the learning of skills necessitated the simultaneous learning of the new pedagogy. This led to a lack of pedagogical perspective as well as reducing even more the time really devoted to learning skills. We propose to generalize our framework. In other words, we propose to apply our evolutionary teaching framework in several distinct course modules at the same time. To do this, it will be necessary to provide teaching support for teachers and strengthen the robustness of our model based on seven principles.

The second improvement concerns ICT assistance. Technology is essential because of its capacities for dissemination, communication, and sharing. In the end, it is everywhere. It extends learning beyond the walls of the university and encourages the learning of high-level skills. We want to take a closer look at possible extensions of the use of ICT in learning scenarios and also highlight its limitations and risks.

7. Conclusion

This article has proposed a framework that allows disciplinary modules to evolve in order to enrich the learning of high-level cognitive skills. This framework is based on seven principles. We have shown its connections with the primary currents of educational psychology: behaviorism, cognitivism, constructivism and social constructivism. We applied our framework to examine various cases, including the three modules described in this article. These modules were run for nearly 10 years in two French universities. The first module is in an undergraduate degree program for students studying computer networks. The second and third modules are in graduate degree programs for students studying, respectively, automated industrial systems and image and sound engineering.

We showed that, despite the diversity of teaching methods in place, our framework allows the teaching scenarios to be implemented and could serve as an evolutionary framework for improving disciplinary modules. We showed that the course modules developed with our framework helped to reduce absenteeism and increased student participation as well as the assistance from other students. We found that the acquisition of disciplinary knowledge and professional skills were effective. On the whole, the new teaching style, including the evaluation, was appreciated by all stakeholders.

In their future, we intend to apply our framework to less technical disciplines, study the impact of its propagation to all course modules in a degree program, and further analyze the impact of introducing ICT.

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