Boosting advanced skills in project management thanks to complex human and technical situations

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INTRODUCTION

Our French graduate engineering school in Information and Communication Technology offers a dual training curriculum for specialized students who spend half of their training time in host companies. One of our ambitions is to train competitive managers able to cope with complex projects.

After five years of learning experience and good feedbacks from the teachers and different stakeholders [1], we felt the need to listen to the points of view of students in terms of their skills improvement perception. Our working hypothesis is that the way we organize the courses and projects (with large groups, unexpected events…) is a skill booster when compared to a traditional course. During the first two years of study, notions in project management are presented, without professional situations. In the third year, we confront our students with a real-life project with a real customer and within given time constraints. Is this first "controlled" experience an efficient way to convey knowledge on complex project management?

In this paper we present the results of a quantitative study based on the students' perception of their skills in a technical approach to project management, in human resources management and in agility. We study skills evolution between the beginning and the end of this students' final year project course unit. A major result is that students significantly improve their abilities in these three items of project management.

In the first section, we describe the key operational principles of our course unit. Then, we present the quantitative method used to analyse the efficiency of this course unit. In the third section, some graphics report the questionnaire results and allow us to discuss them in the final section.

1 CONTEXT AND ISSUES

1.1 Training of students in apprenticeships, partnership between engineering school and companies

Our graduate engineering school in Information and Communication Technology offers different academic programmes ranging from Masters of Engineering to PhDs. One programme is dedicated to apprentices with around 40 students per year. Each student alternates equally between the school and a company over a three year period. The companies vary from small and medium size to large ones such as IT operators. All these companies require that the students are able to work in the complex and fast-changing environment of the Information Technology (IT) industry.
Generally speaking, most project management skills are acquired by experience in professional situations, with challenging constraints on time and resources and with failures from which one hopes to obtain learning opportunities. But, the apprentices experiences in project management are biased by the fact that most of the students are strongly supervised in companies. The room for manoeuver is small because companies want to generate positive results and minimize the risks. The industrial processes are almost fixed in the time scale of the student apprenticeship. The students must therefore identically reproduce these methods with neither modification nor design possibilities. In this way, the students only reach the level 3 of CDIO syllabus V2.0 [2] by only applying methods, analysing and evaluating them. So students are not well prepared for complex projects in which the skills to manage

unexpected events, and the capacity to innovate are main assets. Unlike companies, school is where the students can make mistakes without bad consequences. Failures are advantageous if they are analysed and they bring experience on what must be avoided.

Our Course Unit (CU) aims to make the students able to reach level 4 of the CDIO syllabus [2]. In particular, we want them to reach the meta-level 4.3 "Conceiving, system engineering and management" and 4.7 "Leading Engineering Endeavours" for which they have to create, and then implement management methods thanks to their skills in initiative, complexity and autonomy. In particular, the level 4 attainment is made possible by the autonomy given to the students during the CU. This is combined with a close reflexive monitoring stimulated by the teachers as a steering committee. Our requirement level is high for the skills to acquire and our methods to push the students are unconventional. In this CU, our students are required to perform a technical and economic study for a real customer, involving constraints and unexpected events which may vary during the CU. The students are in large teams (around 15 students) working in parallel on the same subject. Each team acts as a virtual company and has to decide its own organisation (choice of a project leader, design of the Organisational Breakdown Structure, task estimation and distribution). For this purpose, students have to interact with many stakeholders: Customer, Steering Committee, Communication Coach and Technical Experts [1]. During the project, each team produces both technical methodological deliverables. Our goal is to design the training unit with the aim of making the future engineers directly operational in complex project management. We aim to boost the students' skills by introducing the complexity of the industrial world into academic activities.

1.2 Our course unit, the article issue

In complex projects, students are challenged on agility, stress, project management and team-working. But as these skills are relatively absent in standard academic courses, students are neither familiar nor comfortable with them. To highlight these skills, we need to emphasise team-work, self-organization, conflict management and the capacity to deal with unexpected events. Even though, as teachers, we of course verify that the students eventually master these topics to a high level, students must also perform a self-assessment and discuss this assessment with their teachers. Over the last 3 years, we have analysed the students' points of view on their skills improvement. This allows us to tweak the course in order to continually increase students' skills. Moreover, we also have to assess that the students are aware of their skills increase so that they apply this new knowledge with more confidence in their placement company environment.

We observe that most of the students improve their skills and maturity during the CU. But are the students themselves, immersed in the day to day of the project, aware of this skills? It is by stimulating students' reflexivity on their practicing of group relationships and technical skills that we can boost their knowledge of their strong and weak points, of their soft skills and their know-how. How can we boost the students' reflexivity on agility, stress management and team working which students often find much more difficult to assess than their technical skills?

2 METHOD OF OUR STUDY

After two years of such training, it became clear that it would be useful to evaluate student skills in this real-life and complex simulation and also to measure as accurately as possible, the skills differential before and after the CU. It was

necessary for the teachers to objectify the first impression of skills progress even if a qualitative evaluation was yet made (students had to write a text on their own perception of the CU in their final methodological report). We chose to measure their personal perception by a closed questionnaire instead of conducting a normative assessment of rising skills. The assumption is that this CU should enable skills improvement from the points of view of the students. The goal is not that the students feel experts of all complex project management issues but they have mastered the lead concepts. From a methodological point of view, it is a quasi-experiment supported by a framework of "empirical studies" currently being used in software engineering education [3].

2.1 Surveys

The results presented in this article are collected from surveys that are filled in twice by students. The first questionnaire is filled in at the very beginning of the CU in order to set an initial reference level. The second questionnaire is filled in after the end of the CU in order to get a subjective evaluation of their skills evolution. The questionnaire contains twenty seven questions covering the following topics: project management techniques, management, agility/adaptability, customer relationship, conflict management and communication. Students have to rate their skills level on a scale of five levels: (1) No knowledge, (2) Basic knowledge, (3) Proficiency for simple project, (4) Proficiency for complex project, (5) Expertise. We have used the same set of questions for three years. Each student had to answer anonymously and mandatorily. This has no consequence on the project assessment and is purely information for the teachers. All in all, 95 students replied to the questionnaires. We chose three topics and collected the results over three years. Then we aggregated all answers per topics and analysed the resulting diagrams.

2.2 Selected topics

We chose to analyse the following three topics: project management techniques, management and agility. These topics had already been studied and used by students in simple projects so they should hence have basic knowledge of these aspects. But they had never applied this knowledge in a complex project situation which could appear surprising since they spent half their time in company. In fact, as apprentices, they are cocooned in their companies and most of project complexities are hidden from them. As previously described, we introduce complexity through the size of the team, the theme of the project outside that of their usual expertise, the number of stakeholders and unexpected events injected into the project. More specifically, project management techniques are developed through the writing of a Project Management Plan (PMP), schedules and progress reports including risk management. The management skills of students are put in practice by the dispatching of responsibilities. Finally, the size of teams, the kind of project and unexpected events require agility.

The survey includes 6 questions about project management, 6 about management and 2 about agility. We are aware that this classification overlaps.

3 RESULTS ON THE SKILLS IMPROVEMENTS

We analysed over the last 3-year period, the students' perception of their skill about lead on project management techniques, on management and on agility.

3.1 Project management techniques

Mastering the project management techniques is one of the pedagogical goals of our CU. To do this, we selected 5 representative skills which must be handled by a complex project leader, namely: capability to create a Project Management Plan (PMP), to manage risks, to manage tasks, to manage documentation and finally to manage a schedule. We analyse below the sum of the polls on the 5 skills over the last three years (Fig 1).

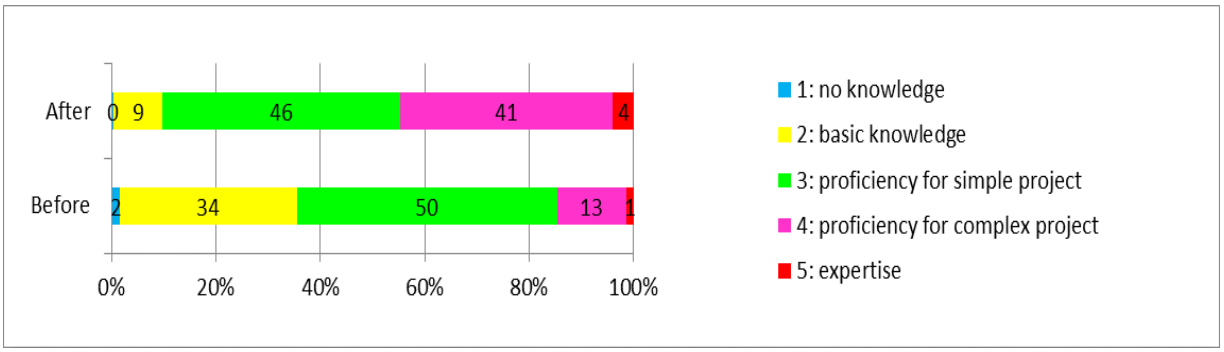
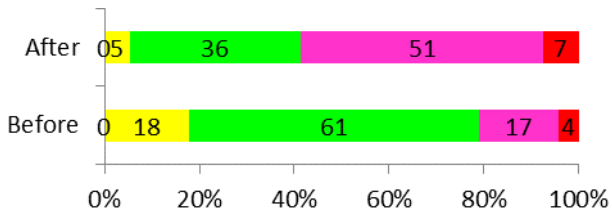
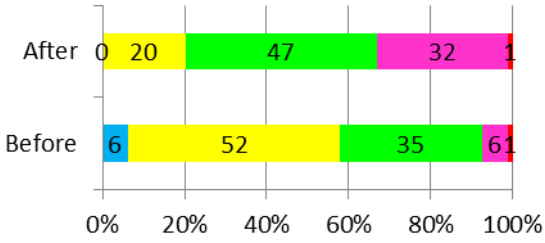


Fig 1: Distribution of the 5 skills on project management techniques

We observe that before the CU, 36 % of the students estimate to have only basic knowledge or no knowledge on project management techniques. This category is reduced to only 9 % after the CU. 45 % of the students consider they have the proficiency in complex projects after the CU while they were only 14 % before the CU. The figure is threefold increased, this is considerable.
By analysing the results for each skill, we observe that each initial feature is tripled or quadrupled after the CU. On Fig. 2(a), we see that before the CU, 21% of the students think they have the skills to deal with the deliverable schedule management for complex projects and 58% consider they have reached this level after the CU. So, the number of students claiming they manage these skills is large. We presume this is due to the efficient CU and also to the students' experience in companies.





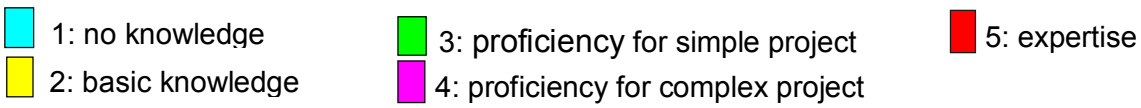


Fig 2(a): Distribution of the ability to manage schedules for deliverables

Fig 2(b): Distribution of the ability to establish a PMP

On the other hand, we observe that few students consider they attain the ability to decide on an initial plan project, to create a Project Management Plan or to manage risks. We see for the PMP design (Fig. 2(b)) that only 7% of the students said they had dealt with a PMP creation before the CU. After the CU, 33 % attained this skill which is a major increase but so far, only one third of the students claim to be able to manage this skill. We also notice that the expertise level for this skill is practically

never attained, even after the CU. This low number of students is probably due to a lack of exposure to PMP design in companies by our students.

3.2 Management

One of the main abilities our students have to improve before leaving the university is the skill to lead a group or sub-group with varying responsibilities. In apprenticeships, our students are protected by their company supervisors who hold most of the responsibilities and limit students' interactions to a few people, to limit risks. Since our students have to be prepared for more realistic situations, we use the CU to create work organizations and situations that help them to improve in the required skills. Fig. 3(a) and 3(b) give the distribution of two abilities: to lead a group of contributors and to be a project leader. The latter implies more responsibilities and interactions with many stakeholders than the former.

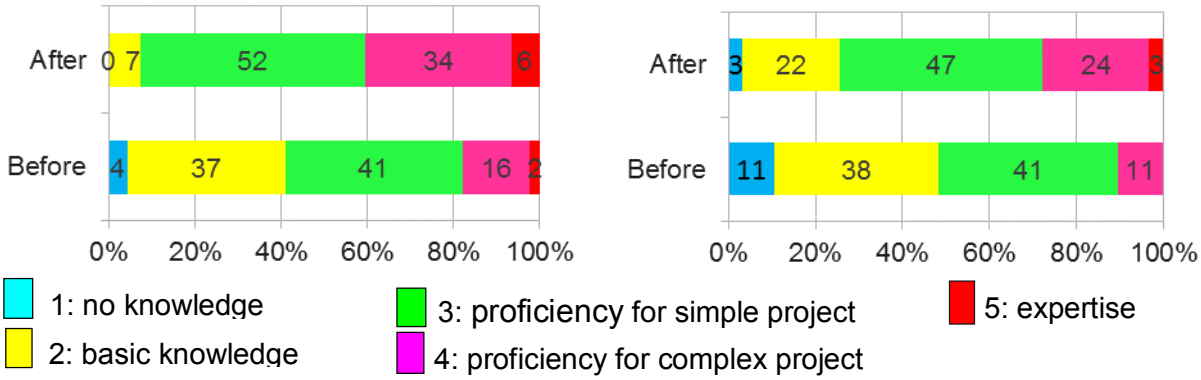


Fig. 3(a): Distribution of the ability to lead a group of contributors

Fig. 3(b): Distribution of the ability to be a project leader

Even though most of the students improve their skills as group leaders and worked on a complex project for 3 months, 59% do not consider themselves able to lead a group of contributors in a complex project. Most of the students seem to consider themselves only as contributors and not as leaders with responsibilities. This is certainly due to the early organization of the groups in which responsibilities are quickly assigned based on individual motivations and "leadership tendencies" experience. Most of the students prefer a comfortable situation with as few risks as possible, while a few students are prone to leadership and battle for power. We also observe that some students do not progress in terms of project leadership and that 25% have a basic knowledge at most. This skill is indeed not easy to develop if a student is not a project leader or work package leader. To avoid a project routine in which the students do not question their own practices and thus do not progress, we as teachers bring some unexpected events. This aims at improving different skills in order to work efficiently in a large group with an acceptable organization and reactive communication. Indeed, the students significantly improve their abilities to work in a large team. Less than 30% of the students thought they attainted the proficiency for complex projects before the project whereas 60% consider they have reached this level at the project end. Thanks to the project, we have doubled this figure.

Meanwhile, students also improved key skills related to working in a large team, namely the abilities to deal with stressing situations and to deal with internal conflicts. As illustrated in Fig. 4(a), we attained a major improvement again from 21% of proficiency or better for complex projects before the CU to 51% after the CU. This cannot be further improved without some action from the customer and from the teachers who bring some unexpected events such as audits, changes in the delivery

dates, introduction of new stakeholders, *etc*. The stressing situations rarely come directly from the students. As teachers, we have to stimulate the students as they will probably become managers in IT companies, where the technological environment, the customer requirements, the market, *etc.* are moving quickly. Moreover, reaching the expert level seems to be particularly difficult since the number of "experts" does not increase after the project: only 3% of the students assess themselves as "experts" able to deal with stressing situations, before and after the CU.

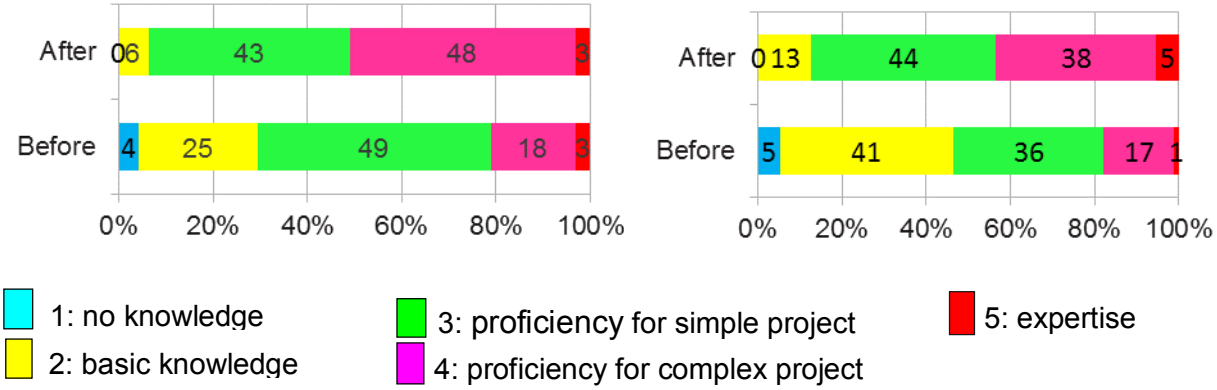


Fig. 4(a): Distribution of the ability to deal with stressing situations

Fig. 4(b): Distribution of the ability to deal with internal conflicts

The proportion of students with at least a proficiency of dealing with internal conflicts for a complex project (Fig. 4(b)) increased from 18% before the CU up to 43% after, but with around 13% of the students thinking they have only a basic knowledge. This is the only skill in management for which more than 10% percent of students self-assessed of being below the proficiency level for simple projects. This is quite surprising since they have many lectures with experts, case studies and they directly experience this during the CU. As teachers, we expect that they should have a higher level of this skill. We have to explore this to understand where this result comes from.

3.3 Agility

Thanks to all the unexpected events introduced to boost the previously mentioned skills, we believe students clearly improved two other abilities. Firstly, 9 % of the students were self-assessed as able to deal with unexpected events with at least a complex project proficiency level before the CU whereas 57 % were self-assessed to this level after the CU. This major improvement is for us a great success since our students will be engineers in quickly moving professional environment where constraints, technologies and concurrency change continuously. Secondly, a large proportion of our students are attracted to new technologies and many even have "geek" tendencies. Therefore, as illustrated in Fig. 5, more than half of our students consider themselves able to adapt to a completely new topic with a proficiency level for complex projects. Improving this skill could be judged as of minor interest, but thanks to the CU we reach a proficiency or better level in a complex project for 81% of the students and a proficiency level or better in simple project for 98%.

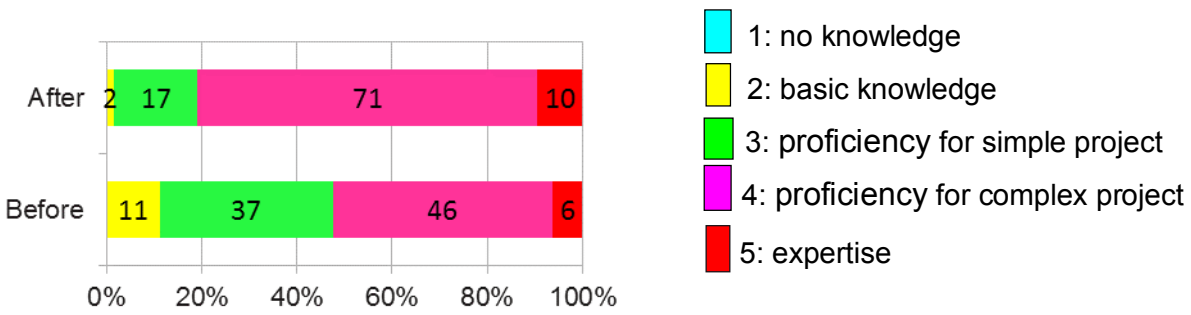


Fig. 5: Distribution of the ability to adapt to a completely new topic

We seem to have significantly improved the agility of our students in this 3-month CU probably because we have not protected them from risks, unexpected events and novelties unlike their experience as apprentices in their companies where their supervisors act as their “guardian angels”.

4 ANALYSIS AND DISCUSSION

In terms of project management tools, the results of questionnaires showed that the learning goals are achieved. All the students improved their skills in this item. However, we have to keep in minds that these students had previously two years of education on project management notions, and two years of company experience. That is not obvious in the graphics “before”. Our CU which puts the students in a real and complex situation seems to boost the improvement of skills which are generally considered as to be developed in companies.

4.1 A counterintuitive statement

Usually, students are too protected in companies by their apprenticeship supervisors and cannot be prepared to complex projects with many stakeholders, unexpected events, high level of constraints and expectations, short delivery delays… At school, the students can fail and take risks whereas in companies this has to be avoided as much as possible. Moreover, the students are rarely aware that their apprenticeship supervisors protect them in companies.

The students mostly improved their skills in working within a large team and dealing with stressing situations. Indeed, this project aims at putting students in the complexity of a realistic project mimicking the life of a company where all the stakeholders have to cooperate. Before this project, our students had always worked in small teams of at most half a dozen students and with only technical objectives. Moreover, most of our students do their apprenticeships with interaction reduced to a few colleagues, far less than 10 people with no real experience of large teams. This new situation obviously triggers stress and conflicts between team members and with the teachers when the project requirements are high or when unexpected events occur. But these events do not occur alone. The teachers have to create situations that will trigger stress and potentially internal conflicts by mimicking realistic situations that are not encountered in the daily life of a student even in apprenticeship.

We have observed that the apprenticeship supervisors minimize critical situations and risks, with clear objectives, adequate tools and information, simple requirements and as few hazards as possible. This situation is quite far from what is the common experience of a project manager in a competitive IT company.

As teachers, we have to prepare our students for real working situations from which they are preserved during their apprenticeships. Companies do not immediately

expect high performance and tolerate errors due to youth and inexperience. While working in a company-like project but only with students, the students are less indulgent than their apprenticeship supervisors.
Therefore, we introduce many hazards during the project to help students attain the aims of experience of complex projects but at a price that we will detail in next sections.

4.2 Complex role of the teachers as stimulators

The role of teachers is delicate: we have to create stimulating situations without reaching a stress level that the students cannot tolerate. The stimulations can come from common hazards such as modifications of delivery dates or customer requirements and from more surprising events such as audits ordered by the customers or the arrival of business angels. These events strongly stress the students who had never encountered such levels of stress and conflict. These aspects were particularly difficult to accept and to manage. The students also admit, after the CU, that these situations helped them to improve their self-knowledge and that of their co-workers. We also observed that the students who consider that they improve their management skills the most were the ones who faced major crises due to internal conflicts which occurred in stressing situations.
The main risk in creating too much stress is that it can be destructive or counterproductive. Some students can refuse the situation or the stress can trigger behaviour that damages a positive team spirit, such as using a group member as scapegoat. We have to put the future managers in realistic situations so that they can criticize their own behaviour and errors before working in a company in position with authority and responsibility. Some management errors which would be destructive in companies can be controlled and highlighted by the teachers. To avoid or at least manage the destructive situations which are triggered, we propose some solutions.

4.3 Necessity of a continuous and close supervision by teachers

The role of the teachers is also to supervise and finely control the stress level to avoid destructive situations. We have concluded that regular (weekly) meetings with a reduced and changing sampling of the students was required and sufficient to efficiently supervise the project. At each meeting, the students have to give an assessment of the group work and conditions to teachers who do not assess the technical results. These results are dealt with by other teachers who communicate with the supervising teachers so that we can correlate work results, events and behaviours. In parallel, the students follow courses (24 hours) on team management and negotiation techniques that certainly help them to face conflicts and stressful situations. Our project activity is successful thanks to a close supervision by the teachers who continuously observe and analyse the students' behaviours and choices without leading their work.

4.4 Limits of the analysis method and of the current course unit

This work has some limits. In terms of learning activity, the results of student skills improvement are strongly dependent on the construction of the group and on the personality and motivation of the leader. Generally, the project manager is very involved in monitoring all of the tasks and lives a stressful but fulfilling experiment. This is not the case for all students and some of them are just concerned by a specialised task. We think that considering a project subject out of students' initial expertise tends to force them to address project management issues, but it can be disruptive and stressful, so that the effectiveness of the training is strongly linked to

the choice of the subject that differs each year. By unexpected events we try to boost students but this must be meaningful and mobilizing.
In terms of methods, we had only statistics on three classes of student (less than 100 responses). A bias can come from the student group or from the technical subject field which motivates students to a greater or lesser extent depending on their interest areas. It is quite difficult to assess skills *a priori*. We assume that some answers are biased for some students by their modesty which diminishes their perceived skills improvement. Empirical studies have some bias but value too [4]. This is a need to increase the number of such experiments.
Up to now, we do not present the questionnaire results to the students. The students would benefit from a personal analysis of their skills improvement. Being aware of not only their own improvement but also of that of their group should help them to understand what was positive during the CU and criticize what can still be improved.

CONCLUSION

The Project Course Unit we have initialized five years ago has proven to be efficient in terms of skills improvement. In particular, two thirds of the students assess themselves to better master project management techniques. A large majority of students feel much more comfortable with leading teams of contributors if they are not project leaders themselves and they feel much more confident in dealing with conflicts within the project team. On a less large scale, students also improve their expertise in dealing with new topics and being a project leader. These meta skills are key points to face complex projects with confidence. The course unit allows the students to reach a level that could not be attained in such a short time with conventional teaching methods. The teachers have to create situations that will trigger stress and internal conflicts by mimicking realistic situations that are not encountered in the daily life of a student even in apprenticeship. The apprenticeship supervisors protect their apprentices by minimizing critical situations and risks so that the students are not completely aware of the complexity of their future job. Our course unit aims to fully train our future engineers by fixing this lack. Thus, we reinforce the cooperation between academic and industrial worlds.
The price to pay for such a course unit is a less stable and comfortable position of both students and teachers during the project. The introduction of unexpected events and a strong involvement of the project stakeholders around the students force them to go beyond the teaching/learning routine that they daily experience during conventional courses.
However, these gross statements have to be refined by getting more data from students especially after their final apprenticeship period. We also decided to give back personal and group questionnaire results to increase the students' confidence. We would like to enrich skill self-assessment sessions with expert third party ones.

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