Multi-Role Project (MRP): A New Project-Based Learning Method for STEM

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Multi-Role Project (MRP): a New Project-Based Learning Method for STEM

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***Abstract*—This paper presents the 'Multi-Role Project' method (MRP), a broadly applicable project-based learning method, and describes its implementation and evaluation in the context of a STEM (Science, Technology, Engineering, and Mathematics) course. The MRP method is designed around a meta-principle that considers the project learning activity as a role-playing game based on two projects: a learning project and an engineering project. The meta-principle is complemented by five principles that provide a framework to guide the working practices of student teams: distribution of responsibilities; regular interactions and solicitations within the team; anticipation and continuous improvement; positive interdependence and alternating individual / collective work; and open communication and content management. This paper presents the implementation of MRP in a course teaching software engineering, UML language and project management. The results show that MRP helped the course's students to acquire important professional knowledge and skills, experience near-real world professional realities, and develop their abilities to work both in teams and autonomously.**

***Index Terms*—E-learning, higher education, Moodle, multi-role project, project-based learning, STEM**

I. Introduction

Possessing technical skills in STEM is no longer sufficient to obtain a well-paid job: businesses require experience in successfully applying know-how, skills, collective work and transverse competences [1]-[3]. From the student point of view, learning based on lectures and seminars no longer meets expectations [4]-[5]. In this context, project-based learning is considered to be a very important learning strategy [6]; its most common implementation takes the form of student projects. Indeed, it has been established that such projects engage students more strongly than does traditional homework [7]-[8], and allow both the integration of methods and techniques learned in different courses, and the development of teamwork [9] and skills for the 21st century [10].

However, there is a lack of pedagogical methods equipped with the necessary tools to allow teachers to teach the methods and apply them effectively in their courses [11]. To address this problem, a project-based learning (PjBL) method - the Multi-Role Project (MRP) learning method - was developed, based on an iterative approach involving more than one hundred student projects supervised over a fifteen-year period. This paper shows that this method is effective in helping students to succeed in both technical and non-technical learning, and promotes learning activities and learning outcomes.

This paper is organized as follows. Section II relates the PjBL learning framework to the literature. Section III presents the MRP learning method. Section IV describes the use of MRP with a group of 41 Bachelor's degree students. Section V analyzes the pedagogical results of this experience. Section VI discusses MRP's broader applicability and prospects for improvements.

II. Related Work

A. Problem-Based Learning versus Project-Based Learning

This paper adopts the convention of Loyens and Rikers [12] in using the acronym PBL for Problem-Based Learning and PjBL for Project-Based Learning. PBL was initially developed at the McMaster University Medical School in 1969 [13], to address students' lack of motivation and low pass rates [14]. This was supported by the work of Barrows & Tamblyn [15]. Today, PBL is used in all disciplines. An essential component of PBL is the presentation of a real-world problem before the content to be studied is introduced. To solve the problem students must identify what they do and do not know, find new resources, and generally work in a group [16]. PBL is aimed more at understanding and defining problems than resolving them. It adopts a Socratic and dialogic approach [17].

PjBL has a longer history. Formally introduced to schools by the philosopher and educator, John Dewey (1859-1952), it was the work of Kilpatrick [18], [19] that contributed to its diffusion. It is also more complex than PBL, as shown in Table I, drawn from [20]. Since it works on more extensive activities, PjBL needs to adopt a more rational, technical approach and often uses project management practices [17]. Its learning objectives are more ambitious than PBL and cover the six levels of Bloom's taxonomy [21], including the *Application* level that is rarely addressed by PBL.

TABLE I
Differences between PjBL and PBL according to [20]

Project-Based Learning	Problem-Based Learning
Often multi-disciplinary	More often single-subject
May be lengthy (weeks or months)	Tend to be shorter
Follows general, variously-named steps	Follows specific, traditionally prescribed steps
Includes the creation of a product or performance	The "product" may simply be a proposed solution, expressed in writing or in an oral presentation
Often involves real-world, fully authentic tasks and settings	More often uses case studies or fictitious scenarios as "ill-structured problems"

B. Lack of a Generic Method

Although it may seem relatively complex to understand and apply, PjBL is a pedagogy for the future. Nevertheless, to the authors' knowledge, no articles in the literature propose complete PjBL methods. For example, [17] states: *"For many educators project-based learning is utilized in such a way that it offers little more than administrative framework for delivering instrumental outcomes"*. The authors of [8] present a general guide that does not claim to be a complete method, but is rather "*an all-embracing concept*" [22].

The meetings-flow method [9] is, to the authors' knowledge, the most advanced and promising PjBL method, but additional work will be necessary to demonstrate its effectiveness outside its privileged application field, and to develop standard software. The lack of generic methods for PjBL makes it difficult to compare the different experiments.

The situation is different for PBL. Here, well-established generic methods exist that are broadly applicable. One example, the POGIL (Process Oriented Guided Inquiry Learning) method [23], even offers complete, ready-to-use case studies. The following section presents the MRP learning method, which distinguishes the concept of a learning project from that of an engineering project.

III. The Multi-Role Project (MRP) method

In 1999, a review of student projects at the University of Littoral Côte d'Opale, France, carried out by more than 50 students in the second year of an undergraduate degree in computer science, highlighted the pedagogical inadequacy of the project experience [11]. It became clear that a method was needed to help both the students and the teachers-supervisors, and for the next 15 years an iterative and incremental approach was followed to develop this. Once part of the method was defined and applied, each application was evaluated by behavioral observations, questionnaires, analyses of computer traces, and semi-structured interviews with students and supervisors. In light of this data, the method was iteratively evolved to address observed defects or the unmet needs.

The method was defined and then designed to be a complete and reusable method for the development of student projects. It is *complete* in that it defines the expected behavior for each actor, and the activities he or she should perform, and provides the conceptual and practical tools to optimize interactions with the other actors; it is *reusable* in the sense that other people can adopt and use it in their own situations. The next five sub-sections define the reusable MRP method.

A. Intended Outcomes

MRP, like POGIL [23], has pedagogical goals linked to both subject-matter content acquisition and the development of high-level skills. For the high-level skill pedagogical goals, the two methods use different approaches. Because of its orientation towards PBL, POGIL aims at more focused knowledge. [24, Table II]. Because of its orientation towards PjBL, MRP aims more to integrate various high-level skills [25, p.5]. Other expected outcomes include accustoming students to reflect on their own activity and facilitating the teacher's work in supervising students. In MRP, the targeted learning goals are recorded in a "pedagogical project" or "educational progress" document, see for example [26].

B. Description of MRP

MRP is based on the meta-principle that *"carrying out a student project is a role-playing game consisting of two projects performed by the student team: a learning project and an engineering project"*. This meta-principle requires that, before the start of the course, a learning project and an engineering project should be proposed, and supervisors appointed to play one or more roles. The meta-principle also serves as a mission statement to supervisors and students while carrying out the projects.

MRP also provides a conceptual framework, consisting of five principles (see Section III.F) to implement, that organizes student teams' operation during their projects. Fig. 1 shows the connections between the meta-principle, the five principles, the participants and the work to be done by the student teams, as will be elaborated upon below.

C. Learning Project versus Engineering Project

The *engineering project* involves creating a product or deliverable for a customer (the client). This can be varied in nature; it could be a feasibility study for an innovative consumer item, or programming a website, the construction of an autonomous robot, etc. From a practical point of view, it is often better to give a project that is "realistic" rather than actually "real", because with the former the teacher can better define the pedagogical goals (especially the content goal); with an actual project for a real client, there is always the risk of failure – the client may not be available, may abandon the project, and so on.

The *learning project* involves the student acquiring a pre-defined body of knowledge that falls into two groups. The first group concerns skills for the 21st century [10], notably those related to project management. The second group concerns professional skills related to the project deliverable. For both groups, the learning project should specify what know-how, skills or competences will be acquired, and to what level, based on an adaptation of the Bloom's classification [21]. This adaptation takes into account the socio-constructivist character of the implemented pedagogy. Each of the two knowledge groups is first ranked according to one of five acquisition levels: 1) know, 2) understand or apply, 3) master (understand and apply), 4) adapt and 5) innovate. Then, the levels selected are classified by the five levels of achievement defined by the Software Engineering Model and Theory group [27] from its "Way of working": 1) initiated, 2) partial, 3) quite good, 4) good, and 5) excellent. This classification remains partly empirical and depends on the expertise of the teachers.

D. Role-Playing is Central to MRP

Role-play is an important concept; poorly-defined roles can have very negative effects on teamwork [28]. The concept of role is very common in research, and can take many forms [29]. In MRP it corresponds to the concept of responsibility in the work, and the concepts of game and role can be defined as follows.

A *game* consists of a set of rules that allow people to interact with each other in order to accomplish a goal. In a game, the set of objectives, behaviors, rights and duties assigned to a person or a group of persons is called a *role*. A person may play several roles, or inversely, a role may involve several people. MRP has four main roles:

1) *The student and his or her team* apply the method, carry out the work for the client and should improve their project skills and their professional skills.
2) *The MRP expert* helps the teams understand and apply MRP and ensures the method is correctly used. The role of MRP expert integrates the traditional role of tutor, so he or she should assist the students in learning and in performing their two projects.
3) *The client* defines the goals of the engineering project and validates them. Where appropriate, he or she will receive or use the deliverable: he or she is the contracting authority in the sense of Biddle [30].

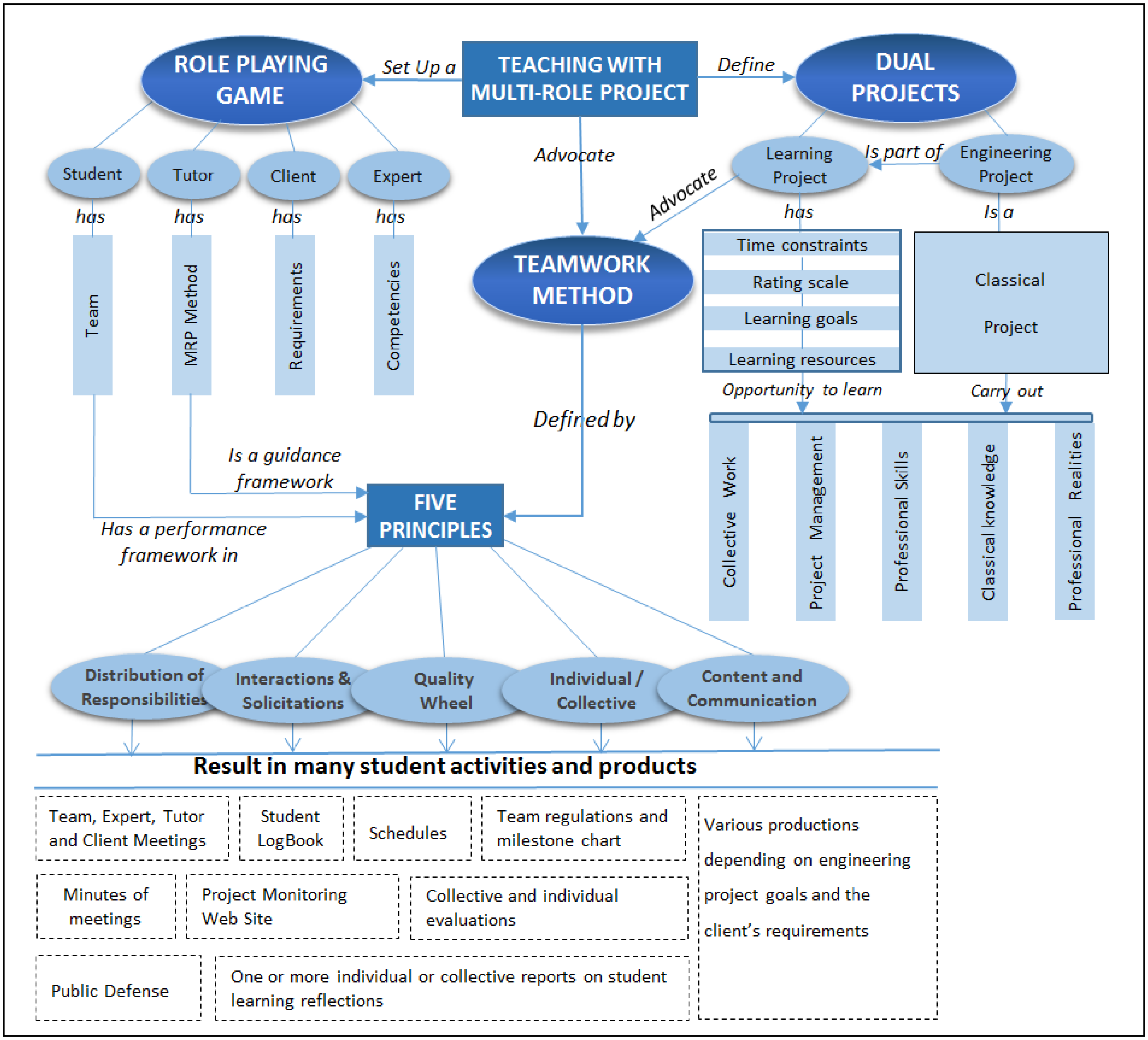

Fig. 1. Overview of the MRP

4) The *business expert* has skills in the specific learning required in the engineering project. His or her role is to answer the teams' questions, advise them and provide them, if necessary, with mini-courses, thus replacing the role of the teacher.

Each of the last three role-players is also an evaluator, participating in the assessment of teams and students. Students' priority is to learn their role while performing the project; for the other actors (the supervisors) their priority is to interpret the role entrusted to them for the benefit of the students.

E. Description of the Role-Playing Game: Project Kits

Three kits define the rules of the MRP role-playing game:

1) *Description of the MRP method (Student kit)* [25]. Understanding this kit and its application are part of the students' learning project. It explains the concepts of learning project, engineering project, role-playing, and so on; it also provides examples of the generic deliverables that the students are required to produce: meeting reports, activity sheets, project schedules, etc.
2) *Guidelines for the learning project* [26]. This kit, given to students at the start of the project, defines the learning project, and describes the targeted learning, the types of deliverables students will have to provide, the date of the final project defense, evaluation procedures, etc.
3) The *Client kit*, designed to help students achieve the learning objectives defined in the previous kit, describes the project to be carried out, and sets the limits of the customer's requirements. This kit is not mandatory, and may be replaced by a few-page technical specification. It helps the project achieve the learning objectives defined in the "Guidelines for the learning project".

F. Five Principles

In addition to the meta-principle described in Section III.B, the students should apply a further five principles to provide a conceptual framework for their projects:

1) *Distribution of responsibilities*: Based on the premise that there

is no effective collective work without a distribution of responsibilities, MRP requires teams to systematically define and share responsibilities.

2) *Regular interactions and solicitations within the team*: the second principle is based on the premise that projects advance better if there are regular interactions and supervisors solicitations within the team: that is, regular communication, and completion of project sub-tasks necessary to the final deliverable. Regular team meetings provide the framework for monitoring this, Fig. 2.

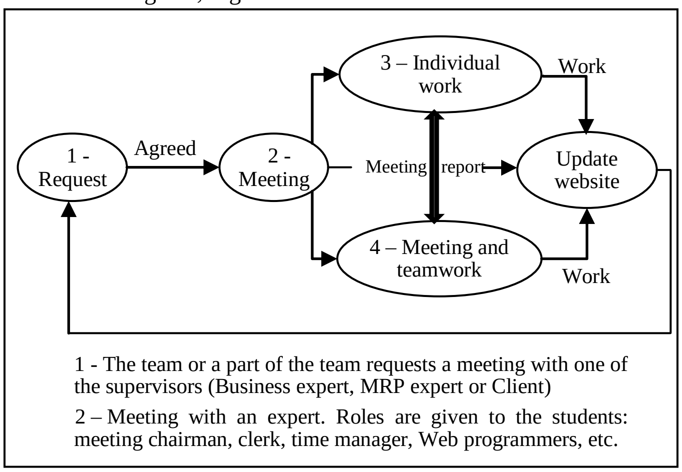

Fig. 2. Basic work cycle for students

3) *Anticipation and continuous improvement* (Quality Wheel): smooth teamwork depends on anticipation, while quality depends on continuous improvement. Anticipation and continuous improvement apply to both the learning project and the engineering project; for each, students should make schedules, regularly monitor their progress and, if necessary, modify the team.

4) *Positive interdependence and alternating individual / collective work*: to be effective and efficient, collective work should be organized with a positive interdependence between team members (meaning that each team member needs one or more other team members to make progress [31]), and should alternate individual work with collective work, to compensate for the relative slowness of collective work [32].

5) *Open communication and content management*: collective work should be based on open communications and content management. In addition to meetings, the team should maintain a project tracking website as the main vector of communication, content management and knowledge capitalization. This is used to monitor both the projects (learning and engineering). In the website, teams are recommended to include the pages: *Home, Presentation, Members, Meetings, Collective deliverables, Individual deliverables, Links*. *Home* describes the website and summarizes the project. *Presentation* gives a more detailed presentation of both projects. On the *Members* page, the members describe themselves, their strong points, points they wish to improve and their roles in the project; they can also provide a curriculum vitae. The *Meetings* page links to all of the reports. The *Collective deliverables* and *Individual deliverables* pages link to the various project deliverables created. Each deliverable has an annex with a version register that traces its evolution, specifying the date, the authors and the nature of the update. On the *Links* page the team can provide additional information and share interesting website links.

IV. Application of MRP

MSP was applied in 2013 in a Master's-level Information System Project (ISP) course. The fifth MRP principle, open communications and content management (Section III.F.5), was achieved by using the Moodle platform, the most widely used platform for university courses [33]. No control group was used; in previous years' sessions MRP has been shown to deliver significant benefits, so the authors felt a control group in this study would be disadvantaged.

A. The ISP Course

The 15-week ISP course, consisting of 12 four-hour teaching sessions, was taught to 41 fourth-year students in the Computer Engineering and Statistics Master's degree program at the graduate engineering school Polytech Lille, France [34]. The students were divided into eight teams of five or six students, and were required to sign a register at the beginning and end of each session. Each student had to perform an extra 48 hours of work outside of these sessions, to meet the requirements for the four European Credit Transfer System (ECTS) [35] credits attributed to the ISP course.

The hours were validated through the individual activity sheets that the MRP method requires students to keep updated throughout the project. The ISP course began with an introductory session that presented the MRP method and the engineering project. At the end of the course, each team gave a project defense presentation in front of their supervisors, during which they had to justify the choices and decisions made in their engineering project. They also had to deliver a two-part (team and individual) learning report. The first part had to describe the organization of the team throughout the project, and the main difficulties encountered and the means employed to overcome them. It also had to analyze the ratio of collective and the individual work for each team member. In their individual parts, students presented their activities and analyzed their learning for each of the knowledge domains targeted by the project. They were also asked to provide constructive criticism of the running of the ISP course.

B. Learning Project

The main goal of the learning project was to understand the MRP method and apply it to the ISP course. The teams had two kits that defined the MRP method [25] and the learning project [26], and they had access to a dozen projects from previous years [36]. The early part of the ISP course was mainly spent on the learning project. The students, in teams or individually, regularly provided learning deliverables on the MRP method. The 2013 students had to make a conceptual map that answered the question: "What are the main concepts of the MRP method?" They had to establish team regulations, a milestone chart for future team deliverables, provisional work schedules, etc. These regular learning deliverables both motivated the students and allowed the experts to check the students' progress in learning, particularly learning the MRP method.

The other learning objectives defined in the learning progress kit concerned the field of software engineering. Specifically, they covered needs analysis, the "Two Tracks Unified Process" (2TUP) development method [37], the UML language, requirements specification and software design. The 2TUP method is a professional software development method that begins with the creation of two parallel processes: one to determine functional needs and the other to determine technical needs. The two processes then merge in the final design and programming of the system. The ISP students only had to learn and use the first stages of the model: the definition of functional requirements, analysis and definition of technical requirements, generic technical design and the preliminary design, stopping at the detailed design stage. Actual programming was not included in the project.

C. Engineering Project

The engineering project was to build a software system to equip emergency posts on ski slopes. The first step was for students to produce an overall project schedule for the specification of this system. In the second step, they had to begin the implementation, including drafting functional and technical specifications and the general and detailed designs. The guidelines specified that the 2TUP method and the UML modeling language be used, neither of which the students knew.

During each session, four supervisors were available to the student teams: two engineers from industry and two teachers (lecturers). Each played one or several roles:

1) One supervisor played the role of the MRP expert, and ensured that the students understood and applied the MRP method.
2) One supervisor played the role of the client, i.e., the owner of the ski slopes for which the engineering project was being designed. He or she defined the needs of the project in terms of functions, budget and deadlines.
3) One supervisor played the role of project management expert. He or she helped the students in their relationships with the client.
4) Finally, one supervisor played two roles: (1) the analysis and design expert, assisting students in learning the 2TUP method and the UML language, (2) the Moodle expert, advising and answering questions from students on the use of the Moodle platform (version 1.9.3).

The main interactions between experts and students occurred during session meetings. The students had to request a meeting with the experts and provide a provisional agenda. The experts validated the agendas and at each meeting a report was written and published on the team's project tracking website.

V. Analysis of the Application of the MRP Method

A. Research Objectives

The MRP method presented here is the result of a 15-year iterative approach, covering more than one hundred student projects. After supervised projects carried out in 2012, the authors felt that MRP had met its pedagogical objectives sufficiently to warrant its publication here. A definition of MRP and an example of its application were given above. This section analyzes to what extent that application achieved its objectives. More specifically, four research questions are studied:

1) To what extent was the MRP method applied? This is a central issue if the results are to be relevant.
2) To what extent were the learning objectives of delivering experiences similar to professional realities, and having collective working practices, achieved?
3) To what extent were students' business skills developed?
4) To what extent does the application of the MRP method encourage the students to work harder?

B. Design of the Application Analysis

In the action research-based analysis, the MRP expert is one of the authors. This is treated further in the discussion. Results are based mainly on "tangible" feedback from students, namely the written work submitted, including the data in the teams' project tracking websites and the questionnaires completed by the students at the beginning and end of the course, which had nine and 56 questions respectively. Other data sources considered included the teacher-student interactions during sessions and six semi-structured interviews at the end of the course. Four interviews with four randomly-selected students, and two interviews with two of the external professional supervisors, were used either to contextualize the previous data or to complement them when they were insufficient. The remainder of this section details, for each research objective, the question, the analysis of the data obtained, and the results of that analysis.

C. Applicability of MRP

The research question posed was "to what extent was the method applied?" - crucial in order to demonstrate the relevance of the results. Table II summarizes the results obtained, showing that the method was applied to at least a satisfactory level.

TABLE II
APPLICATION OF THE METHOD

Application criteria	Validated?
1. Implementation of learning project / engineering project duality	Yes
2. Establishment of roles	Yes
3. Distribution of responsabilities	Yes
4. Regular team interactions and solicitations	Yes
5. Anticipation and continuous improvement (Quality Wheel)	No
6. Positive interdependence and alternating individual/collective work	Yes
7. Open content and communications management	Yes

To answer this question, it is first necessary to ask: "What is meant by 'the method was applied'?" Since the method is defined by a meta-principle and five principles, it can be considered to have been applied if these principles were applied. Since the meta-principle has two aspects, namely role-play and learning project / engineering project duality, seven criteria are obtained, Table II. The analysis methods used for each of these seven criteria are:

1) *Implementation of learning project / engineering project duality*: this criterion was evaluated by analyzing the organization of the project tracking web sites and the contents of the two learning reports submitted by the students. These analyses, confirmed by the supervisor-student interactions, show that students struggled to integrate this concept of duality at the start of the project. It was only after submitting the third learning deliverable on the understanding of the MRP method that the learning project / engineering project duality was acquired for the rest of the PSI. Activities and deliverables were clearly separated between the two projects.
2) *Establishment of roles*: this criterion was evaluated based on a detailed analysis of material available through the wiki for "setting up and monitoring of meetings with the supervisors" that gave access to the full list of all requests for meetings, all agendas and all reports of meetings between supervisors and students.
3) *Distribution of responsibilities*: this criterion was evaluated first by analyzing the part of the learning reports in which students had to record how easy or difficult it was to share responsibilities within teams, and second, through the responses to five questions in the final questionnaire that related to this criterion.
4) *Regular team interactions and solicitations*: this criterion was evaluated based on the content of the project tracking websites and the large amount of data available on the Moodle platform used for interactions and for submission of work.
5) *Anticipation and continuous improvement (Quality Wheel)*: this criterion was evaluated by analyzing the content of the work submitted by the students, complemented by the semi-structured

interviews and supervisor-student interactions. For the submitted work, at the start of the project teams were required to make a first provisional schedule of tasks to be realized. Half way through the project, they had to analyze this provisional schedule using their activity sheets and reschedule the remainder of their project. At the end of the project, the students had to submit an analysis of the discrepancies.

6) *Positive interdependence and alternating individual and collective work*: this criterion was evaluated based on the contents of the meeting reports and the learning reports submitted by students. Notably, in the latter, the teams had to provide an analysis of the relationship between the collective work of the team and the individual work of each member.
7) *Open content and communications management*: this criterion was evaluated by analyzing the maintenance quality of the project tracking websites.

D. Delivery of Experiences Close to Professional Reality, Aptitude for Collective work and Autonomy

The research question posed was "To what extent were the learning objectives concerning the delivery of experiences close to professional realities and collective work practices achieved?"

TABLE III
DEVELOPMENT OF SOFT SKILLS

Professional practices	Achieved?
Accounting and monitoring of work	*Yes*
Holding of meetings	*Yes*
Distribution of tasks	*No*
Scheduling	*Yes*
Allocation of individual work / collective work	*Yes*

Table III summarizes the results and shows that the practice and acquisition of professional practices were evaluated as achieved for all the criteria studied, except for the distribution of tasks.

The analysis method studied five professional practices that represent some important qualities expected in the professional world. The appearances of these qualities during the ISP course were noted and evaluated. Table III summarizes the quality of the professional practice adopted by the students.

1) *Accounting and monitoring of work*: this was evaluated by retrieving the activity sheets from the students' project tracking websites, and analyzing them one by one on a predefined evaluation grid. Of the 41 activity sheets, 38 met or surpassed the required level. Only three individual activity sheets were just partially completed. This practice was thus evaluated as being achieved.
2) *Holding of meetings*: this practice was evaluated by retrieving the contents of the wiki pages for "setting up and monitoring of meetings with the supervisors" in the Moodle course. The analysis shows that 261 meetings were held between the four supervisors and the eight teams during the twelve teaching sessions, an average of almost 24 meetings per four-hour session. Each supervisor attended more than six meetings per session on average, taking into account two absences of supervisors. The instructions for managing meetings, including the meeting request, the production and validation of an agenda, and the writing of a report, were nearly always respected, with only three exceptions in 261 meetings. This point is therefore also evaluated at 100% satisfaction. However, the supervisors only respected the instructions 191 times out of 261, i.e., 70% of the time. In addition to the 261 student-supervisor meetings, the students held over 50 meetings without the supervisors, in which they continued, at a rate of 75%, to respect the rules of conduct for meetings learned with the method. Giving identical weights to each of the parameters, this practice was evaluated as achieved.
3) *Distribution of tasks*: this practice was evaluated based on a) learning analyses that the teams had to produce in their final learning report, b) student responses to the final questionnaire and finally, c) interactions between the MRP expert and the student teams either during the regular meetings that took place during the project or during the semi-structured interviews. It appears that the quality in the distribution of work was slightly lower than for the other learning objectives. The student responses to the final questionnaire established that although 100% of students agreed that a distribution of tasks was made, 69% of the students responded that it was always done and 31% that it was often done. Nevertheless, 49% of the students considered that making the distribution was not easy. The criterion of fair distribution achieved 70% satisfaction, while that of respect for the shared work achieved only 56% satisfaction. Interactions with the students showed that two factors influence this result: students' motivation and workload at the time of the distribution. The target levels of occurrence and quality for this criterion were evaluated as not achieved.
4) *Work scheduling*. Work schedules were explicitly requested from the students. Based on the marks obtained by the students for the elaboration of their provisional schedule, the quality level was evaluated by the supervisors at 577 points out of 820.
5) *Individual work in addition to collective work*. This evaluation was based on the final learning report submitted by each team at the end of the project, and supplemented by the interactions with the students. The report included a section on "allocation of individual / collective work". On this basis, the criterion was evaluated as achieved. This high estimate is not surprising since the subject is designed to be complex and to incur a significant workload. The collective work allows the team to cope with the complexity, while a sufficient distribution of work among the members allows them to handle the workload.

E. Work and Acquisition of Professional and Project Management Skills

The research question posed was "To what extent were the students' business skills developed?" Figs 3 and 4 show that the method provides students with an opportunity to work, and that this work is accompanied by a satisfactory increase in skills (Fig. 3) with respect to the effort provided (Fig. 4). This is an important result since it reflects a difficulty that was encountered in previous versions of the method where students complained about having too much work relative to the gains in acquired skills.

The analysis method is based on 39 student responses to the final questionnaire, for three of the four criteria in Figs. 3 and 4. Criterion 2 - project management skills – was not addressed by the questionnaire, so the results for project management are an estimate.

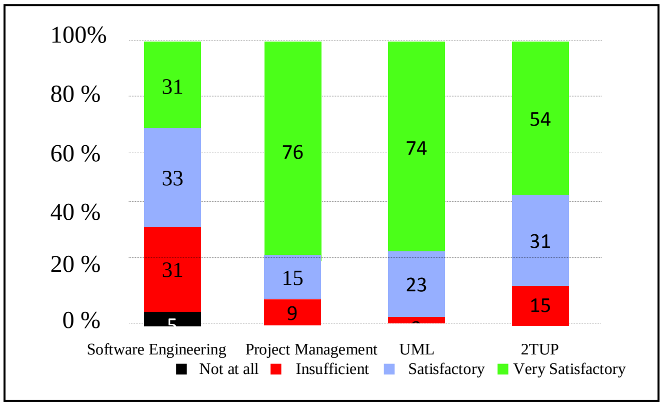

Fig. 3. To what extent has ISP provided an opportunity for students work?

This estimate was established from an in-depth analysis of the learning reports written by each student at the end of the project. It should be noted that, in Figs. 3 and 4, the learning of needs analysis, requirement specifications and software design have been grouped under the theme software engineering.

Fig. 4, produced from the students' responses to the questionnaire, shows that 90% of students evaluated their acquisition progress in software engineering as "Very satisfactory" or "Satisfactory", 91% of students for acquisition progress in management project, 88% for acquisition progress in UML and 77% for acquisition progress for the 2TUP method.

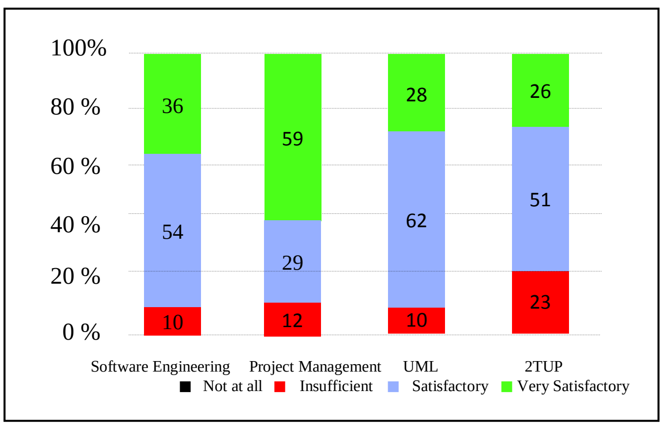

Fig. 4. To what extent has ISP advanced the skills of students?

F. *The MRP method as a Working Framework*

The research question posed was: "To what extent does the application of the MRP method promote the students' active participation?" This question is important because, although working does not guarantee progress, it is rare for students who do not work to progress. The results shown in Table IV summarize student feedback on the impact of the MRP method on the amount of work they did, under four headings, and on the likelihood of their using the principles of the method in another project.

The analysis method studied the answers to five questions in the final questionnaire on this aspect. This showed that the MRP method encourages students' to work harder and improves the quality of their learning. Their commitment is strong. Row 1 of Table IV shows that the MRP method increases the quantity of work for 69% of students. For learning quality, the effect of the method is even stronger. Row 2 shows that it promotes methodical work for 87% of students, collective work for 77% and the quality of the work submitted for 77%. Finally, 79% of students envisage reusing MRP during their professional lives.

TABLE IV
PEDAGOGICAL PERTINENCE OF THE MRP METHOD AS A FRAMEWORK

Five relevance criteria	YES	NO
Quantity of work	69	31
Methodological work	87	13
Collective work	77	23
Quality of submitted work	77	23
Reuse of MRP	79	21

VI. DISCUSSION AND DIRECTIONS FOR IMPROVEMENT OF MRP

The previous sections have shown the relevance of MRP for the achievement of the targeted learning objectives. This section contextualizes the results obtained.

A. *Discussion*

As a preamble to the various discussion points, it should be noted that the work reported here was a research study, which introduces a potential bias. Some of the evaluations were performed by the MRP expert, one of the authors. In addition, the evaluations of the teachers, like all teacher evaluations, contain a certain amount of subjectivity.

The first point to stress concerns the applicability of the method. The results show that the students applied most of the MRP method at a *Very satisfactory* level. No element of the method was considered below average. The most poorly rated criterion was the distribution of tasks (60% applied). The method is therefore applicable. Other examples of applications can be found on the project tracking websites accessible via the site [36]. However, it should be noted that two elements are essential: 1) the existence of technological support for the learning interactions; (2) the commitment of the supervisors.

Indeed, a method without a tool to support it cannot be effective and conversely, nor can a tool without a method to guide its use. The application of the MRP method described in this paper was performed on the Moodle platform, using a relatively rich set of tools, called "activities" in Moodle, that included wikis, forums, databases (under Moodle), homework submissions, MCQs, and document uploads. Nevertheless, these tools, although they may not be in common use in universities, are easy to implement and their usage should become more widespread. Furthermore, the technological support of the MRP method can be provided by Web-based Google tools, ensuring a certain universality. In addition to the Moodle platform for communication among members, the teams also used many Web tools such as Facebook or Twitter.

The application presented shows that MRP promotes team experiences close to professional realities. However, it should be noted that MRP reproduces only a part of professional realities. The experience takes place on a limited time scale - the duration of the course in the educational program concerned - while in industry the managed periods of work may be spread over several years.

Similarly, the study application did not address other common issues in real life, such as power conflicts, salaries, etc. However, it is the responsibility of the Client and Expert to make the experience as close to professional reality as possible. In this application, the Client and Expert were engineers from commercial corporations outside of the university. In discussions with former students, some of them said that they continue to use the MRP method directly or indirectly in their professional life. This is indirect evidence that students replicate the learning achieved in the application of the MRP method in their professional lives.

Concerning the high level of learning satisfaction, Fig. 3 shows that 91% of students responded that the project management activity was *very satisfactory* or *satisfactory*, in terms of number of hours during their ISP project. It shows that 88% responded that they had progressed in a *very satisfactory* or *satisfactory* manner in this discipline. However, it should be noted that if these two statistics (91% and 88%) are analyzed in more detail, by distinguishing between the *very satisfactory* and *satisfactory* responses, we observe that 79% of students responded *very satisfactory* concerning the quantity of work done but that in terms of progress, they were only 59%. This suggests that, for the students, progress was satisfactory, but at the expense of a workload that was judged too heavy. The same phenomenon is observed for the learning of professional skills. An analysis of the reasons behind this and directions for improvement are proposed below.

B. Directions for Improvement

The observations and student interviews indicate a need to control the distribution and the performance of work by team members, for a systematic improvement for all of the projects. An experiment is planned to evaluate a peer review system called "plus-minus-equal matrix" [38] within the teams. In this system, each student evaluates the participation of the other members of his or her team based on a certain number of criteria. For each student, a table is generated with the criteria in the rows and the other members of the team in the columns, as shown in Table V. The intersection of a row and a column contains the estimation of the student as "more", "less" or "equal". The student has to estimate, for each criteria and each member of his or her team whether the teammate did "more", "less" or "equal" to him or her, in terms of work and involvement. This system is not designed to give a mark directly, but serves primarily for the internal project team discussion.

TABLE V
PART OF A PME MATRIX

Name1-FirstName1	**Name2-FirstName2**	**Name3-FirstName3**	**Name4-FirstName4**	**Name5-FirstName5**	**Name6-FirstName6**
Involvement in the project*: proposed or implemented actions to organize, advance or implement the project.*					
Creativity*: proposed or suggested innovative ideas or actions leading to a useful result*					
Work*: contributed a large amount of work*					

The analysis of the application highlighted the fact that the targeted learning objectives were achieved to a high level of satisfaction, but at the expense of considerable effort from the students. In other words, the "effort / learning progress" ratio may be greater than 1. The MRP method increases how much work students do, and the majority of the effort is transformed into learning, but it seems that a part of this effort is lost and does not generate learning progress. In fact, the observations in the field show that the pedagogy used is almost entirely based on project-based learning, with students receiving little traditional education in the targeted learning objectives. The authors infer that the proposed project-based leaning is not the most suitable one for the learning objectives of levels 1 and 2, the Knowledge and Understanding levels, of Bloom's taxonomy [21]. A potential direction for improvement would be to propose before, or at the very beginning of projects, different learning activities, in order to allow the students to advance on these two levels: Knowledge and Understanding. The MRP method could focus on the other learning objectives, aimed at know-how, skills and competences.

VII. CONCLUSION

This article has provided a reusable PjBL method and an analysis of its application for student projects in a French higher education establishment. The results show that the students applied the method well, developed close communications to coordinate the team and acquired technical and non-technical knowledge to a high level of satisfaction. In the future, the authors will establish (1) a peer review system to promote a better distribution of tasks within the teams and (2) preliminary learning activities to allow the students to acquire knowledge for which project-based learning is not optimal. Documents describing the MRP method are available from the web site, http://mepulco.net, in French and in English. Training videos for the method are also available.

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