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# Modeling and implementing an innovation process in project-based learning activities: Case of mechanical engineering training in Morocco

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**ABSTRACT:** Engineers are recognized as key players in the development of innovative projects thanks to their professional experience and their training. However, in some growing countries such as Morocco, involving innovation in engineering education is poorly integrated within engineering training curricula. In this study, we propose an innovation process model proper to the design and realization of innovative projects within engineering schools, particularly in the field of mechanical engineering. Our modeling approach is based on systems engineering. Experiments were conducted in the mechanical engineering department of an engineering school in Morocco to implement the proposed model in student projects. The students were guided to implement the proposed process and deploy innovative methods, then a quantitative assessment that considered their innovativeness and adherence to the innovation process was led. The innovativeness of the projects was assessed based on international patterning criteria, and an assessment system was used to analyze the level of compliance of the demonstration projects with the steps and support means and methods of the model's process. The findings of the study enabled us to improve our model of the innovation process by including methodologies and instruments personalized to the environment of engineering schools and based on a technological approach that emphasizes interdisciplinary theoretical and methodological contributions. The current study enabled us to confirm that an innovative project carried out within an environment characterized by the interaction and management of a set of material and human resources and methods and engineering skills can help to boost innovation in engineering education.

**KEYWORDS:** action research, creativity, project based learning, modeling, innovation.

## 1 INTRODUCTION

In the era of technological and digital revolutions, innovation has become a central theme in government strategies and plans aimed at driving technical, socioeconomic, and scientific advancement. It serves as a key lever for wealth creation, especially in emerging economies such as Morocco, and is essential for addressing the challenges of globalization. These challenges include the internationalization of markets, intense global competition, the accelerating pace of digital transformation, and the rapid transfer of technology and information.

The roles of engineers and other innovation actors have evolved to meet the increasing complexity of today's problems. Engineers now contribute to organizational competitiveness through various means: developing new products, creatively combining existing technologies, optimizing project management, and delivering targeted technical solutions within research and development [1]. In Morocco, engineers play a crucial role in driving innovation and ensuring the success and continuous improvement of large-scale development initiatives across all socioeconomic and scientific sectors [2], [3], [4].

These demands have intensified the need to reassess and prioritize the skills and competencies required for innovation [5]. Engineers are increasingly viewed as agents of progress, with a core responsibility to introduce technological advances that enhance societal well-being [3]. This raises important questions about the role of engineering education—particularly in Morocco—in cultivating the capacities that enable innovation [6].

Our research focuses on the complexity of fostering creativity within a project-based learning (PBL) framework in mechanical engineering education. We specifically address industrial innovation, which encompasses both product and process innovation, and its application in student engineering projects. We conceptualize innovation as a complex system—a process structured in defined stages, involving multiple stakeholders and integrating diverse domains of knowledge and expertise, such as technology, science, and management [7], [8]. Using a systemic approach, we aim to analyze and model how this innovation system operates.

This leads us to explore whether the early-stage project work of engineering students could be professionalized through the adoption of a structured innovation process. Such an approach may result in tangible innovations eligible for intellectual property protection and potentially generate revenue for educational institutions.

In this study, we seek to bridge project-based learning in engineering education with the creative methods employed in industrial settings. Our goal is to design and apply a model for an innovation process that can enhance the innovation capacity of mechanical engineering students. Drawing inspiration from industrial management practices that boost performance and goal attainment, we investigate whether engineering schools should similarly adopt structured innovation methodologies to foster successful innovation projects.

Building on our previous research that assessed the state of innovation within engineering schools [9], [10], [11], we have identified the stages, tools, and strategies necessary to support students and faculty in managing and guiding innovative projects. This paper advances that work by proposing a systemic model of the innovation process in mechanical engineering education. We then evaluate its implementation in student projects to test its relevance, identify challenges, and refine the model for greater effectiveness.

## 2 Literature Review

### 2.1 The Innovation Process

It is difficult to give a single and precise definition for this concept, as each study perceives innovation from a different point of view. However, our work needs to frame the definition of innovation to be able to design tools to judge a project as innovative or non-innovative.

Different authors, among others; [12], [13], [14], [16], [6], and [17] highlight three main criteria for talking about innovation: the creation of a novelty (whether it is a concrete object such as a product, a machine, a technology, a process or an abstract one such as a service, a procedure, an organizational or commercial form), the added value, in particular, the response to a need expressed by actors at different levels (individuals, organizations, society, etc.), and the dissemination which is translated in economic terms into marketing.

We have identified the common characteristics included in the definitions of the different authors. We can define the concept of innovation as a complex system allowing the improvement or creation of a new solution (in the form of a product, service, process, etc.), likely to generate economic, environmental, or societal value, by following a multidisciplinary process involving different types of factors.

In our work, we are particularly interested in industrial innovation, which concerns only products or processes developed by the industrial sector. Our choice is mainly justified by our scientific positioning related to the field of mechanical engineering. We consolidate our choice by the results of the study carried out by [18] on innovation in engineering education, which showed that the field of innovation with a business (or even entrepreneurial) orientation is dominated by the discipline of industrial engineering, while the production of innovative tools and equipment allowing the development of new products, is dominated by mechanical and electrical engineering. We focus on incremental innovation, which consists of the improvement or creation of new features of products, services, or processes in the marketplace, following creative problem-solving approaches. On the one hand, the latter does not require large investments or rare and sophisticated equipment for its development, which corresponds to the context of engineering schools with limited financial and material resources. We support our choice by the interdependence between incremental innovation and the cooperation between several actors in an innovation project that characterizes our model of the innovation process [19].

There are different works in the literature proposing models of the innovation process (among others, [20], [21], [14], [22], [23], and [24]. Although the titles of the different stages constituting the innovation process may differ from one model to another, the meaning and content of these stages are common. Among the stages that are repeated in most models are creativity, idea generation, development, realization, and diffusion or commercialization. These stages are organized in a chronological sequence and link several resources and information. Additional steps can be added to the main process, such as feedback, continuous process improvement, and knowledge management [25].

Several authors have proposed and tested systemic modeling based on different methods in industrial companies. After a deep study of these several models, a comparative analysis unveiled that the more adequate model of the innovation process that we are studying could be similar to the model proposed by [24].

The modeling approach in [24] begins the process of innovative new product design as a set of operational, sequenced, and continuous steps and places the designer at the center. This reflects the importance of the capabilities and competencies of the main actor of an innovation process in its progress and their impacts on the results. In our work, we also try to highlight this dependence of the innovation process on the capabilities and competencies of its main actors, which in our case are the young future engineers.

Contemporary research on innovation processes proposes models of open innovation. In this case, we cite the work of [23] where they propose a systemic model of the open innovation process using the Business Process Management formalism.

All of the previous models break down the process of creating and developing innovations into a set of interacting steps, which can be broken down into activities, tasks, and procedures. Ensuring that these steps are carried out and that the desired results are achieved, is conditioned by the mobilization of a set of mechanisms and centered on the stakeholders in the process, which differ from one model to another.

### 2.2 Training Engineers To Be Future Innovators

The roles performed by engineers within companies evolve according to the challenges and changes of each area and territory. Today, the technological revolution has influenced the characteristics of markets and the behavior of customers (organizations or individuals) through the opening up of international markets and the almost continuous connection to social networks. Thus, the successful marketing of innovative products requires the presence of varied and highly qualified knowledge and skills. In addition, information technology (IT) has become the primary driver of innovation in industrial companies in the new era of Industry 4.0. These latter increasingly require young engineers to have IT skills and knowledge for production. Faced with all these facts, the young engineer is expected not only to be able to design and manage the process leading to innovations (production, quality, logistics…) but also to be agile and aware of the economic, social, and environmental properties of the market [3], [26], [27].

Engineers' training in innovation is now an inevitable challenge for engineering schools especially in our Moroccan context. These institutions are increasingly making efforts to strengthen innovation among future engineers by integrating innovation concepts into curricula and encouraging various active learning methods, in particular projects.

A study by [27] distinguishes three main approaches that encompass the different forms of innovation training and serve as foundations for designing educational systems that can strengthen innovation in engineering schools:

- Training in global engineering, oriented toward responding to societal needs
- Training in research, focused on the production of knowledge
- Training in technological development, aimed at producing objects or services through different types of projects carried out inside or outside the educational institutions.

In this research, we are particularly focused on the third type of innovation due to the technical nature of mechanical engineering education.

Accordingly, our attention has been placed on project-based learning activities, which encourage the development of innovations. These activities enable the transformation of basic technical and transversal skills into innovation skills by engaging students in complex and real-world situations. Project-based learning activities enhance students' desire to learn and allow for the integration of theoretical knowledge through practice [27]. They are an effective strategy for increasing student participation in their learning environment, encouraging and developing creativity, discovering new concepts and experiences, and the frequent use of technological and digital tools [28].

Several authors have shown the vital role played by student projects in their schools or during internships in companies in the development of a set of skills that enhance the capacity of innovation and creativity in engineering education such as [29], [30], [31] and [31].

The capacity to innovate is based on the combination of a set of skills and abilities. It is defined as the set of skills, knowledge, and abilities that make an individual able to think and act innovatively in the field in which he or she works and masters. These competencies consist mainly of a combination of technical and non-technical skills [3]. The Commission of engineer's grade (CTI) is increasingly interested in the issues of innovation, creativity, and entrepreneurship in its reference frameworks and documents. The competencies targeted by engineering education for innovation from the CTI perspective [32] can be classified under four families:

- Scientific and technical skills: designing an innovative business project;
- Relational and managerial skills: anticipating and deciding in situations of uncertainty
- Cognitive skills: creative problem solving, inventing, innovating;
- Cross-cutting knowledge: entrepreneurship, intellectual property.

These competencies can be reinforced by pedagogical and extracurricular activities that allow students to carry out personal or collective business creation projects based on listening to needs, creativity, experimentation, and the development of business plans [32].

In conclusion, it appears that innovation is treated in training in two ways, innovation as an individual's ability to produce a novel and inventive solution, and innovation as a result obtained through the completion of a project. On the other hand, few works present an overall organization of the innovation system within engineering education institutions and in particular in Morocco, and highlight the approaches followed for the production of innovations, the resources put into service for this purpose, and the actors who contributed to these activities.

The present work makes it possible to establish a bridge between the concept of the innovation process and engineering education. This may lead to an introduction of innovation engineering into knowledge-producing bodies such as higher education institutions, and in particular engineering schools. Therefore, we propose to adopt it within mechanical engineering education as a learning and teaching approach to carry out innovation projects. The objective of its adoption goes beyond the promotion of the acquisition of skills necessary for innovation in future engineers, to the fact of living a real professional experience that can lead, in the case of availability of resources and expertise, to the realization of innovations and even to the production of intellectual property.

## 3 METHOD

### 3.1 SYSTEMIC MODELLING AND ACTION RESEARCH

To give meaningful answers to our aims, we proposed a holistic method to understanding and studying the phenomena of innovation within engineering education, followed by modeling it. Systemic modeling is an important methodological framework in our study. All of the data acquired, processed, and interpreted using the previously stated research methodologies is being used to build a comprehensive model of the innovation process.

The systemic model has been extensively used as a consequence of scholars' interest in comprehending complexity and approaching a system's linkages and evolution [33]. The construction and development of a model in the form of diagrams or schemas, utilizing symbols to explain and communicate the many components of a complex system and their interactions, is referred to as modeling [34].

In previous studies [7], [8], [9], we have carried out in-depth case studies of the current state of innovation in engineering education in different institutions, particularly in the case of mechanical projects. This stage allowed us to collect data on various projects through observations and interviews, to deduce their constituents, strengths, and weaknesses, as well as the place of innovation in the studied area. This first step corresponds to the analysis phase of the systemic approach. Then, we deployed process modeling methods used in engineering sciences to represent and characterize the resulting innovation process. The last step of the systemic approach is the simulation of the system, which refers to the realization of a cycle of experiments that allowed us to put into practice and test the validity of our model, which requires an action research approach allowing a round trip between practice and theory. These experiments were conducted in the mechanical engineering department at the National High School of Electricity and Mechanics in Morocco (ENSEM).

The model's implementation and verification require a presence in the field as well as suitable methodologies and techniques from theory to apply and assess its efficacy and validity in real scenarios. This back and forth between theory and practice is entirely consistent with the logic of action research. It stresses the researcher's active engagement in the action [35].

As a result, the experimenter is no longer impartial, but rather engages in action with the actors who are the subjects of the research. Action research is described as a participatory approach based on a strategy of practical studies used to investigate the features and behaviors of a phenomena while incorporating the human factor. Its primary instruments are action, contemplation, and active involvement, all of which are used to generate practical answers [36]. Action research may be visualized as a cycle with a series of steps. The first phase is to characterize the problem using data from field observations and papers, which are then evaluated to produce an action plan for the stated problem [35]. The next step is the implementation and analysis of the action through the evaluation of its results. This analysis is used to modify and improve the action plan.

### 3.2 SYSTEMIC MODELLING OF INNOVATIVE PROJECTS' PROCESS IN MECHANICAL ENGINEERING TRAINING

We express the dynamism of the capacity of innovation in future engineers through the process of an innovative project. Our process aims not only at the realization of an innovative project but also at inculcating in the student engineer, who is the central actor of the process, certain knowledge, and skills related to innovation.

At the beginning of the process, the future engineer already has skills and knowledge that he or she may have acquired before and during his or her enrolment in engineering school, which may be technical (writing specifications, sizing, modeling, drawing, using design software, choosing materials, etc.), or non-technical (analyzing, associating, communicating, imagining, etc.) These skills can be acquired in different ways during the future engineer's training, but also reinforced through extracurricular activities within the school (school clubs), by joining external associations, or through personal initiative projects. At each stage of the innovation process, each engineering student involved in the project can call upon various skills and knowledge that differ according to the nature of the project, the means available, but also their personal qualities.

The application of these skills, in reality, allows them to be reinforced and can lead to the creation of new skills and competencies in the student engineer. We can summaries them in the ability to innovate or "innovation skills" representing a new output of the innovation process. Otherwise, the use of certain technical methods and the use of certain equipment requires the possession of certain skills and know-how in the field of mechanics. We propose the mechanical engineering education's process as a parallel process to the whole process because it allows future engineers to acquire technical and transversal competencies necessary for the support and realization of the different stages of the innovation process.

Thus, our mapping differs from the classic mapping of the process approach through the addition of an extra process, which is the training process constituting a basis and a reinforcement for the realization process. In Figure 1 we show our innovation process map, where we have added the training process, and we have mentioned innovation training as a main activity of the management process.

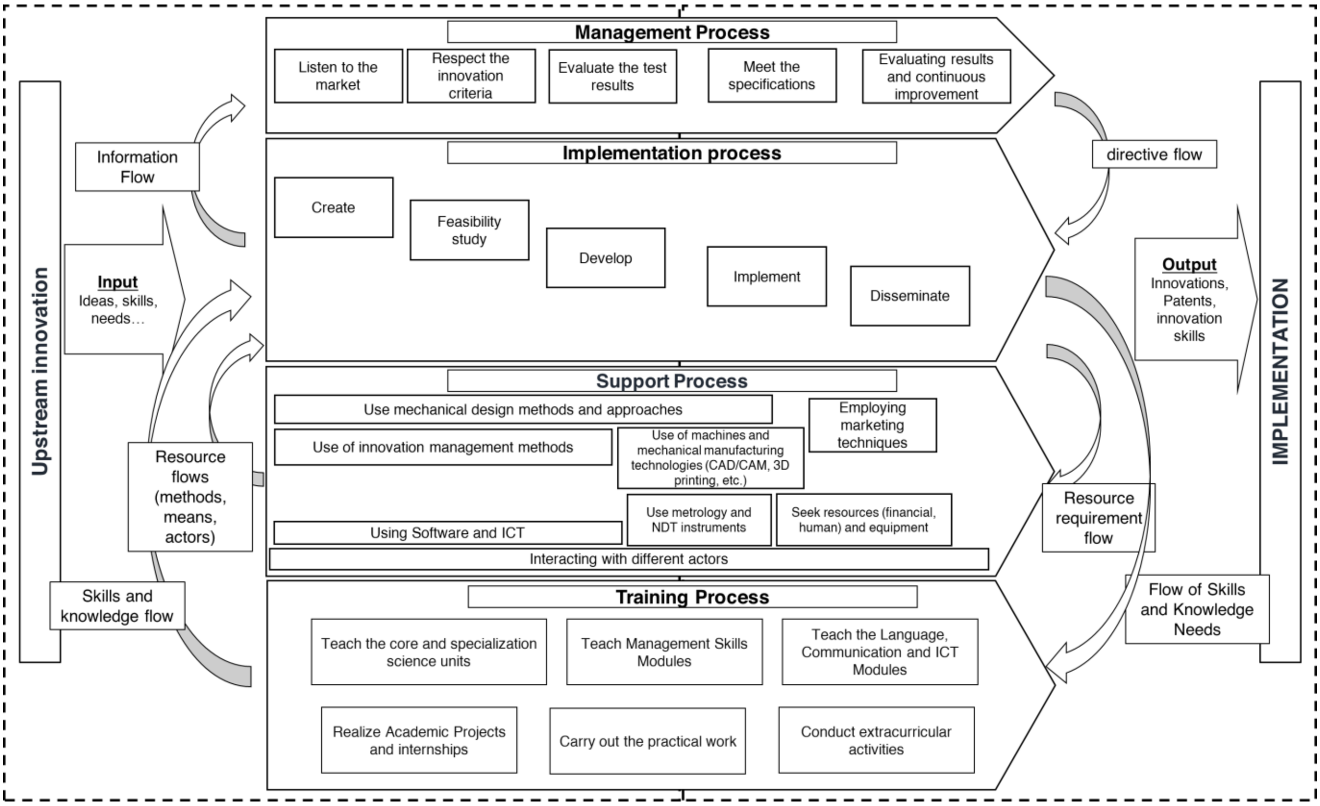


*Fig. 1. Systemic model of the Innovation Process in mechanical engineering training*

We have also highlighted the different interactions between the four processes. These interactions are represented as flows of different natures exchanged between the different processes, which we detail in Table 1.

*Table 1. Nature and characteristics of innovation process flows*

| Nature of the flow | Sending process | Receiving process | Characteristics |
|---|---|---|---|
| **Information flow** | Realization process | Management process | -Feedback<br>-Results of the steps<br>-Problems to be solved |
| **Directive's flow** | Management process | Realization process | -Standards and criteria to be respected (documents, procedures, and reference systems)<br>-Main objectives<br>-Customer and market requirements |
| **Information flow** | Realization process | Support process | -Needs to be expressed for each stage in terms of methods, materials, and human and financial resources. |
| **Resource flow** | Support process | Realization process | -Methods, materials, and human and financial resources. |
| **Skills needs flow** | Realization process | Training process | -Needs to be expressed for each stage in terms of technical and transversal skills |
| **Skills and knowledge flow** | Training process | Implementation process | - Technical and cross-cutting skills |

From this model and based on the findings of the synthesis of the state of the art and the inventory of innovation projects in engineering schools in Morocco, we put forward the following general hypothesis: “An innovative project approach carried out within an environment characterized by the interaction and management of a set of material and human resources, methods and technical and managerial skills, could boost innovation in the context of engineering education”.

To verify this general hypothesis, which represents the result of our theoretical modeling, we propose to break it down into secondary hypotheses, each of which focuses on one of the main elements of our environment (skills, resources, methods, actors).

The hypotheses of our model are formulated as follows:

- H1. A project respecting the proposed steps of the innovation process can lead to innovative solutions.
- H2. A support process providing the project actors with technical and managerial means and methods could improve the capacity to produce innovative solutions among engineering students.
- H3. A support process that brings together different actors could improve the capacity of engineering students to produce innovative solutions.
- H4. A management process that ensures that each stage of the implementation process is monitored and adhered to would improve the ability of engineering students to produce innovative solutions.

## 4 FINDINGS

### 4.1 IMPLEMENTATION OF THE INNOVATION PROCESS MODEL IN MECHANICAL ENGINEERING PROJECTS

The experiments of our model are carried out within the mechanical engineering department of the ENSEM, they take the form of projects of various types achieved by engineering students. These projects aim at solving complex and varied problems: quality management, mechanical design, environmental management, and sustainable development. The complexity of these projects lies in their diversity but also in their richness in terms of interaction with different actors, the use of problem-solving tools, the development of technical and soft skills, etc.

We attended and contributed to coaching sessions and innovation workshops throughout the course of various projects (graduation projects, and projects carried out as part of a course). During the first experimentation, we participated in the accompaniment and the animation of coaching sessions for the graduation projects of mechanical engineering students and the establishment of comparative studies with control projects. In the second experiment, we integrated innovation workshops into an environmental management course intending to generate innovative projects at the end. The objective of this experimentation, which was conducted as a set of projects parallel to a course, was to generate ideas for innovations in the field of environmental management.

#### 4.1.1 PROCESS OF THE FIRST EXPERIMENT

The sample is six final year projects carried out by 10 students in the 3rd year of mechanical engineering at ENSEM in different industrial companies.

We participated in the supervision of the first three projects with the academic supervisor and the industrial supervisor, where we ensured the application of the steps of the proposed process and the respect of its components. We considered them as demonstration projects.

In parallel, we selected three projects that were considered to be classic and that took place under standard conditions, to compare the results. It is important to note that the demonstration projects and the classic projects were carried out under similar conditions (study program, the company where the internship takes place, students’ fields of study, supervising professors belonging to the same department of mechanical engineering), the only difference is the approach to the supervision and implementation of the project, which influences the steering and management of the project. The details of the projects studied are explained in Table 2.

*Table 2. Characteristics of the sample of graduation projects subject of the experiment*

| Reference | Project themes | Project area or business sector | Project nature | Number of students in the project | Project type |
|---|---|---|---|---|---|
| P1 | Design of a micro-hydropower system | Energy | Design of a mechanical system | 2 | Demonstration project |
| P2 | Solving technical problems to prepare for ISO 9001 and ISO 14001 certification | Agriculture and food industry | Quality management | 2 | Demonstration project |
| P3 | Improving the quality of deliverables of an automotive design project | Automotive | Quality management | 1 | Demonstration project |
| P4 | Maintenance of public lighting structures. | Energy | Maintenance of mechanical systems | 2 | Classic project |
| P5 | Improvement of the maintenance engineering of sugar manufacturing machines | Food and drink | Maintenance of mechanical systems | 1 | Classic project |
| P6 | Study and design of a car bonnet | Automotive | Mechanical system design | 2 | Classic project |

These graduation projects last on average 4 months. Weekly meetings are held between the academic supervisors and the engineering students. In addition, the students meet regularly with their industrial supervisor in the company hosting the project.

We organized the coaching sessions according to the objectives and expected results of each phase of the innovation process. In the first phase of the project, we focused on creativity and the generation of innovative ideas. After having carried out an inventory and an analytical study of the various problems in the field, the engineering students are led to use the tools of the creative problem-solving approach to generate innovative ideas, based on a technological watch to be up to date with the novelties in the field of their project. We also worked with the students on innovation engineering methods that are not included in the curriculum of all courses, such as design thinking.

Next, decision-making methods (including multi-criteria matrices) are used to select the most appropriate solution. This phase ends with the technical solution that will be developed in the following stages.

The second phase consists of the preliminary study of the feasibility of the project. In this phase, the students drew up sketches and kinematic diagrams of the proposed solution to examine the technical coherence, as well as a preliminary estimate of the project costs. This phase provided a blueprint for the management of the entire project and ended with the preparation of a project portfolio which is fed in parallel with the progress of the project. The third phase, the technical development of the innovative solution, represents the core of the project, where the engineering students apply the different technical knowledge and skills they have acquired during their years of training in mechanical engineering. They used methods of design, dimensioning, technical drawing, and calculation, and they used computer-aided design and simulation software. This phase ends with the prototyping and testing of the developed solution.

In the last phase, the students are encouraged to look for funding, materials to implement their solutions, and all the documents and guides needed for its implementation. Then, the future engineers are encouraged to try to start the complete or partial realization of their solution in case the resources and means allow it.

Finally, the dissemination of the results of the project can take different forms: firstly, a presentation of the project's results to the managers of the company where the internship took place, and secondly, a presentation of the project in the school to an evaluation board made up of professors and industrialists. If the result of the innovation process is a new product, this could be marketed by the company itself or by some other means.

At the end of the process, we obtain not only innovative solutions developed by the students but also feedback that the teachers can use to improve the conditions for future projects and the engineering curriculum in general.

#### 4.1.2 Process Of The Second Experiment

Our sample is composed of 10 projects carried out by 49 students belonging to two consecutive classes in the third year of the Quality Maintenance and Industrial Safety course. These projects are integrated into an environmental management system (EMS) course. The students were asked to work on solving technical problems related to compliance with environmental standards in various areas of their school (boarding school, practical workshops, grounds, green spaces, restaurants, and classrooms) by proposing innovative solutions integrating the dimension of smart cities.

The five projects carried out in the first year of the experiment are considered to be classic projects and are carried out by 25 students divided into five groups. In this case, we asked the students to propose and develop innovative solutions to the project's problem without guiding them towards following the innovation process related to our model. They worked on an autonomous, freeway and by deploying classical problem-solving approaches.

The five projects carried out in the second year of the experiment are considered to be demonstration projects and are carried out by 24 students divided into five groups. In this case, we applied the guidelines of the innovation process that we have modelled. The first two sessions of the course were devoted to the theoretical notions related to the subject matter. Then we devoted one 4 hours' session per week to the first three stages of the process: creation, feasibility study, and development. A final session was dedicated to the evaluation and presentation of project results. These sessions took place in the form of workshops in which we participated in the facilitation and supervision in the presence of the professor in charge of the course.

The conduct and supervision of the workshops were similar to Experimentation 1, and we ensured the implementation of active teaching methods and the integration of digital technology to help students develop the skills necessary for innovation. At the end of the course, the groups formed by the engineering students presented a detailed report with steps and results and gave an oral presentation of the results of their work. Table 3 shows the subject projects of Experiment 2.

***Table 3. Characteristics of the sample of projects integrated within the EMS course subject of experiment 2***

| Reference | Project themes | Number of students in the project | Project Type |
|---|---|---|---|
| **P7** | Intelligent shower water recycling system | 4 | Demonstration project |
| **P8** | Waste sorting with the help of the Smart Bin for automatic waste separation and sorting | 5 | Demonstration project |
| **P9** | Innovative redesign of the mechanical workshop | 5 | Demonstration project |
| **P10** | Change management in the school restaurant using industrial engineering management | 5 | Demonstration project |
| **P11** | Intelligent watering system for green areas | 5 | Demonstration project |
| **P12** | Proposal of innovative solutions to solve environmental problems in the students' residence | 5 | Classic project |
| **P13** | Proposal of innovative solutions to solve environmental problems in the practical workshops in mechanics at ENSEM | 5 | Classic project |
| **P14** | Proposal of innovative solutions to solve environmental problems in the ENSEM classrooms | 5 | Classic project |
| **P15** | Proposal of innovative solutions to solve environmental problems in the ENSEM restaurant | 5 | Classic project |
| **P16** | Proposal of innovative solutions to solve environmental problems in the grounds and green spaces of ENSEM | 5 | Classic project |

#### 4.1.3 PROJECTS ASSESSMENT

Although the different experiments took place during different periods, we carried out the same assessment method.

An evaluation board consisting of 3 professors and 2 doctoral engineers evaluated all these projects. They first judged the innovative character of the different projects using the innovation criteria used by international organism to assess the patentability of inventive proposals: novelty, industrial applicability, and inventiveness.

According to these organisms an invention must meet a set of conditions in order to be protected by a patent. These conditions are as follows [37], [38]:

- The project must describe a specific, substantial, and credible utility that can be achieved within the industry.
- The project must be novel, meaning it is not already known or described in an existent "state of the art." The state of the art includes all information and data that are publicly available through patents, oral presentations (such as lectures or seminars), exhibitions (such as trade shows), or written publications (such as prior patent applications, commercial brochures, scientific or technological journals, articles, or press releases).

- The project must involve inventive activity (i.e., it is not obvious). A skilled person in the relevant field can determine whether this condition is met by analyzing three main characteristics of the invention: the problem that the invention seeks to solve, the ingenuity of the proposed solution and its adequacy to the existing problem, and the novelty and advantages offered by the invention compared to products (or services, processes, etc.) already defined by the state of the art.

Then, the evaluation board assessed for each project the level of compliance with the various components of the proposed innovation process, namely: the stages of implementation, the methods, and means deployed, as well as the project management mode (control or classic).

This evaluation is based on the analysis of the content of the reports and documents representing the deliverables of each project including the technical file and the business plan using an evaluation grid constructed from the modeling and its assumptions. Table 4 develops all the criteria relating to the stages of the innovation process, their sub-stages, and the supporting elements (methods and means).

***Table 4. Project assessment criteria***

| **Analysis criteria** | | **Observed Elements** |
|---|---|---|
| **Implementation steps** | C1. Create | C1.1. Analyze the need<br>C1.2. Carry out a survey<br>C1.3. Generate creative ideas<br>C1.4. Evaluating and selecting a creative idea |
| | C2. Study the feasibility | C2.1. Carry out the preliminary technical study<br>C2.2. Carry out a preliminary financial analysis<br>C2.3. Define a business plan<br>C2.4. Create a provisional schedule |
| | C3. Develop | C3.1. Define the technical specifications<br>C3.2. Study the technical risks<br>C3.3. Design and dimension the product components<br>C3.4. Choose the material<br>C3.5. Detailing the product assembly<br>C3.6. Carry out the complete design on software (CAD)<br>C3.7. Produce a prototype<br>C3.8. Test and validate |
| | C4. Realize | C4.1. Choosing suppliers<br>C4.2. Search for funding<br>C4.3. Produce a sample<br>C4.4. User testing<br>C4.5. Industrialize |
| | C5. Diffuse | C5.1. Market prospect, Advertising and Marketing |
| **Supporting elements** | C6. Support methods | C6.1. Quality tools<br>C6.2. Innovation engineering tools<br>C6.3. Innovative mechanical design tools<br>C6.4. Project management tools, operational research<br>C6.5. Studies and calculations of structures and mechanical characteristics<br>C6.6. Assembly methods and manufacturing processes<br>C6.7. Mechanical test analysis and metrology<br>C6.8. Marketing, sales and finance techniques |
| | C7. Support means | C7.1. Various software<br>C7.2. Automated machinery and CAD/CAM<br>C7.3. Manufacturing, measuring and testing machines and equipment<br>C7.4. Marketing and communication tools<br>Databases<br>C7.5. Guides and reference documents |

The weighting of the criteria in the analysis table is based on a qualitative binary scale. If the criterion representing the sub-step is present in the work, then it is scored 1, otherwise, it is scored 0.

#### 4.1.4 Innovativeness Of The Projects

During the assessment, each member of the evaluation board has attributed a grade for every innovativeness 'criterion to each project according to its response to the criteria description detailed in the table 5. If the project meet the description it was marked 1 unless then 0. To be considered as innovative, a project must meet all the innovation criteria.

Projects that were judged as innovated are the projects which met the three innovativeness criteria that were described in the section project assessment. The assessment was led by the evaluation board. Table 5 summarizes the results obtained on the innovative character of the graduation projects.

***Table 5. Results on the innovative character of graduation projects***

| Projects | Innovativeness criteria | | | Innovativeness |
|---|---|---|---|---|
| | New | Being industrially applicable | Involving inventive activity | |
| **P1** | 1 | 1 | 1 | Innovative |
| **P2** | 1 | 1 | 1 | Innovative |
| **P3** | 0 | 1 | 0 | Not innovative |
| **P4** | 0 | 1 | 0 | Not innovative |
| **P5** | 0 | 1 | 0 | Not innovative |
| **P6** | 0 | 1 | 0 | Not innovative |

Of the three projects to which we applied the innovation process, two projects succeeded in proposing and developing innovative solutions that met all the criteria. For the classical projects, it turned out that none of the projects are innovative. These results also allow us to touch qualitatively on the influence of the supervision and guidelines we proposed to the students to pilot a project on the production of innovative solutions.

These results show the positive impact of project management according to the proposed innovation process model on the innovative character of projects.

We proceeded in the same way for the analysis of the results of the second experimentation. Table 6 shows the innovative character of the projects carried out by the engineering students.

***Table 6. Results of the innovative character of the projects integrated into the EMS course***

| Projects | Innovation criteria | | | Innovativeness |
|---|---|---|---|---|
| | New | Being industrially applicable | Involving inventive activity | |
| **P7** | 1 | 1 | 1 | Innovative |
| **P8** | 1 | 1 | 1 | Innovative |
| **P9** | 1 | 1 | 1 | Innovative |
| **P10** | 0 | 1 | 0 | Non- innovative |
| **P11** | 0 | 1 | 0 | Non- innovative |
| **P12** | 0 | 1 | 0 | Non-innovative |
| **P13** | 1 | 1 | 1 | Innovative |
| **P14** | 1 | 1 | 0 | Non- innovative |
| **P15** | 0 | 1 | 0 | Non-innovative |
| **P16** | 0 | 0 | 0 | Non-innovative |

According to these results, we ended up with three innovative projects out of five for the case of the demonstration projects. For the classical projects, only one of the five projects was found to be innovative. Among the three non-innovative projects, we obtained an extreme case that did not meet any innovation criteria.

These results support those we found for the graduation projects. Indeed, the supervision of the projects by respecting the approach resulting from our model of the innovation process contributed to the improvement of the innovative character of the projects.

### 4.1.5 RESULTS OF THE LEVEL OF COMPLIANCE WITH THE INNOVATION PROCESS

The following table details the qualitative assessment of the respect of the realization process steps that we proposed in our modeling within the demonstration projects studied during the two experiments 1 and 2. Only in the supervised projects where students were led to implement our proposed model. The assessment criteria used in the table below were explained in the section 4.1.3, table 4.

*Table 7. The innovation process assessment system for the demonstration project*

| Project | Innovation process | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Create | | | | Study the feasibility | | | | Develop | | | | | | | | Realize | | | Diffuse |
| | C1.1 | C1.2 | C1.3 | C1.4 | C2.1 | C2.2 | C2.3 | C2.4 | C3.1 | C3.2 | C3.3 | C3.4 | C3.5 | C3.6 | C3.7 | C3.8 | C4.1 | C4.2 | C4.3 | C5.1 |
| P1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| P2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| P3 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| P7 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| P8 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| P9 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| P10 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P11 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

To analyze the contribution of the compliance with the implementation process that we proposed in our modeling on the demonstration projects, we used the previous data in table 7 to calculate the rate of compliance with this process using the indicator expressed by the following formula.

***The formula used to calculate the compliance of projects with the implementation process***

$$Rate\ of\ compliance\ with\ the\ implementation\ process = \frac{\sum total\ scores\ for\ the\ step}{total\ number\ of\ sub - steps} \times 100$$

***The formula used to calculate the overall rate of compliance with the process steps***

$$The\ overall\ rate\ of\ compliance\ with\ process\ steps = \frac{\sum scores\ obtained\ in\ all\ steps}{total\ number\ of\ all\ sub - steps} \times 100$$

Table 8 shows the rates of compliance with the different stages of the innovation process that we have calculated using the previous formulae. We cross-reference these results with the innovative character of each project in the same to deduce the correlation between them.

*Table 8. Rate of compliance of graduation projects with the stages of our innovation process model*

| Projects | Rates for the steps of the Innovation Process | | | | | Overall rate | Innovativeness |
|---|---|---|---|---|---|---|---|
| | Create | Study the feasibility | Develop | Realize | Diffuse | | |
| **P1** | 100% | 75% | 75% | 60% | 0% | 79,1% | Innovative |
| **P2** | 100% | 75% | 62,5% | 40% | 0% | 58,33% | Innovative |
| **P3** | 75% | 75% | 25% | 20% | 0% | 37,5% | Non-innovative |

We note that P1 and P2 having respected the creation phase which represents the basis for generating and proposing an innovative and creative solution, we're able to develop innovative solutions, unlike the third project which respected just 75% of this phase.

All projects met the feasibility study phase to the same degree.

The compliance rates for the innovative solution development phase are different. Indeed, the first project, whose main objective was the design of a mechanical system expressed from the beginning by the host company, was able to give more time and interest to the details of the technical development of the innovative solution. This was in contrast to the second project, where the company's need was to implement quality and environmental management systems. In addition, the engineering students were under pressure to meet the needs of the company on the one hand and to respect the approach we proposed on the other. Although they proposed an innovative solution, they were not able to realize and test a prototype for it, as the nature of their project required them to focus more on audit and quality management procedures.

The realization phase was 60% completed by the P1 project, 40% by the P2 project and 20% by the P3 project. The low rates are due to a combination of factors including lack of time and resources.

The last phase of project dissemination as described in our innovation process is the most critical, as none of the projects managed to accomplish this stage due to a certain time and resource constraints. Indeed, the previous stage of realization has not been completed, so, logically, one cannot disseminate or market a product that is not yet realized. This phase was replaced during the experimentation process by an evaluation of the project within the company on the one hand, and at ENSEM on the other.

For the second experimentation, the results analysis follows the same procedure. Table 9 shows the compliance rates of the five demonstration projects of the second experimentation with the phases of the innovation process.

***Table 9. Compliance rate of the projects integrated into the EMS course with the steps of our innovation process model***

| Projects | Rates for the steps of the Innovation Process | | | | | Overall rate | Innovativeness |
|---|---|---|---|---|---|---|---|
| | Create | Study the feasibility | Develop | Realize | Diffuse | | |
| **P7** | 100% | 75% | 75% | 20% | 0% | 58,33% | Innovative |
| **P8** | 100% | 75% | 100% | 40% | 0% | 66,66% | Innovative |
| **P9** | 100% | 75% | 62,5% | 20% | 0% | 58,33% | Innovative |
| **P10** | 50% | 25% | 12,5% | 0% | 0% | 16,66% | Not Innovative |
| **P11** | 50% | 25% | 12,5% | 0% | 0% | 16,66% | Not Innovative |

These results confirm the results of the previous experimentation. Indeed, the projects qualified as innovative completed the entire creation and generation phase of the innovative idea. On the other hand, the two non-innovative projects only completed 50% of the sub-stages of the creation phase.

Regarding the feasibility study, 75% of the innovative projects and 25% of the non-innovative projects completed it.

For the development of the innovative solution stage, the P8 project completed the entire stage. This project is the only one in the sample that managed to produce a prototype of the innovative solution and test it. This solution consists of the realization of an intelligent waste bin that sorts and shreds waste.

The other two innovative projects met the development stage with rates of 75% for P7 and 62.5% for P9, but they only carried out the design and study of the technical specifications of the solution. As for the non-innovative projects, they complied with only 12.5% of the development stage.

The realization and dissemination of innovative projects are critical stages in this second experiment, as they were in the first, and none of the projects was able to meet all the requirements. In the case of this experimentation, the main factors are the lack of time and financial means to implement innovative solutions.

#### 4.1.6 RESULTS OF THE RESPECT OF THE SUPPORT PROCESS

We proceeded in the same way to analyze the results related to the respect for the support process in the different projects studied. According to the proposed model, the support process is mainly based on the methods and tools of innovation engineering, innovative design and project management, as well as the means and resources necessary for the deployment of the project. Table 10 details the assessment system used by the evaluation board. It shows the different marks given to the demonstration projects of both experiments according to each criterion of the means and support process (Section 4.1.3, table 4).

*Table 10. The respect of the proposed support means and methods assessment system for the demonstration project*

| | Support means | | | | | | | | Support method | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **C6.1** | **C6.2** | **C6.3** | **C6.4** | **C6.5** | **C6.6** | **C6.7** | **C6.8** | **C7.1** | **C7.2** | **C7.3** | **C7.4** | **C7.5** | **C7.6** |
| **P1** | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| **P2** | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| **P3** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| **P7** | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| **P8** | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 |
| **P9** | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 |
| **P10** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| **P11** | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |

To verify the influence of the proposed support process on the level of innovation, we studied the rate of deployment of the methods and means we proposed through the innovation process, only in the supervised projects where students were led to implement our proposed model.

We calculated the rate of methods and means deployed according to table 11 and using the following indicators.

***The formulas used to calculate the rate of compliance with the support process***

$$Rate\ of\ methods\ deployed = \frac{\sum notes\ of\ the\ methods - deployed}{total\ number\ of\ methods\ deployed} \times 100$$

$$Rate\ of\ means\ deployed = \frac{\sum notes\ of\ means\ deployed}{a\ total\ number\ of\ means\ deployed} \times 100$$

Table 11 shows the rates of methods and means deployed in graduation projects, as well as the innovative character of the projects.

*Table 11. Rates of methods and means deployed in graduation projects according to the innovative character of the projects*

| Projects | Rate of methods deployed | Rate of means deployed | Projects innovativeness |
|---|---|---|---|
| P1 | 75% | 50% | Innovative |
| P2 | 50% | 50% | Innovative |
| P3 | 37,5% | 50% | Not innovative |

These results show that the rate of methods deployed by the innovative project is higher than that of the non-innovative projects. This shows the importance of the use of different methods in the support process for the generation and development of innovative solutions.

Indeed, the P1 project employed the highest rate of methods from our innovation process, in particular the tools of innovation management and innovative mechanical design (brainstorming, design thinking, FAST creativity, methods of calculating the characteristics of mechanical structures, etc.).

On the other hand, the tools and approaches of quality assurance and project management are applied to all projects. This reflects the knowledge and technical skills that the engineering students have acquired during their training in mechanical engineering at ENSEM. This training is characterized by a curriculum rich in basic technical and management courses, but which remain classical and do not allow students to implement new engineering tools for innovative and creative design projects, products or mechanical processes.

Concerning the deployment of support resources, the all projects in Experimentation 1 used half of the proposed resources.

For the second experiment, the results are shown in the Table 12 below.

*Table 12. Rate of methods and means deployed in the EMS course projects according to the innovative character of the projects*

| Projects | Rate of methods deployed | Rate of means deployed | Projects innovativeness |
|---|---|---|---|
| P7 | 62,5% | 50% | Innovative |
| P8 | 87,5% | 66,66% | Innovative |
| P9 | 50% | 66,66% | Innovative |
| P10 | 25% | 50% | Non-innovative |
| P11 | 25% | 50% | Non-innovative |

These results show that the three innovative projects achieved a high rate of deployment of the methods we proposed, up to 87.5%. This is in contrast to the non-innovative projects which did not exceed 25%.

We also notice that the projects: P7 which is an innovative project, and P10 and P11 which are non-innovative projects have deployed 50% of the proposed means while the two projects P8 and P9 which are innovative have deployed 66.66% of the means. These results show that the availability of methods and resources is important for the development and implementation of innovative solutions.

## 5 Discussion

We have calculated the average compliance rate for all innovative and non-innovative projects respecting our innovation process specifications. The aim is to highlight the impact of our model on the innovative character of the projects at the end of the experiments and to verify the modeling hypotheses.

We summaries all the results obtained previously and classify them according to the nature of the project: innovative or non-innovative. We then calculate the average of the rates calculated previously by dividing the sum of the rates obtained for all projects of the same nature (innovative or non-innovative) by the number of these projects. According to the results of the two experiments, the control projects to which we applied our innovation process are divided into 5 innovative projects and 3 non-innovative projects.

- **Verification of modeling assumptions**

Table 13 shows the compliance rates for all components of the proposed innovation process and the average compliance rates for the innovative projects.

*Table 13. Summary of compliance of innovative projects with the proposed innovation process*

| Projects | Compliance with process steps | Compliance with the proposed methods | Compliance with the proposed means |
|---|---|---|---|
| **P1** | 79,1% | 75% | 50% |
| **P2** | 58,33% | 50% | 50% |
| **P7** | 58,33% | 62,5% | 50% |
| **P8** | 66,66% | 87,5% | 66,66% |
| **P9** | 58,33% | 50% | 66,66% |
| **Average** | **64,15%** | **65%** | **56,66%** |

In Table 14, we present the results for the non-innovative projects.

*Table 14. Summary of compliance of non-innovative projects with the proposed innovation process*

| Projects | Compliance with process steps | Compliance with the proposed methods | Compliance with the proposed means |
|---|---|---|---|
| **P3** | 37,5% | 37,55% | 50% |
| **P10** | 16,66% | 25% | 50% |
| **P11** | 16,66% | 25% | 50% |
| **Average** | 23,6% | 29,16% | 50% |

- We note that the innovative projects complied with 64.15% of the stages proposed in our model, unlike the non-innovative projects, which complied with only 23.6%. This reflects the positive impact of the structuring of the project implementation process on the valorization of innovation in the projects carried out by the engineering students. This result allows us to confirm hypothesis H1. We can say that a project that respects the proposed stages of the innovation process can lead to innovative solutions.

- Concerning the deployment of the methods proposed in our model, it was respected by 65% of the innovative projects and only 29.16% by the non-innovative projects. Similarly, the exploitation of the means necessary to carry out the projects was respected by 56.66% of the innovative projects and by 50% of the non-innovative projects. This result confirms hypothesis H2. The deployment of a set of support elements consisting of the technical and managerial resources and methods necessary for the project to be carried out improves the ability of engineering students to produce innovative solutions.

- Concerning the interactions with the stakeholders of our process, the graduation projects allowed the students to meet different actors during the internships carried out within industrial companies. Indeed, during each phase of their project, they were accompanied by professionals, in particular engineers, department heads, and administrative staff. The latter helped to provide the students with the information and data necessary to describe and analyze the problem of their subject, dimension their mechanical system according to the field data, and prepare the administrative documents necessary at each stage. Other actors who differed from project to project, such as experts in materials, or mechanical manufacturing processes, facilitated certain activities in the process, particularly in the development phase.

In the academic environment, the engineering students were able to benefit from the supervision of research professors and doctoral students, which enriched their work on the theoretical level. However, the richness in terms of relations with professional actors and experts was missing in the case of the projects integrated into the environmental management course. They indeed had relationships with different people within the school, such as the administration staff, the department heads, the heads of the mechanical workshops or the boarding school, the PhD students and the professors, but the links with external institutions and individuals were very limited. From the analysis of these observations, we deduce that hypothesis H3 is confirmed. We can say that putting engineering students interact with different actors in the innovation process improves their ability to innovate.

The results of the experiments have shown that the innovation project management process, which in our case is implemented by the supervisors, makes it possible to propagate the culture and spirit of innovation among the engineering students. The proposed management approach encouraged the students to be creative and motivated them throughout the project to respect the innovation criteria and generate innovative ideas. This confirms that the act of innovating among students is not intuitive and automatic, but requires guidance and support. Thus, we can say that hypothesis H4 is confirmed. A management process that ensures that the guidelines for each stage of the realization process are followed, improves the ability of engineering students to produce innovative solutions.

Otherwise, even though the demonstration projects were supervised and were led to implement all the guidelines of our innovative process, not all the projects were innovative due to many constraints. According to the first experiment, we observed that despite the presence of resources and interaction with different actors, not all projects are innovative. This is due to several problems that we were not able to address in our study, such as personal factors and company policy and fear of risk and lack of time and resources. During Experiment 1, certain steps such as problem analysis, design, and sizing were blocked due to problems related to flow fluidity and management inside the companies where the projects are deployed within the process. Indeed, expressing needs in terms of resources and data collection sometimes proved to be a difficult task for some students. Exhaustive procedures can also hinder data collection or the acquisition of certain equipment, which can prevent the completion of the project.

For the second experiment, we identified the following problems: time and resource constraints, and the high cost of solutions deployment. We noticed that the means used by the projects in our experiment are often software or basic means existing in laboratories or mechanical manufacturing workshops. These means do not require significant or additional funding. However, the realization of some innovative projects requires high-tech machines and equipment that were lacking in the school (such as CAD/CAM machines, 3D printers, or full and professional versions of certain mechanical design and analysis software). This is mainly due to a lack of budget dedicated to this type of projects.

Regarding the application of new innovation engineering tools, we found that most of the mechanical engineering students in our sample encountered several difficulties. Although we proposed several innovation engineering tools, the students were only able to use basic and classical innovation tools. This is partly due to the duration of the projects, which prevents them from learning new tools, and to the basic training. In fact, by examining the different mechanical engineering student training programs, we noticed the absence of a course on innovative design tools or innovation engineering.

## 6 CONCLUSION

This paper describes the construction of innovation process model in mechanical engineering projects carried out in an engineering school. Its framework and principles refer to tools of systemic modeling of complex systems used in the field of mechanical and industrial engineering. We then provided details to characterize our innovation process and deduced hypotheses to verify it.

The hypotheses relating to the model of the innovation process were confirmed through a set of experiments within the academic context of the mechanical engineering department of ENSEM through the supervision of projects of different natures, which leads to the validation of the following general modeling hypothesis: An innovative project approach carried out within an environment characterized by the interaction and management of a set of material and human resources, methods and technical and managerial skills can help to boost innovation in the context of engineering education.

The systemic approach that we have adopted has enabled us to identify the phenomenon of innovation in the context of mechanical engineering in a global manner. Thus, we have highlighted the tangibility of interactions within an innovation system and its complex character. Our modeling had double objective of describing the innovation process on the one hand, and on the other hand, implementing it in order to test and improve its functioning.

The action research carried out to implement our innovation process allowed us to test and analyze the modeling hypotheses through tools and performance indicators. We designed tools and indicators to measure the innovation process specific to our study. We have tried to transform the results of qualitative observation into a set of quantitative rates and indicators. The analysis of these indicators allows at the same time to measure and analyze the performance of our innovation process and to verify the modeling assumptions.

We have tried to introduce the concept of innovation in engineering schools through different aspects. In particular, we find:

- The integration and implementation of an innovation process within project-based learning activities;
- The use of innovation and creativity management tools and approaches;
- The involvement of actors from within and outside the engineering school;
- The experience of giving engineering students' projects a broader and professional dimension and the ambition to file patents.

This research work is only the first step of a more global project on innovation engineering. We intend to build on the present results and develop them for new research objectives, especially after the major changes that have occurred in the Moroccan context recently. Indeed, with the health crisis due to the outbreak of the COVID-19 virus, the terrain in Morocco has become more fertile and welcoming for innovation initiatives. The new Moroccan strategy encourages the production of innovations through the facilitation of procedures and project financing. All these facts encourage us to deepen our work in the field of engineering and management of innovative projects through extending the experiments to other specialties (electrical, computer science, civil engineering, etc.) within different engineering schools and universities in Morocco. These studies will help to make our model more global and flexible, and to draw a generalizable canonical form of it. We will also have the opportunity to integrate new forms of innovation such as disruptive innovation, or the creation of start-ups, which are more common in the field of computer and industrial engineering. In the future, we aim to implement and adapt our innovation process model to scientific and technical research centers and laboratories.

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