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# Industry 4.0: introduction to the continuous improvement of an industrial process for Master's students

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**Abstract:** Among the many pedagogical strategies for improving students' motivation, life skills, and know-how, project-based learning is often cited as an example. It is in this context that a challenge entitled "New digital processes for the plant of the future" was launched in 2019 for Master's students learning in the field of "mechatronics". Seven teams formed randomly with last year students of the HEI graduate school of engineering, therefore, they took part in this challenge. The technical issues to be addressed were vast because they had to meet certain needs and services dedicated to issues related to the digital industry or industry 4.0. This paper details the pedagogical strategy that has been adopted, the technical specifications and the planning to be respected. It also proposes some significant results. A measurement tool concerning the efficiency of the method has also been implemented. According to these results, we refine our feedback on the challenge and thus refine our educational policy.

**Keywords:** industry 4.0, Edunet network, Skkynet, project pedagogy, IoT, engineering students.

## 1. INTRODUCTION

Among the many pedagogical strategies for improving students' motivation, life skills, and know-how, project-based learning has often been cited as an example for several decades Bavota et al. (2012), Blumenfeld et al. (1991), Reverdy (2013). One of the essential characteristics of projects or challenges dedicated to students is their relatively long duration, which is in all cases longer than the usual pedagogical activities. This duration requires consistency in action and reflection, with organizational management of the group or working groups. However, it is necessary to be vigilant and anticipate certain actions in order not to fall into certain excesses (Blumenfeld et al. (1991), Fig. 1). In our department at the University of Orléans, combined with others (HEI campus Centre, INSA Centre Val de Loire), we are active in pedagogic innovation according to Bégot et al. (2011), Vrignat et al. (2015), Vrignat et al. (2017).

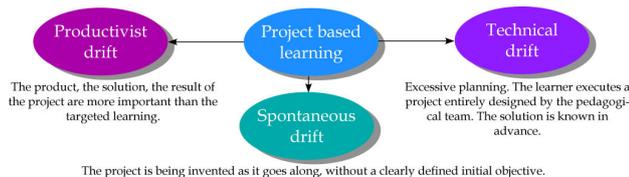


Fig. 1. Possible deviations from the pedagogy by project.

A project is characterized by a duration whose end is known in advance. Between the beginning and the end of the project,

there is a learning process in Midler (2012) described as "an irreversible dynamic in which we move from a situation where we know nothing or little but everything is possible, to another where, on the contrary, the level of knowledge has reached its maximum but where all the room for maneuver has been used". Fig. 2 shows a possible representation of this situation. We used a modern measurement tool to try to reproduce this feedback on pedagogical experience (Kahoot<sup>1</sup>). Section 5 of this paper is devoted to a Benchmark on this subject.

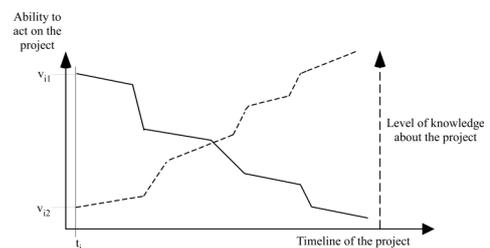


Fig. 2. Adapted representation of the dynamics of the so-called "project" situation in Midler (1993).

As teachers, we have noticed that student enthusiasm depends on the study subject. This subject needs to be at the same time motivating, attractive, topical, playful and demonstrative. The theme chosen for this experiment was de

<sup>1</sup> <https://kahoot.com/>. Kahoot is an online quiz system that is easy to use and challenging for participants.

facto carried out following industrial challenges according to, Bartodziej (2017), Champaney (2017), Lluansi et al. (2017). Higher technical, technological and scientific education already provides some answers by offering appropriate training on many topics related to the industry 4.0. This paper is composed of six sections. After this introduction, section 2 presents the technical context of the challenge associated with 2 industrial partners. Section 3 describes the pedagogical approach to work with students. Section 4 presents a range of significant results obtained by different groups. Section 5 proposes an educational Benchmark obtained at the end of the challenge. We end with a conclusion.

## 2. TECHNICAL CONTEXT OF THE CHALLENGE

The proposed work consisted of setting up an operational structure showing the foundations of a communicating industrial architecture in a process of monitoring and controlling production. It provides many numbers of additional information compared to the papers in Chemla et al. (2013), Endi et al. (2010) and Vrignat et al. (2014). Based on the information from the process studied, the different groups had to develop and use several clients in a SCADA<sup>2</sup> approach in Riera et al. (2005). It was necessary to show in this work several solutions to be implemented to carry out a wide range of tests. To do this, the data had to be centralized in an OPC DA<sup>3</sup> server and made available to different OPC clients (Fig. 3). The entire solution was also intended to make it possible to track a certain number of variable contents (Items<sup>4</sup>) associated with the quality of the products manufactured "online". The states of proper functioning and dysfunction of the system also needed to be the subject of a specific work. This work was to be based on the work presented in Vrignat et al. (2018). Sensitive production-related information had to be sent to a recipient through two transmission strategies:

- ✓ SMS with an associated message on a mobile phone (maintenance or production manager).
- ✓ Mail with an associated message on a mailbox (maintenance or production manager).

Fig. 7 presents in detail the different technical constraints that the students had to manage. The latter had to extract relevant information about the process (sensor information, button information, pre-actuator information, safety element information, production information, etc.) without disrupting

<sup>2</sup> SCADA: Supervisory Control and Data Acquisition. The objective of a SCADA environment is to conduct reactive process management. A SCADA environment consists of 4 subsets: the acquisition function, the control function, the monitoring function, and the supervision function.

<sup>3</sup> The OPC Data Access Specification is the first of a group of specifications known as conventional OPC specifications. OPC Data Access is a group of client-server standards that provide specifications for real-time data communication from data acquisition devices such as Industrial Programmable Logic Controllers (PLCs) to display and interface devices such as Human Machine Interfaces (HMIs), SCADA systems and ERP/MES systems.

<sup>4</sup> Item: designation of an object associated with a variable that can be processed by the OPC server and potential clients.

the operation of the system. The process is described in Fig. 3.

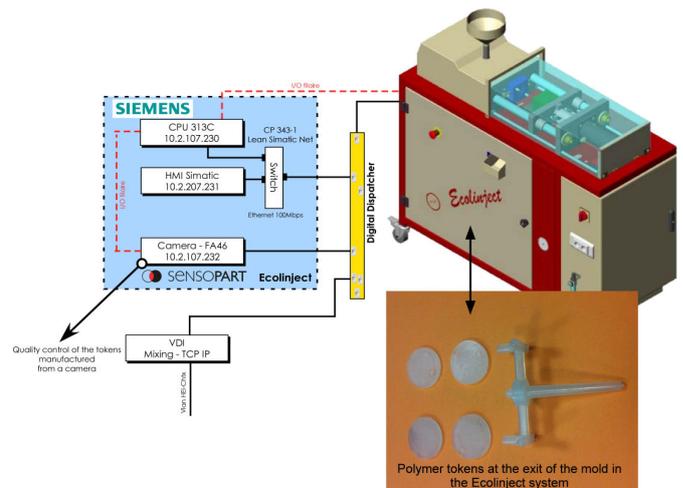


Fig. 3. The production system

This part integrates many primary functions that can be found on an industrial process:

- ✓ temperature regulation with different manufacturing recipes,
- ✓ hydraulic injection press, supplying polymer balls to mold (4 cavities),
- ✓ controlling the quality of the tokens thus produced via a camera (Fig. 3).

All this is automated with different Siemens brand products PLC (Industrial Programmable Logic Controller), operator panel, pre-actuators, etc.). Fig. 4 presents in detail the functional set for the Ecolinject part. This will be the core of the work support for the challenge.



Fig. 4. The token making system - <https://youtu.be/NCw1b8vUljq>

The PLC used is a PLC from the Phoenix Contact manufacturer (ILC 151 GSM/GPRS). The proposed platform was to be able to process on-demand the information desired by the various customers (Fig. 5). Two software tools have been installed on the students' personal computers for this purpose. These software platforms were:

- ✓ AutomationWorx 2018,
- ✓ Cogent Data-Hub V9, an office automation suite (Office or other (> 2010)).

The hardware solutions used had to fit well into a context where digital wireless communications are extending their influence according to Loubert et al. (2010). With the help of the international university network EduNet<sup>5</sup>, Phoenix Contact encourages exchange and collaboration between various universities working with skills in the field of process automation as well as in Research and Development. Nowadays, this international network of contacts and skills includes 110 high schools and universities in 30 countries (Fig. 5). It is within this framework that the partner training structures design their courses using Phoenix Contact equipment offered by this convention. In exchange, they must make their educational materials and experiences available to the community registered on the EduNet Internet platform. Also, "Phoenix Contact" laboratories are collaboratively initiated within Universities, thus facilitating the entry of students into the professional world. In July 2017, the Orléans University and the IUT de l'Indre signed the first agreement for France with this network in Phoenix Contact, (2017). This collaboration since then has enabled us to integrate new technologies for the challenge with negotiated hardware and software purchase rates (Fig. 8). A software platform (PC Worx, Fig. 6) is available to configure, program and diagnose the PLC (ILC 151 GSM/GPRS). The 2<sup>nd</sup> collaboration allowed us to integrate an international software publisher: Skkynet (<https://skkynet.com>). We have been working for 3 years with this software publisher and an environment called Cogent DataHub. Cogent Data-Hub (Fig. 7) is a unique tool that allows you to connect, concentrate, integrate and redistribute data in real-time between different devices (PLCs...) and users (supervision applications, database...). The publisher agreed to provide the necessary licenses for the challenge so that students can use this platform on their personal computers or school computers (Fig. 8).

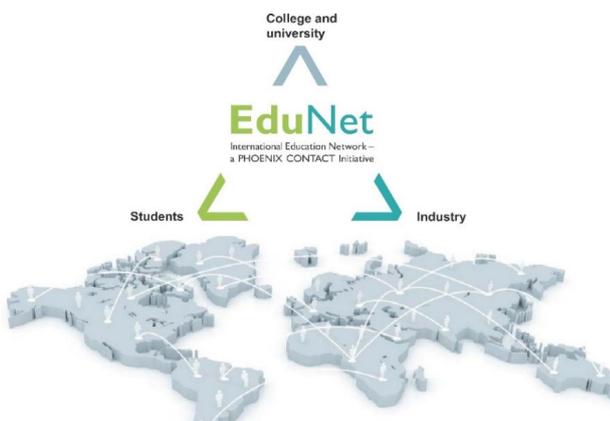


Fig. 5. Edunet network

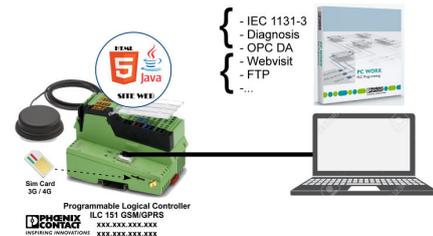


Fig. 6. PC Worx development platform

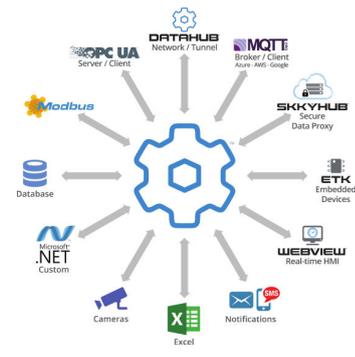


Fig. 7. Cogent DataHub proposed by Skkynet

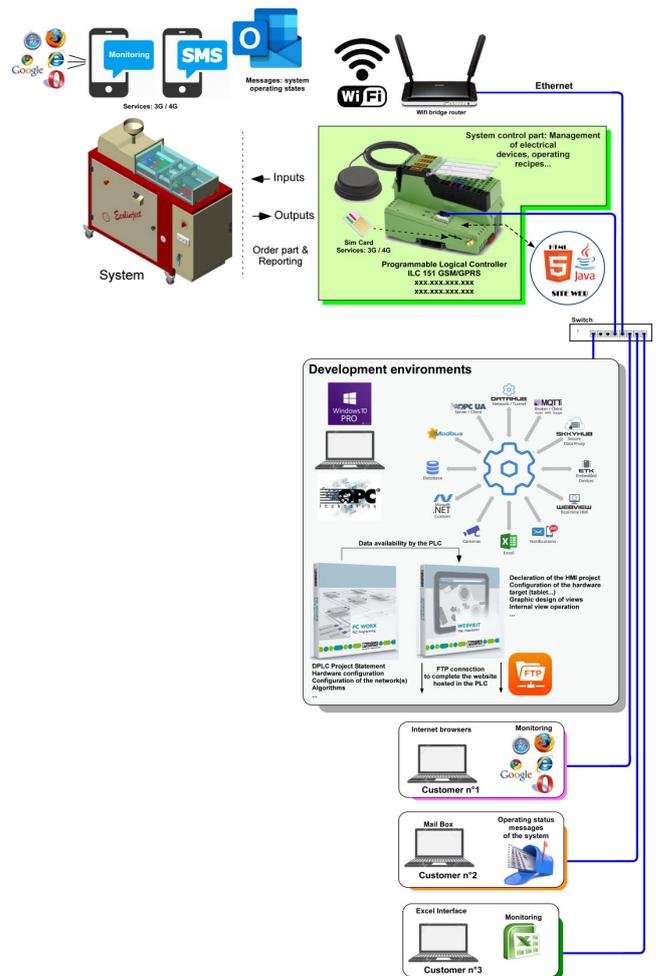


Fig. 8. Hardware and software architecture of the challenge

<sup>5</sup> <https://elms.ccad.eu/moodle/index.php>

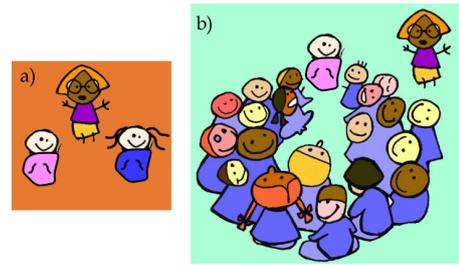
### 3. THE PEDAGOGICAL WORKING APPROACH ADOPTED FOR THE CHALLENGE

The proposed challenge was submitted to apprentice engineering students in the 5<sup>th</sup> year (HEI campus Centre). This challenge was compulsory for the entire student's promotion. In recent years, we have all seen at the University that pedagogical modalities and strategies must evolve in response to new learners. It is in this context that we have radically modified the pedagogical strategy adopted to date for this type of teaching, which concerns a module called "Supervision of industrial processes" (Courses, Tutorials). The objective was then to work from a strategy called "project-based learning", validating skills and high levels of individual and collective involvement. It was natural to activate this challenge with 7 groups of students (4 people). These seven groups formed random and competed at the same time, over a limited and supervised period of 35 hours. The distribution of the different tasks to be carried out was the responsibility of a leader. 7 hours and 30 minutes were devoted upstream to provide the theoretical elements. All the necessary resources were available on the learning platform: technical documents, examples of programs to start, video presentation of the challenge... Both material resources made available were also identical for all groups. At the end of the challenge, each group had to present their work in English in a "My project in 180 seconds" format. A video game presenting the material and the different services to be reached was also the subject of available resources. Fig. 9 provides access to this resource called "La cagnotte de Pascal".



**Fig. 9.** A fun demonstrator to start the challenge (<https://youtu.be/2Q6VYkoxn8I>)

At the end of each half-day of work, a quiz with the Kahoot environment was proposed to all students to measure their level of motivation, involvement, coordination, and skills. Finally, a complementary pedagogical strategy has also been implemented based on the so-called "active" pedagogy in Lin (2011). The purpose of this strategy was to validate the ability of some students to provide information to others (leader to other participants in the group, Fig. 10, (a) and (b)). Given the many tasks to be handled, this strategy also made it possible not to mobilize all human resources at the same time with the teacher. The specific knowledge contributions on the different software environments were disseminated only to leaders (Fig. 10, (a)). The leaders then had to give back, according to the needs, the knowledge they had previously acquired (Fig. 10, (b)).



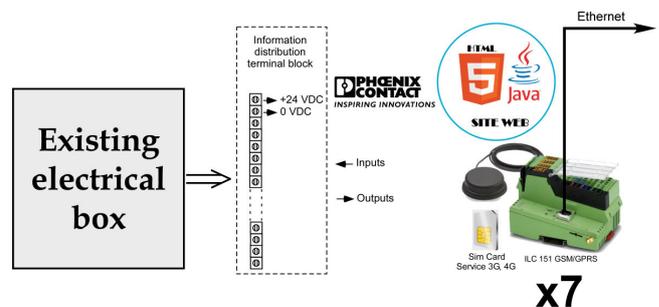
**Fig. 10.** Reverse classroom

### 4. SIGNIFICANT RESULTS OBTAINED BY DIFFERENT GROUPS

Very often, when faced with a problem that has arisen and needs to be solved, our reasoning process proposes the solution(s) too quickly before intellectually contextualizing the subject or exercise to be addressed. This reflex is often present to reassure us, an intellectual subterfuge not to leave our circle of trust. We have all experienced this. Sometimes, the exercise to be treated is ready for a very quick reaction and action. It is necessary to react as well as possible at the moment... Nevertheless, and very often, many problems can and must be contextualized with the use of formalization tools (functional blocks, Boolean equation, flowchart, structured analysis and design technics, algorithm...). Before any operational intervention, the various groups had to consult each other to bring out the essential data issued by the system (without modifying either the program stored in the PLC and the operator panel, or the wiring of the electrical cabinet). The majority of the groups wanted to be able to process the following information:

- ✓ Management of on and off modes: system on or off, emergency stop, electrical protection of the conveyor belt disconnection, opening/closing of the protective cover, jamming, de-stemming, thermal protection of the heating rings present before the mold.
- ✓ Management of the manufacturing recipe: opening and closing the mold, position of the hydraulic cylinder, information on the quality of the tokens, the number of tokens produced.

To carry out this subject, Fig. 11 describe the concatenation work that has been carried out in global concertation between the different groups. The technical documents of the system manufacturer had to be studied with the utmost seriousness.



**Fig. 11.** Electrical connection constraints

Fig. 12 shows the cabling work that was necessary to provide all the necessary signals previously selected by the different teams.

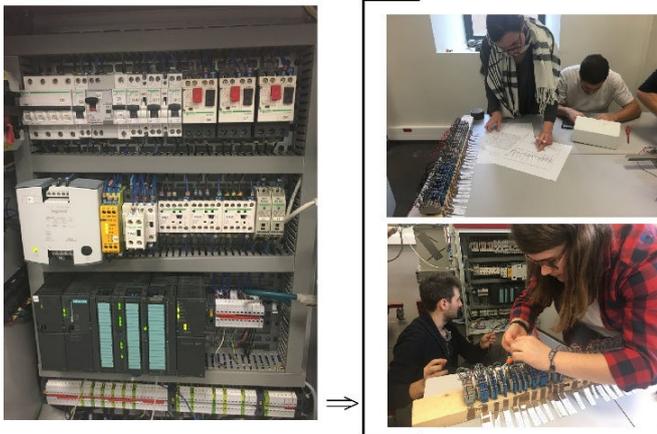


Fig. 12. Electrical connection constraints

As we have mentioned, each group had all the resources to carry out the challenge. Fig. 13 shows a board being assembled: (a), the PLC and its SIM card (subscription to be chosen from a telephone access provider); (b), the beginning of wiring and programming for a group.

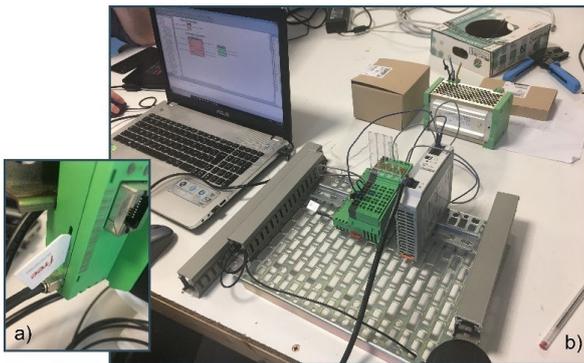
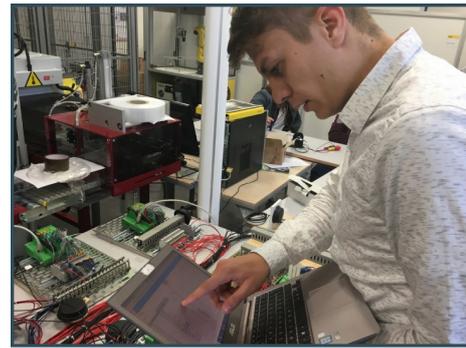


Fig. 13. Electrical connection constraints

Fig. 14 (a) presents the result for all the necessary interconnections. The students were particularly aware of the constraints that can be associated with electrical wiring. Each group has also managed the obligation to check the first conformity checks that must be carried out before starting such an installation (Fig. 14 (b)). These conformities concern electrical potentials, electrical safety, input states (detectors, sensors), the initial state of the operating part, the initial state of the program in the PLC...



a)



b)

Fig. 14. Global interconnections and test phase

The results obtained were of very good quality. The result for a group is presented in Fig. 15 and Fig. 16. The video had to be made with a single shot including the various demonstrations. The students could carry out as many tests as they wanted beforehand.



Fig. 15. An example of results  
<https://youtu.be/RTw6IUUp57JY>



Fig. 16. A 180-second presentation of the project for a group  
<https://youtu.be/9gwX7VarkfM>

## 5. EDUCATIONAL BENCHMARK

The first very positive feedback from this challenge concerns the technical results obtained by the 7 groups. Not specialists in the field and discovering during this challenge all the hardware and software, the students were particularly efficient and organized. Kahoot was used in our case to (five surveys were proposed over the challenge period):

- ✓ Revitalize groups in the restart... or sleep phase!
- ✓ Establish a diagnosis of the students' work and motivation.
- ✓ Evaluate the challenge.
- ✓ Evaluate our work (teachers).

These statistical results from the various surveys correspond to response criteria between 1 and 4. The ability to act on the project was important at the start of the challenge (3.4); mobilization of working groups, appropriation of software, hardware ... This mobilization has declined over time. The technical locks were opened step by step. The results

established by the tool are presented in Fig 17. We can indeed see an increase in the degree of motivation between the beginning and end of the challenge. This degree was at 2.8 at the beginning and ends at 3.6 (out of 4 (maximum score)). When asked about their level of prior knowledge, the results obtained are significant (1.14 at the beginning of the challenge and 3.8 at the end). The students greatly increased their knowledge and skills after the challenge.

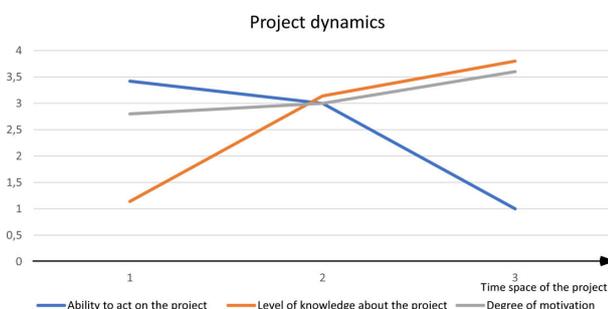


Fig. 17. Evolution of skills and motivations

## 6. CONCLUSION

Engineering schools have been adept at challenges for many years (internal, inter-school, national and even international challenges). This challenge initiated for the first time in this training is a complete success in several respects: student involvement, the involvement of external professionals, results obtained, student motivation, a significant increase of individual and collective skills... We have shown that so-called "project-based" and "active" pedagogies can be a very good teaching strategy. But as we have shown, much preliminary work must be done by the teacher. Institutional partners: Orléans University, HEI campus Centre, IUT de l'Indre. Industrial partners: Phoenix Contact, EduNet, Skkynet.

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