Appendix 1

ENSIC – Training

> I don't believe I can really do without teaching..... I have to have something so that when I don't have any ideas and I'm not getting anywhere I can say to myself: "At least I'm living; at least I'm *doing* something." (Feynman 2000)

> Instead of adding content to content [...], at the pace of the knowledge movement, without hope of achieving it, we should seriously consider how to develop the capacities of understanding, reflection, and invention, without which content is neither understood, mastered nor perceived as a starting point for new creations. (Jouary 1996)

> Implicit school culture, [a] set of routines, rituals, norms that belong to the informal space and that regulate the behavior of teachers and students, without being explicitly expressed. They are part of the daily routine of the school activity. (Paun 2006)

The *École nationale supérieure des industries chimiques* was founded in 1887 under an agreement between the city of Nancy and the Ministry of Education. Initially the Chemical Institute of Nancy underwent many reforms, which we will not detail here, while wishing to keep training engineers in chemistry and process engineering, whose vocation is to meet the expectations of industrialists and society.

The school is supported by two research laboratories (Reactions and Process Engineering Laboratory, LRGP[1], and Macromolecular Physical Chemistry Laboratory, LCPM[2]) to which most of the school's teacher-researchers are attached.

1 *Laboratoire réactions et génie des procédés*.

2 *Laboratoire de chimie physique macromoléculaire*.

Process Engineering Renewal 1: Background and Training,
First Edition. Éric Schaer and Jean-Claude André.

In 1997, the original chemical industry engineering course, for which the school holds an accreditation prior to 1936, was enriched by a new course also accredited by the *Commission des titres d'ingénieur*, known as "*Filière d'ingénieur des techniques de l'industrie*". This recent training, focused on chemical engineering, relies on industrialists from professional sectors to train its engineers through work-study programs.

ENSIC Nancy is now a component of the University of Lorraine. In this context, ENSIC engineering students have the opportunity to obtain an additional Master's degree during their third year of training, in Process and Bioprocess Engineering.

The school is therefore authorized to award two engineering diplomas:

– chemical industry engineer (known as I2C, traditional sector);

– engineer specializing in chemical engineering (known as FITI, alternating course).

Every year, it welcomes some 140 new engineering students onto these two courses.

A1.1. Chemical industry engineering stream

A1.1.1. *Description*

The aim of this course is to train engineers with dual skills in chemistry and physical chemistry and in chemical and process engineering. The pedagogy is therefore organized towards the acquisition of basic scientific and technical knowledge and skills in chemistry and chemical engineering, supplemented by more advanced training in process engineering, product engineering, or biotechnological process engineering. Scientific and technical training is supplemented by courses in the humanities, management, law, economics, and social sciences, as well as language training.

The pedagogical program is based on a common core curriculum of three semesters (S5 to S7, the school recruits at the end of the fourth semester, S4, the end of the second year of university), which forms the basis for the essential general knowledge (the core curriculum detailed above). In addition to the teaching units corresponding to the different subjects taught, students carry out three projects in groups, which allow an integrated approach to the different teaching units and are subject to specific supervision and evaluation:

– the IT project (S5);

– the reactive systems project (S6);

– the industrial project (S8).

The training continues with specialization courses, which take place in semesters S8 and S9, and which the students choose according to their motivations and their professional project:

– the “advanced process engineering” course;

– the “process engineering for products” path;

– the “biotechnology process engineering” course.

The first path concerns, more particularly, the development and extension of methodological aspects of process engineering to complex, multiphase, and multi-constituent systems. Particular attention is paid to sustainable processes and processes developed in the field of energy. The second path presents teaching that integrates, in a multidisciplinary and multi-scale approach, the design, formulation, and engineering of product development to obtain the desired functions of use. Finally, the third path concerns the application of process engineering to the characterization, design, and optimization of industrial installations in the fields of pharmaceuticals, fine chemistry, or specialties using biocatalysis, fermentation, or living chemistry.

From S9 onwards, students can continue their studies:

– at the school in the specialization program chosen at S8;

– at the school under a professionalization contract (PROCEDIS course);

– at a university abroad (may be limited to one semester);

– in another engineering school of the Gay Lussac Federation (FGL);

– at the National Institute of Nuclear Science and Technology;

– at the IFP School, through apprenticeship.

The last semester, S10, is devoted to the engineering internship.

As in many French schools, a student may choose to temporarily interrupt his or her training to complete a break year between semesters S8 and S9. Finally, a period of two months must be devoted to a research and development project which may be carried out either in a research laboratory in France or abroad, or in a company.

Students must spend at least 28 weeks in industry, during two to three internships:

– a mandatory work placement of at least 1 month at the end of the first year;

– a mandatory six-month engineering internship (5 months required) at the end of the third year;

– an optional engineering assistant internship (3 months maximum) at the end of the second year.

Visits to industrial sites, presentations of companies and professions of former graduates and participation in various forums also enable students to better understand the objectives of the training and to specify their professional project.

A summary description of the study process is presented in Table A1.1.

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Table A1.1. *Overview of the studies – "chemical industry engineer" course*

The pedagogy is based on the integration of courses, tutorials, practical training in labs and projects, supplemented by the use of methods and tools for active learning. Industry professionals are also involved in training, through courses, conferences or project follow-ups, both in the core curriculum and in specialty courses, in the teaching of scientific disciplines or those in the humanities, law, economics, and social sciences.

The evaluations are in line with the European harmonization framework. They are validated by the capitalization of ECTS credits and take into account the learners' time working.

In the same context, one or more stays abroad, of at least three months, are mandatory during the school year. Some engineering students complete additional university training abroad, while others do their internship in a company.

A1.1.2. *Recruitment*

The "Chemical Industry Engineer" program is accessible through national competitions in the first year and through parallel admissions after an entrance examination and interviewing in the first and second years.

In the first year, most of the recruitment is done through the common polytechnic competition, at the end of the preparatory classes for the *grandes écoles* (CPGE)[3]. Students come from PC (50 places), MP (5 places), PSI (5 places), or BCPST (5 places)[4].

Admission on the basis of qualifications, after analysis of the application files and interviews, also allows students from the *DUT*[5] *de génie chimique, DUT de mesures physiques, licence de chimie-physique, cycle préparatoire intégré, or cycle préparatoire polytechnique* courses to enter the program (26 places).

In the second year, it is possible to enter the school after analyzing the applications and interviewing non-European students from the n+i network for holders of Masters 1 or 2 degrees in chemistry, physical chemistry, material sciences or process engineering, and for students who have completed the fifth year of pharmaceutical studies, industry option (25 places available).

Finally, a few places are offered for continuing training, for employees who hold a DUT and who can prove that they have been employed for three years. Admission, on the basis of a file and an interview, can be preceded by course to bring these applicants up to the program's level of study initiated by the continuing education program at the University of Lorraine.

A1.1.3. *Teaching units of the core curriculum*

The different teaching units of the core curriculum, their training objectives, and corresponding ECTS credits are detailed below:

3 *Classes préparatoires aux grandes écoles*.

4 PC stands for "Physique, Chimie", the Physics and Chemistry program. MP stands for "Mathématiques, Physique", the Mathematics and Physics program. PSI stands for "Physique et Sciences de l'ingénieur", the Physics and Engineering Sciences program. BCPST stands for "Biologie, Chimie, Physique et Sciences de la Terre", Preparatory classes for Engineering Schools in Biology, Chemistry, Physics and Earth Sciences.

5 DUT stands for "Diplôme universitaire de technologie", University Degree in Technology.

Teaching units for semester 5	ECTS	Training objectives
Organic chemistry I	5	Basic knowledge of organic chemistry. Reactivity and design of strategies for the synthesis of a target molecule.
Reactive systems and processes I	6	Mass and energy balances. Balance sheets in ideal reactors (Batch, CSTR, Plug Flow Reactor). Kinetics of homogeneous reactions and heterogeneous catalytic reactions. Interfacial phenomena.
Thermodynamic and energetic	4	Principles of thermodynamics, fundamental quantities. Estimation of the properties of a pure component. Operation of thermal machines. Description of subsonic and supersonic flows.
Transfer phenomena I	3	Description of mass transfer concepts, knowledge of fluid mechanics and applications in process engineering.
Computer science, numerical methods, and statistics	6	Algorithmic basics, languages and programming techniques. Numerical methods. Statistical concepts, experimental designs and probability laws. Application of concepts in computer projects.
Management and economics I	3	Knowledge and integration of human, social, economic and legal issues related to occupational health and safety in the company. Knowledge of the main dimensions of the functioning of an organization. Introduction to MBTI behavior analysis. Interpersonal communication (verbal and non-verbal). Writing of CVs and cover letters.
Languages I	3	Minimum level B2 in English. Minimum level B2 in German or Spanish. Development of professional skills to work in an international context.

Table A1.2. *Lessons learned in semester 5*

Teaching units for semester 6	ECTS	Training objectives
Mineral chemistry	5	Concepts of inorganic physical chemistry. Relationship between the chemical and physical properties of solids and their structure. Predicting, through the use of physiochemical and thermochemical data, the reactivity, stability and compatibility of chemical systems.
Chemistry and analytical engineering	5	Acquisition of basic knowledge of chemical and physiochemical analysis methods. Mastering all aspects of an analytical process from sampling to the exploitation of results. Providing basic concepts essential to a phenomenological understanding of corrosion.
Reactive systems and processes II	4	Understand, describe, and analyze the coupled transport and reaction processes observed in catalytic and heterogeneous reactions. Select and size reactors for the implementation of catalytic and heterogeneous reactions. Basic knowledge and concepts in simple and stepped isothermal separation processes. Select and design the type of separator appropriate for a given situation.
Reactive systems and IT	4	Design a complex industrial reactor using a combination of knowledge and skills in kinetics, CRE, digital methods and computer science.
Transfer phenomena II	5	Heat transfers by convection, conduction and radiation, energy balances. Diffuse and convective mass transfers, mass balances. Heat and mass transfer analogies. Operation and design of heat exchangers.
Management and economics II	3	Assessment and control of risks to health and safety at work. Analysis and modeling of workstations. Business management: accounting and financial management, marketing and information systems management.
Languages II	3	Continuation and consolidation of S5 knowledge and skills: acquisition of English of a minimum level B2, acquisition of German or Spanish of a minimum level B2. Development of professional skills to work in an international context.
Industrial conferences I	1	Better knowledge and understanding of the industrial world. Development and elaboration of the professional project.

Table A1.3. *Lessons learned during semester 6*

Teaching units for semester 7	ECTS	Training objectives
Polymer chemistry	3	Basics of polymers. Different types of polymerization and their main characteristics. Polymerization kinetics and calculation of the molar masses obtained.
Industrial processes and sustainable development	7	Engineering of polymerization processes, link between structure, process and properties. Operation and characteristics of homogeneous and heterogeneous reactors. Working conditions, chemical risks, occupational health and process safety regulations. Main risks related to industrial processes. Fundamental principles and foundations of sustainable development. Analysis and design methodology taking into account environmental and safety aspects.
Transfer phenomena III	3	Description of solid fluid polyphase flows: fixed beds and fluidized beds. Mechanical fluid-solid separation and agitation. Sizing of the installations associated with the different unit operations.
Thermal separation processes	5	Description of multi-constituent systems by chemical potential. Phase diagrams of homogeneous liquid binary systems. Design of balanced separation operations: binary distillation, wet air operations and drying.
Process systems engineering	5	Modeling, synthesis, analysis, simulation, optimization and control of systems, to design and manage complex and high-performance processes. Computer-aided process design, optimization, dynamics and process control.
Management and economics III	2	Understanding of the issues and key factors influencing the success of organizational change. Identification and management of resistance to change. Analysis of the laws that govern the dynamics and process of change.
Languages III	3	Preparation for the TOEIC/TOEFL/IELTS test, to obtain a minimum level B2 in English. Continuation and consolidation of S6 knowledge and skills: acquisition of German or Spanish of a minimum B2 level, development of professional skills to work in an international context.
Options	1	Complement scientific and technical cultures on different subjects (metrology, photophysical engineering, history of science, financial and budgetary management, microfluidics, biopolymers, vaccines and modeling).
Industrial conferences II	1	Use of the skills of the chemical engineering engineer in the industrial world. Introduction of the courses of semester 8 through conferences of industrialists working in these 3 sectors.

Table A1.4. *Lessons learned during semester 7*

A1.1.4. *Teaching units for specialization courses*

Teaching units for semester 8	ECTS	Training objectives
Management and economics IV	2	Description of technological innovation processes in industry, from a strategic, organizational, cultural and scientific perspective. Design and development of an innovative product or process by mobilizing the tools and principles of project management. Building a business plan: competition, suppliers, customers, budget, technology, legal, etc.
Languages IV	2	Continuation and consolidation of S7 knowledge and skills: acquisition of English of a minimum level B2, acquisition of German or Spanish of a minimum level B2. Development of professional skills to work in an international context.
Industrial project	6	Design of an industrial production process in a collective and autonomous working environment. Interaction with academic experts and engineers working in the industry. Writing of a scientific document in English.
Worker internship	4	Get in touch with professional life, assess ability to adapt. Observation of the life of the company in all its aspects in a participating situation.
Opening project	3	Get out of the school environment to manage an original project. Apply the project management tools seen in progress. Manage a budget, a schedule and a group. Get to know each other better, develop your capacity for innovation and inventiveness. Enrich and differentiate your CV with an original experience.
Options	1	To complete scientific and technical cultures on different subjects (surface functionalization, aerosols and safety, supramolecular organization, advanced thermodynamics, waste treatment, health products, molecular simulation and industrial polymerization processes).

Specialization course: "Processes for energy and the environment"		
Polyphase reactors and separations	4	Analysis and design of multiphase reactors. Analyze and design crystallization, precipitation and chromatographic processes.
Sustainable processes	4	Analysis of the different life phases of a process, with regard to health, safety, environmental protection and sustainable development concerns.
Process design and simulation	4	Concepts of energy thermodynamics and exergy analysis. Separation of complex mixtures by distillation. Dynamic process simulation.
Specialization course: "Innovative products: from chemistry to processes"		
Micro- and nanostructured products	4	Knowledge, characterization and analysis of micro- and nano-structured products and formulated products. Link between structural characteristics and product behavior.
Introduction to product engineering	4	Organization, positioning and specificities of the formulated products industry. Batch process engineering. Life cycle analysis of a product.
From molecules to products	4	Product design strategy: molecules, shape, manufacturing process, and characterization of the finished product, links between use properties, physical properties and chemical structure of the molecules used. Rheology concepts as a tool for characterizing complex systems.
Specialization course: "Processes for biotechnologies"		
Introduction to the biological sciences	4	Biology concepts: the cell, its functioning and its main constituents, functions and uses in biotechnologies. Techniques for structural, physiochemical characterization and separation of biomolecules.

Biocatalysts and bioreactors	4	Biological process engineering: enzymatic and bacterial kinetics, mass balances in biological reactors, hydrodynamics and mass and heat transfer phenomena. Bioprocess modeling and sizing of equipment and extrapolation.
Bioseparations	4	Separate technologies used in biotechnological production. Analysis of the phenomena involved in bioseparation processes. Calculation of the different separation processes used in biotechnology. Criteria for choosing equipment.

Table A1.5. *Lessons learned during semester 8*

Teaching units for semester 9	ECTS	Training objectives
Management and economics V	2	Global business management simulation leading to rapid strategic and operational choices, based on market developments, competition, and other cyclical factors.
Languages V	3	Consolidation of the B2/C1 level acquired in English and German or Spanish. Development of professional skills to work in an international context.
Option	3	Complement scientific and technical cultures on different topics (polymer processes and products, materials and nanomaterials for catalysis, fuel kinetics and combustion, biorefinery, numerical resolution of transport equations).
Research and development project	10	Initiation to the research and development process. Carry out a detailed bibliographical analysis, join a team, write a summary report, issue a scientific opinion and demonstrate autonomy.

Specialization course: "Processes for energy and the environment"		
Process engineering and energy	4	Technological and societal challenges related to energy production. Chemical phenomena involved in combustion for industrial applications. Exergy analysis of a process.
Dynamic optimization and advanced control	4	Dynamic models of processes and resolution methods. Dynamic optimization, CVP resolution, sensitivity method and use of gPROMS software. Parametric identification methods, transfer function control for monovariable systems and in the status space for multivariable systems.
Process intensification and innovation	4	Equipment and technologies for process intensification. Structured approach leading to process intensification and innovation. Calculation of membrane separation processes.
Specialization course: "Innovative products: from chemistry to processes"		
Specialty products	4	Radical copolymerization, main types of copolymers and characteristics and reactor calculation. Plastics industry and processes for shaping plastics. Physiochemistry, characterization and behavior of polymers in solution, at interfaces and in emulsion, for formulation applications.
Properties and quality of products	4	Design of experiments and their use. Batch workshop planning. Macroscopic properties of polymers and associated structural and morphological characteristics, degradation and impact on properties and stabilization methods. Design of a drug shaping process according to the "Quality by Design" process.

Teaching units for the first half of the year 9	ECTS	Training objectives
Case study - innovative product design project	4	Create an innovative product by using standard innovation processes and innovative project planning, and by mobilizing existing chemical engineering skills in the field of specialty chemistry.
Specialization course: "Processes for biotechnologies"		
Bioprocesses	4	Life cycle analysis and safety. Thermal valorization of biomass. Techno-economic analysis of processes.
Industrial biotechno-logical processes	4	Industrial applications of biotechnological processes in the health, chemical and energy sectors. Specificities of biological processes for the design, characterization, understanding and control of industrial processes.
Tools and methods	4	Technological and societal challenges related to biotechnology production. Design of a biotechnological production unit. Techno-economic analysis of a biotechnological production unit.

Table A1.6. *Lessons learned during semester 9*

A1.1.5. *Engineering internship*

The last semester is entirely devoted to the engineering internship, which must be carried out in a company or in an EPIC, lasting five to six months, and validating 30 ECTS credits.

This internship is the first significant experience in the professional world. Its purpose is to present the engineering student with the reality of the engineering profession, both in its technical aspects and in its human, organizational and regulatory dimensions.

The objectives of the internship are related to:

– the performance of scientific and technical engineering work on solving complex problems, presenting concrete conclusions and proposals and providing technical expertise and decision-making support;

– writing a report and presenting your work;

– the use of human, social and possibly managerial skills in the course of the internship.

A1.1.6. *Work-study training "processes, products, and biotechnologies – processes"*

Finally, the school offers a final year of work-study training, under a professionalization contract, for students who wish to move into the sectors of fine chemicals, specialty chemicals, pharmaceuticals or parachemistry, cosmetology or food processing. This training, which lasts a maximum of 15 months, takes place during the S9 and S10 semesters, offering short periods of alternating academic and on-the-job training. Students in this field are required to develop specific skills in the field of simulation, sizing or operation of discontinuous equipment forming part of a batch production workshop, and in the management of a single or multi-product batch workshop as well as in the scheduling of tasks.

Students follow one of the courses offered in S8 and S9 ("Advanced Process Engineering", "Process Engineering for Products", or "Biotechnology Process Engineering") as well as some specific courses, detailed below.

Teaching units for semester 9	ECTS	Training objectives
Batch process engineering	4	Resolution of coupled mass and energy balances in batch mode. Solving a dynamic optimization problem, CVP resolution method combined with the sensitivity method. Fundamental and technological aspects of industrial crystallization and precipitation.
Design and management of installations multi-product	5	Design of a batch unit. Sizing of discontinuous installations. Batch workshop planning. Operational management of a company. Be able to integrate as a scientific expert into a structured activity in a project group.

Table A1.7. *Specific lessons for semester 9*

Semester 10 Teaching Units	ECTS	Training objectives
Engineer internship	30	Carrying out scientific and technical engineering work on solving complex problems, presenting concrete conclusions and proposals and providing technical expertise and decision-making support. Writing a report and presenting work. Implementation of human, social and possibly managerial skills in the course of the internship.
Tutored project	10	Carrying out a research and development study on the implementation of a new product or equipment in a batch production workshop. Writing a report, presenting the work to a defense committee and defending the choices made.

Table A1.8. *Specific lessons for semester 10*

A1.2. Engineering with a chemical engineering specialization

A1.2.1. *Description*

The aim of this second course is to train, through work-study programs and under student status, production and process engineers, specialized in chemical engineering, to work in the processing industries in a wide range of sectors: energy, petrochemicals, pharmaceuticals, the environment, basic or fine mineral and organic chemistry.

The skills targeted concern the design, organization, optimization and supervision of manufacturing resources and processes, with a production objective, while respecting the requirements of safety, environment, quality, costs, deadlines and quantity.

This engineering degree is accessible in two ways: initial training and continuing education. The two populations are deliberately mixed so the senior technicians in continuing education enrich the various courses with their professional knowledge and skills. All students follow the same alternating rhythm, with periods of six months of academic training followed by periods of five to six months of professional experience.

A partnership agreement between the University of Lorraine and the Hochschule Mannheim enables students admitted to the Franco-German integrated curriculum to obtain the diplomas of both institutions. This is a program supported by the Franco-German University.

A summary description of the conduct of the studies is presented below:

Binational sector	Academic training at the Hochschule or ENSIC	In-company training in the partner country	Academic training at the Hochschule	Academic training at the Hochschule	Training academic in Nancy	In-company training
National channel	Academic training	In-company training	Academic training	In-company training	Academic training	In-company training
	S5	**S6**	**S7**	**S8**	**S9**	**S10**

Table A1.9. *Synoptic of studies – engineering field, chemical engineering specialization*

The pedagogy is based on an alternation of courses, supervised work and projects, supplemented by the use of methods and tools allowing active learning. Industry professionals are also involved in training, through courses, conferences and project monitoring, both in the teaching of scientific and technical disciplines and those in the humanities, legal, economic and social sciences. This training does not include practical work, because of the initial training of its students, who already hold a DUT or BTS[6].

The evaluations are in line with the European harmonization framework, are validated by the capitalization of ECTS credits, and take into account the learners' time working. In the same context, one or more stays abroad, of at least three months, are mandatory during the school year. Some engineering students complete additional university training abroad, others do their internship in a company.

A1.2.2. *Recruitment*

Admission to the FITI program is by competition: selection on the basis of an entrance examination file, followed by an interview and evaluations on the levels of scientific subjects and English.

For initial training, for admission to S5, the number of places offered is as follows:

– 30 places for students with a DUT or BTS;

6 BTS stands for "Brevet de technicien supérieur", Higher Technician's Certificate.

– 1 place to a candidate from the joint polytechnic competition;

– 2 places for students with an L2 degree;

– 2 places for students from the ATS program;

– 10 places for students at the Hochschule.

Admission to the continuing training program takes place during the semester S7. Six places are reserved for senior technicians (holders of a DUT or BTS or after validation of prior experience) with at least three years of professional experience.

A1.2.3. *Teaching units*

The different teaching units of the core curriculum, their training objectives and corresponding ECTS credits are detailed below:

Teaching units for the first half of the year 5	**ECTS**	**Training objectives**
Physical and structural chemistry	4	Plan the physiochemical properties of the elements according to their electronic structure. Compare intramolecular and intermolecular interactions. Differentiate crystalline structures and their associated properties. Describe the different interfaces by associating them with remarkable application properties. Determine the equilibrium composition of a complex ionic medium that may be the site of acid-base reactions, complexation, precipitation or oxidation-reduction.
Chemical kinetics	2	Understanding of the kinetic phenomena involved in chemical transformation in different types of model reactors.
Organic chemistry	2	Basic knowledge of organic chemistry. Reactivity of organic compounds.

Chemistry industrial	2	Mass and energy balances on an industrial unit. Understand and analyze continuous processes.
Transfer phenomena I	4	Basic knowledge of fluid mechanics and transfer of matter and heat by conduction and diffusion. Choice and sizing of pumps.
Thermo-dynamics I	2	Principles, quantities, and tools of thermodynamics, uses and applications in energy balances, in the forecasting of the states of matter, in the forecasting of system evolution and in the dimensioning of simple energy installations.
Applied mathematics I	4	Reinforce students' heterogeneous knowledge of mathematics. Acquire the techniques of formal analytical computation useful in solving engineering problems.
Management and economics I	6	Be familiar with the principles, tools and methods of risk assessment and control and integrate them into its practices. To know the human, social, economic and legal issues related to occupational health and safety in the company. Industrial management tools and methods, analysis of a company's balance sheet and profit and loss. Understand the different behaviors of individuals through self-knowledge tools, know the dimensions and tools of interpersonal communication (verbal and non-verbal). Identify the content of a CV and cover letter. Describe and analyze the main dimensions of change management in an organization. Know how to access scientific documentary information and documentation management.
Languages I	4	Develop the skills to reach/maintain a minimum level B2 in English. Consolidate the first level in German or Spanish. Develop professional skills to work in an international context.

Table A1.10. *Lessons learned in semester 5*

Teaching units for semester 6	ECTS	Training objectives
Technician internship	30	This internship, which lasts at least 4 months, aims to develop communication skills, consolidate technical knowledge, knowledge of the company, discover the responsibilities of an executive and become familiar with the engineer's culture.

Table A1.11. *Lessons learned during semester 6*

Teaching units semester 7	ECTS	Training objectives
Chemistry of the material	2	Knowledge of materials. Phenomenological understanding of corrosion.
Transfer phenomena II	6	Understanding of the mechanisms of mass and heat transfer in the presence or absence of a phase change. Sizing of heat exchangers. Description of flows and transfers in fixed and fluidized beds and in fluid solid separation operations. Theoretical and practical concepts to understand how industrial boilers work.
Thermo-dynamics II	2	Description and characterization of chemical and phase equilibria, including chemical potential. Use and application in the design of conventional separation processes and chemical reactors.
Chemical reaction engineering I	4	Basic knowledge of homogeneous reactors, heterogeneous catalytic reactors and polymerization reactors. Essential concepts for the choice and design of such chemical reactors.
Separation processes I	2	Knowledge of simple and stepped isothermal separation processes. Concepts underlying the different separation operations. Select and size the type of separator appropriate for a given situation.
Applied mathematics II	4	Acquire techniques for solving certain analytical problems through the Laplace Transform. Basics of programming in a structured language, approach digital techniques for solving engineering problems and discover statistical tools to help in decision-making.

Teaching units for semester 7	ECTS	Training objectives
Management and economics II	2	Describe and understand the process of technological innovation in industry: identify the strategic, organizational, cultural and scientific enabling factors. Design and develop an innovative product or process by using project management tools and principles. Build a business plan by developing the aspects related to the project: competition, suppliers, customers, estimated budget, technology, legal aspects, etc.
Option I	5	Opening course (24h) organized within the Collegium Lorraine INP. One option (42h) within ENSIC: energy (geopolitical context, new low-carbon energies, biomass biofuels, energy storage, main greenhouse gas reduction technologies) or industrial biotechnologies (biomolecules, kinetics, biological reactors, and analytical methods).
Languages II	3	Preparation for the TOEIC/TOEFL/IELTS test to obtain a minimum level B2. Consolidate the level acquired in LV2. Develop professional skills to work in an international context.

Table A1.12. *Lessons learned during semester 7*

Teaching units for semester 8	ECTS	Training objectives
Assistant engineer internship	30	This professional internship, carried out in a company or in a public industrial and commercial establishment for a minimum period of 5 months, aims to allow the acquisition of technical knowledge on processes and equipment.

Table A1.13. *Lessons learned during semester 8*

Teaching units for semester 9	ECTS	Training objectives
Unit operations	4	Characterization and sizing of stirring devices. Rheology of Newtonian and non-Newtonian environments. Analysis and sizing of balanced separation operations: binary distillation, wet air operations, drying and crystallization.
Security and sustainable development	4	Design of cleaner, more efficient and safer processes. Treatment of aqueous, gaseous and solid industrial effluents. Knowledge of the main energy conversion technologies. Analysis and sizing of the main energy systems (compressors, ejectors, nozzles, thermal machines, refrigeration machines, heat pumps, etc.).
Chemical reaction engineering II	2	Analysis and design of heterogeneous catalytic and non-catalytic reactors and recycling systems. Introduction to process intensification. Global design of heterogeneous reaction processes.
Industrial processes II	4	Knowledge of industrial processes in various sectors of activity: mineral chemistry, refining, petrochemistry, fine chemistry and nuclear. Principles, implementation and sizing of unit operations.
CPAO - Control command	5	Simulation and process simulators, organization of physiochemical properties and static applications with PRO/II software. Dynamic characterization of systems, identifications and industrial applications. Monovariable continuous time systems: PID-based control and tracking techniques, dynamic consequences of control on processes. Theoretical and practical aspects of metrology, importance of sensors in process control.

Management and economics III	4	Global business management simulation: rapid strategic and operational choices, based on market developments, competition and other cyclical factors. Main support and transversal functions in a company. Knowledge of labor law and treaty provisions. Recruitment techniques and tools, personality interview and job interview. Learn the techniques of conducting a meeting. To know the stakes of ethics in companies. Develop your entrepreneurial potential.
Industrial project	3	Team analysis of an industrial problem: choice or design of a unitary chemical engineering operation with financial aspects, safety, deadlines and communication.
Languages III	4	Preparation for the TOEIC/TOEFL/IELTS test to obtain a minimum level B2. Consolidate the level acquired in LV2. Develop professional skills to work in an international context.

Table A1.14. *Lessons learned during semester 9*

Semester 10 Teaching Units	ECTS	Training objectives
Engineer internship	30	This professional internship, carried out in a company or in a public industrial and commercial establishment for a minimum period of 5.5 months, aims to strengthen the scientific, technical, and managerial skills of the future engineer in a professional situation.

Table A1.15. *Lessons learned during semester 10*

Ignorance is sometimes masked by too much knowledge. (Girel 2017)

Man is naturally inclined to know; it is with effort that he seeks to know how he knows. (Brenner 2003)

Any technical product affects the entire technical organization [...]. As a result, no work process can be isolated and considered independently of this organization. (Jünger 2018)

Technology also offers us consistent perspectives in possible worlds, perspectives that it intends to realize. Technical innovation (or invention) projects plausible fictions in front of it. It is consubstantial to them. (Sfez 2002)

There is a constant fear of contamination of scientific results, either by natural objects invading the experimental environment to produce ‘dirt’ or ‘noise’, or by the intervention of social, economic or political interests that are suspected of compromising their reliability – or fundamentally the truth. This is the reason for the strength of scientists’ commitment to the autonomy of science and their conviction that it must remain independent of other institutions and systems in society. (Nowotny *et al*. 2003)

Within a given cultural universe, we cannot perceive the world in any way: perception operates in that universe according to very specific conventions, culture designating stimuli to be perceived, while associating symbols and values (positive, negative) and specifying the type of emotional expression that should be adopted in front of them. (Vinsonneau 2000)

Innovation strategies must therefore strive to mobilize all skills, absorb new ones, combine them in a different way, in order to launch new products that are difficult to imitate and whose implementation or performance remains opaque or poorly understood in the eyes of competitors. (Martinet 2003)

The engineer’s job is to mobilize the technical knowledge at his disposal to devise innovations that represent a compromise acceptable to all stakeholders. Technical perfection is the poison of the economy. You have to be ready to tinker to satisfy as many people as possible. The resources of technology are such that you can only believe an engineer who assures you without blinking that there is only one efficient and cost-effective technical solution and that you must choose it. (Callon and Lacoste 2011)

Communicating about your uncertainties or the imperfections of the act you have just performed is difficult because revealing your difficulties means taking the risk of exposing yourself to negative judgment about your professional qualities, especially in an environment where the culture of error is not strongly present, or if the team is not united. (Clergue 2009)

The higher up in the hierarchy of a company, the less technical the tasks, the more political they are. In other words, the less account is taken of technical expertise [...] and the more account is taken of adherence to the company's values and objectives. (Woda 2016)

Understanding complexity requires a holistic understanding of reality, which consists of taking an interest in all the fields of reality without knowing how to steer them or accept the wisdom of time to embrace them… So this multidisciplinary approach opens up a wide variety of fields, some of which do not have the instructions for use to master them – this requires many years of research and practice. This then contributes to global chaos. (Marsan 2018)

If France has become a follower in innovation, it is because the bottom-up culture is not rooted in French culture, which is always looking for innovation through the State or large companies. However, innovation no longer occurs in large groups, but in small, agile structures. (Lahrer 2018)

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