PEP | Program Educational Project

Continuous Improvement and Quality Monitoring of Undergraduate Programs

CHEMICAL ENGINEERING PROGRAM

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La UNIVERSIDAD aprende

School of Engineering
Bogotá Campus

UNIVERSIDAD NACIONAL DE COLOMBIA

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Introduction

The Program Educational Project (PEP) of the Chemical Engineering Program of the Universidad Nacional de Colombia, Bogota Campus, presents the curriculum resulted from the reform process of the curricular programs of the university. This reform process was carried out to adapt the curricula to Agreement 033 of 2007 of the University Superior Council (CSU by its Spanish acronym). This Agreement defines the basic guidelines for the education process of students through the curricular programs, as well as the principles of education, namely: academic excellence, integral education, contextualization, internationalization, research education, interdisciplinarity, flexibility and management for academic improvement.

This PEP (update of the PEP of 2015 (2)) recognizes the scientific and technological state of Chemical Engineering and incorporates them into the curriculum, which is a result of the experience accumulated by an academic community throughout almost seven decades in the inherited work of professors, students, graduates and support, technical and administrative staff. This academic community has contributed to the education of around 5,000 chemical engineers, who exercise their professional work in different fields of action in Colombia and in other countries.

Initially, this document presents a definition of Chemical Engineering as a profession along with a brief description of its development outlined through three paradigms: the unitary operations, the continuum or scientific foundations and the product design. Then, a brief historical review of the curriculum so as to show its evolution through time is described. Next, the educational guidelines of the students of the Universidad Nacional de Colombia are identified and discussed, as well as the skills and abilities that Chemical Engineers must have nowadays, according to several social actors of recognized importance for the profession. These guidelines and characteristics constitute the conceptual foundation for the definition of the curriculum.

Based on the aforementioned, the curriculum objectives and the profiles of applicants and graduates are established. Subsequently, the curriculum of the Chemical Engineering program is defined, along with the teaching methodologies, the development of each skill, the expected results in the graduates educational process and, finally, the resources to materialize this PEP.

A. Chemical Engineering

In accordance with Law 18 of 1976 of the Ministry of Education, which regulates the exercise of the chemical engineer profession in Colombia,

> *Chemical Engineering is the application of knowledge and means of Physical, Chemical and Mathematical Sciences and Engineering, in the analysis, administration, direction, supervision and control of processes, where physical, chemical and biochemical changes are made to transform raw materials into elaborated or semi-finished products, except for chemical-pharmaceuticals. It is also applied in the design, construction, assembly of plants and equipment for these processes in every entity, University, Laboratory and Research Institutes that need this knowledge and means* (3).

> *Throughout the world, and for almost a century, chemical engineering, along with mechanical, electrical and civil engineering, form the quartet of traditional engineering, with clearly defined academic contents and professional competences (4). Chemical Engineering is an open area, based on the basic sciences, Mathematics, Physics and Chemistry. It is in constant evolution, with labile borders and interacts, complements, overlaps and is overlapped by traditional engineering fields and by others that had appeared more recently (4).*

In addition, The Institution of Chemical Engineers (IChemE) of Great Britain, establishes that Chemical Engineering is a discipline related to the safe and cost-effective transformation of raw materials into daily use products. Chemical Engineers understand how to alter the chemistry, biochemistry or physical state of a substance to create everything, from facial creams to fuels (5). According to IChemE, "Chemical engineers often work in multi-disciplinary teams with mechanical, electrical and other types of engineering as projects benefit from different perspectives and areas of expertise". They need to make decisions to answer the following questions (6):

Which reaction route should be used to make the product?

How to purify the desired product?

How to control the process and ensure it is safe?

How to make the process cost effective?

What should be done with any by-products formed?

How to reduce the amounts of unwanted by-products?

What to do with unreacted raw materials?

How to recycle energy within the process?

Considering this professional picture, it is clear that the responsibilities faced by the chemical engineer are many and varied but all of them can be framed in one of the three listed below (7):

- Design and operate chemical processes for generating products that are useful and meet the specifications of customers.
- Maintain safe conditions for personnel and residents near a production facility.
- Protect the environment and human health, not only during the production step but throughout the entire life cycle of the product, which includes its transportation, use, recycling and disposal.

These responsibilities are framed within the sustainability concept, which was defined in the Brundtland Report from a modern perspective (8). This has positively impacted the way in which chemical engineers conceptualize new products, processes and industrial facilities without leaving behind traditional concepts such as reactions, separations, energy, efficiency and low-cost, safety, the environment and the social impact. According to Martínez Hernández (9), until the last century, chemical processes were traditionally designed inside the walls of the plants and had low cost as main objective, frequently neglecting environmental consequences. Currently, the rise of awareness regarding the negative environmental impact of human activities has encouraged governments to implement new regulations. Additionally, this persuades the industry to generate and implement the following solutions: preserve vital resources such as water, utilize raw materials provided by renewable natural resources, reduce energy consumption and the generation of emissions, and finally, conduct suitable management of waste and emissions (9).

Finally, in the development of the profession, there are three paradigms distinguished by Kuhn in his book *The structure of scientific revolutions* as the specific ways of seeing scientific reality (10) and at the same time mark its evolution (11). First, at the beginning of the 20th century, in 1915, Arthur D. Little presented the concept of unit operations, accepted and extended (12) in 1922 by the Education Committee of the American Institute of Chemical Engineers –AIChE. Then, in the decade of the 1950s, the paradigm of the continuum or the scientific foundations was supported by the syllabus of Transport Phenomena courses and strengthened with the publication in 1960 of the book Transport Phenomena, by Bird, R., Stewart, W. and Lightfoot, E. Nowadays, the paradigm of design and product engineering is rising. Macroscopic variables are designed and controlled through the manipulation of the fundamental units, the molecules, in which process design (process synthesis) is other stage.

The design of chemical products seeks to obtain the highest added value for a product through the improvement of its properties. Undoubtedly, this problem is more complex than a applying a mathematical treatment to maximize the benefit because to some extent, it will depend on a complex set of properties that might not be identified previously. Consequently, product design and the solution of new engineering problems require the strengthening of the scientific foundation and the use of specialized engineering tools. For these reasons and because a new body of knowledge is necessary, since 1988, product design and engineering were recognized as the third paradigm of Chemical Engineering (10).

B. Historical Overview of the Program[1]

Although the origins of the Chemical Engineering as an academic program in the country date back to 1937 at the Universidad Pontificia Bolivariana of Medellín and 1941 at the Universidad del Atlántico, the Universidad Nacional de Colombia was the first to create a Department specifically designed to the study of Chemistry as a Science in 1936. In that year, the teaching team was formed and the essential logistics was assembled to focus on the teaching of different specialties and applications of the discipline. Before then, this task was performed independently by the schools that included chemistry courses in their programs. In fact, in a few years, this Department created the Chemistry and Chemical Engineering programs and became a School.

The Department of Chemical Sciences was instituted in the Agreement No. 11 of October 29, 1936, from the Board Council of the University (currently the University Superior Council - CSU). One of the main objectives was "to improve the teaching of Chemical Science and gather the elements dispersed in the different Schools of the University under one direction". The rapid success of this Department led the Directives of the University to strengthen and organize it as a direct division of the Rector's Office, with a Special Director and a Council composed by the Deans of the Medicine and Engineering Schools and by the Director of the School of Pharmacy. On February 10, 1938, Professor Antonio García Banus, Spanish professor at the University of Barcelona, was appointed as the first Special Director.

B.1 Creation of the Chemistry and the Chemical Engineering Program

In the imminence of the Second World War, the work of the Professor García Banús and his experience in the Spanish Civil War offered a clear vision about the need of manufacturing in South America the products that until then had been imported from Europe. In order to meet this challenge, it was essential to prepare qualified professionals in the field of chemistry (at a scientific level) and in the industrial production. The concerns of Professor García Banús were accepted opportunely by the Direction of the University and supported by the National Government.

As a result, with the administrative support of the Department of Chemical Sciences, the Board Council structured the curriculum for the titles of Doctor of Chemical Sciences and Doctor in Chemical Engineering with the favorable concept of the Academic Council in the Agreement No. 26 of 3 March 1939. The program established four years of regular studies and a fifth year of optional specialization. In this Agreement, students could complete the compulsory four years and present a "validation" exam to receive a diploma in Chemical Sciences, which they could use to start their professional practice. Then, the graduate could choose one of the following alternatives: 1) present and defend a thesis to obtain the title of Doctor of Chemical Sciences; 2) take courses in Pedagogy and Methodology, with the advice of the Superior Normal School, and perform teaching practices in General Physics and Chemistry, to qualify as a teacher; or 3) take a 1-year complementary course of industrial specialization, to receive the Chemical Engineer diploma.

Thanks to the Agreement 26 of 1939, which presented a program of studies and the regulations for the education of chemical engineers, the Universidad Nacional de Colombia can be considered as the pioneer of this profession in the country, even though it became a fact only a few years later. The courses started in 1939 and in their first stages were developed as planned, which allowed

[1] *Most of the information of this historical overview and the Reform of 1973 was taken from the 'Chemical Engineering Degree, Curricular Reform', Bogota, February, 1994 (14).*

the first eight chemists to graduate at the end of 1942. The Agreement 26 also indicated that the industrial specialization program would be implemented only when the equipment and facilities of a semi-industrial type (now called the Pilot Plant) were available and after the graduation of the first chemists. It was necessary to wait until 1946 to begin the assembly of the first equipment in the new building, in the campus of the Universidad Nacional.

B.2 School of Chemistry and Chemical Engineering

The relevance and development of the Department of Chemical Sciences, its services to the different programs and, especially, the boom of the Chemistry Program motivated the CSU of the University to convert it into a School through the Agreement 147 of 1940, clearly with all the inherent obligations it brings. The provision of services that the Department offered was also met. All these changes supported the initiatives of Professor García Banús since he considered the Chemical Sciences as a fundamental career for the development of the country, that had to be provided with the basic elements for its existence and progress.

B.3 Structure of the Chemical Engineering Program

With the adequate academic structure and the semi-industrial facilities (Laboratory of Basic Unit Operations), the School was able to fulfil the original objectives of the Agreement 26 and initiate the complementary courses for the education of Chemical Engineers. The curriculum was revised, which led to the issuance of the Agreement No. 193 of 1948: "By which the Chemical Engineering studies at the University are regulated". Then, a five-year curriculum was established. Although it maintained the basic education for the Chemists, specific Chemical Engineering courses were added in different levels: Statics, Dynamics, Mechanics of Fluids, Resistance of Materials, Electricity and Economy. The fifth year, specifically for Engineers, corresponded to the courses of Inorganic Industrial Chemistry, Electrical Engineering and Laboratory, Water Treatment, Economics, Metallurgy and Chemical Engineering and Projects.

B.4 Evaluation of the curriculum of 1953

The arrival of Professor Zbigniew M. Broniewski, Army and Chemical Engineer of the Polytechnic University of Warsaw and specialized in Uppsala (Sweden), and its vinculation to the teaching staff of the Universidad Nacional strengthened the Thermodynamic, Design and Pilot Plants areas.

In 1953, the common program was modified and reduced to only two years. Then, the student had the freedom of choosing between Chemistry or Chemical Engineering, taking two and three additional years, respectively. In 1956, the common program was reduced to the first year. Although several courses were common (Mathematics, Physics, Mineralogy and Electrochemistry, among others), these were placed in their respective curriculum, to avoid students taking courses of another program. In Chemical Engineering, the schedule of some courses was adapted to include others such as Stoichiometry, Thermotechnics, Materials and Corrosion. The Chemistry and Chemical Engineering School Board of Directors implemented these modifications gradually following the "minor changes" system over the decade of 1950. In addition, in 1959, the reform of the teaching methodology of the Mathematics subject reduced the class hours and the number of courses and allowed students to schedule their classes earlier in the day, apart from permitting other courses to be also rescheduled.

The elimination of some courses helped including other indispensable ones at the end of the curriculum. Some of these courses were Chemical Industries, Industrial Organization and Process Control.

Since 1959, the Chemistry degree was prolonged to five years. During this period, the education of Chemical Engineers had a strong orientation towards Chemical Sciences and Analysis, as a logical result of the common origin with the Chemistry degree. Nevertheless, the areas related to the design, assembly and operation of industrial plants improved gradually and some economic and administrative aspects were incorporated. The general picture up to 1965 was the following: Chemical Engineers educated to the light of these parameters were able to start their professional exercise in aspects such as production, industrial processes, economic studies and design. At the same time, they were capable of managing efficiently other aspects such as the analysis, quality control and chemical development.

On the other hand, at the beginning of 1960, the Engineering School carried out a great reform concerning the methodology and the content of the Civil Engineering program. This consisted of six annual academic terms and later on it became a five-year degree of 10 semesters. Additionally, the Electrical and Mechanical Engineering degrees started with the same system of academic terms by semesters.

B.5 The integration of 1965

In 1965, the President of the University José Félix Patiño proposed and carried out an integration of some Schools and Departments, which gradually brought new academic adjustments. The School of Chemistry and Chemical Engineering became the Department of Chemistry, which was integrated to the new School of Sciences but at the same time it was overshadowed by the Chemical Engineering degree. As a result and at the request of professors and students, the CSU, through the Agreement 188 of August 19, 1965, created the Department of Chemical Engineering, attached to the School of Engineering. The program was transferred to this School, which was integrated then by the Departments of Civil Engineering, Electrical Engineering, Mechanical Engineering and Chemical Engineering, each one administrating their respective degrees.

For the integration and operation with the other departments, the Chemical Engineering program had to modify its curriculum, adapt it to the semi-annual modality and adopt the first semester in common with the other engineering programs. This reform was evaluated by the Academic Council and formally approved by the CSU, through the Agreement of January 8, 1966. Besides dividing the annual courses into two semesters and relocating others that were already semiannual, some common courses were introduced, such as Spanish I and II, Descriptive Geometry I and II, and Humanities. As a result of the influence of the practical approach of Engineering, there was a notorious change in the philosophy, orientation and objectives of the program in comparison with the initial scientific emphasis promoted by the founders of the Department of Chemical Sciences. The undergraduate thesis was replaced by a directed degree project that students had to perform during their last semester of studies.

The implementation of the reform of 1966 revealed a series of concerns that could not be detected due to time pressure. They occurred mainly because the one-year courses were divided into two semesters to fulfil the semester requirement established before. The program comprised eighty-six courses, theoretical and practical (laboratories), with 35 class hours per weeks. Very soon, the evaluation of the curriculum recognized that it was not compulsory for a chemical engineer to be an expert on all the engineering and chemical abilities applied in the industrial, technical and administrative fields. Complementary areas such as Mineralogy, Strength of Materials, Mechanics, Machine Elements and Analytical Chemistry (Qualitative and Quantitative) must be conducted by professionals in the area (Civil Engineers, Mechanical Engineers, Chemists) who would integrally work with Chemical Engineers. In consequence, Chemical Engineering professors would concentrate on professional topics to improve students' educational process.

The program assessment contributed to identify the need for reducing the academic load, rationalizing the number of courses and their contents and giving the student more time for consultation in library, preparation of reports and participation in the laboratories. It was a gradual restructuring through some minor changes that led to the institutional reform of 1973 described below.

B.6 The Reform of 1973

As a consequence of the evaluation mentioned above, a new curriculum was submitted for consideration to the School Board of Directors, which was accepted and sent for its analysis and approval to the Academic Council and the CSU. The result was the Agreement 166 of November,1973, in which the curricula for the degrees of the Engineering School were approved. The curriculum of the Chemical Engineering Program comprised sixty-four courses to be taken in ten semesters, including the non-technical and the technical electives. The eleventh semester contemplated the elaboration of the Degree Project. Additionally, the English course was suppressed, and the humanities were replaced by non-technical electives to permit the student to enrol freely in non-professional courses according to their own interests. Some complementary Engineering courses continued to be offered as technical electives. The intensity of the normal semesters did not exceed 27 hours per week and the limit allowed was 30.

The curriculum of 1973, in effect until 1994, was permanently evaluated by the Curricular Committee and the Board of Directors to identify aspects that required updating or restructuring.

B.7 The Reform of 1994

The Agreement 14 of 1990 of the Academic Council (13) outlined the general criteria to structure the curricular programs of the Universidad Nacional de Colombia. The objectives were: to integrate more intensively teaching, research and specialized consultancy; to make curricula more flexible to promote the integral and pluralistic education of students; to increase autonomy and commitment in the education; and to offer possibilities of study in areas of national and regional priority that respond to the needs of the country. It also intended to establish appropriate forms of organization for the development of research and specialized consultancy activities, which started to be offered by then. One of the most important aspects of this reform was the design of the programs with core and flexible components, the latter including technical electives and context courses. The aim was to focus the program towards the Engineering Sciences, which meant strengthening the concepts and foundations on basic sciences (14).

A curriculum was designed consisting of 58 academic activities programmed in ten semesters and divided into four education cycles: Basic Sciences, Foundations of Engineering, Chemical Processes Engineering and Technical Electives. The courses were classified in the areas of Mathematics, Physics, Chemistry, Computer Science, Socio-Humanistic Context, Industrial Management, Chemical Processes, Transfer Operations and Thermodynamics. Initially, the technical electives were Petrochemistry, Materials, Biotechnology and Electrochemistry, and Corrosion, which were later complemented with Environmental Engineering and Food Engineering. This curriculum was approved in the Agreement 22 of November 17, 1993 of the Academic Council (14).

In 2003, some changes were introduced in the curriculum: some pre-requisites were established and the courses Simulation of Processes, Polymeric Materials and Bioprocesses were added to the technical electives. These courses enhanced the options to meet the requirement of taking at least three technical electives (15). In the Agreement 001 of 2005 of the CSU and the Resolution 114 of the same year of the School of Engineering Council, the requirement of the Final Work Degree was modified and regulated, defining the following topics:

- Number of credits: 6.
- Grading: numerical and individual.
- Modalities: research work (monographic work, research seminar, participation in research projects and final work), specialized consultancy practices (participation in teaching activities and internships) and special activities (postgraduate courses).
- Evaluation: In charge of the professor.

B.8 The Reform of 2008

The curriculum of the Chemical Engineering Program was adapted to comply with the provisions of the Agreement 033 of 2007 of the CSU. This Agreement defines the basic guidelines for the process of education of students through the curricular programs, as well as the principles of education, namely: academic excellence, integral education, contextualization, internationalization, research education, interdisciplinarity, flexibility and management for academic improvement, as it was mentioned in the Introduction.

The guidelines of this reform are summarized in the Agreement 252 of the Academic Council (2008). According to this Agreement, the number of credits required for the program is 180. The definition of the courses in each component, the number of credits and their requirements were validated and updated in the Resolution 146 of 2010 of the Engineering School Council. Likewise, it established that the modality of Final Work Degree can correspond to research work, specialized consultancy practices or postgraduate courses.

In 2013, after reviewing the outcomes of the 2008 academic reform, some modifications were made to the curriculum through the Agreements 2 and 16 of 2013 of the Engineering School Council. This new plan, which is an essential part of this report and is described in numeral 8, included the modification of the requirements and co-requisites of some courses, and enhanced and modified the offering of technical electives in thermodynamics, administration and materials.

C. Basic guidelines for the education of the students of the program

The expectations of the different interested parties, called constituents, were taken into account in order to establish the education guidelines for the students of Chemical Engineering. The constituents identified in the Chemical Engineering Program are listed below:

- Universidad Nacional de Colombia
- School of Engineering
- Department of Chemical and Environmental Engineering
- Curricular Area of Chemical and Environmental Engineering
- Professional Council of Chemical Engineering (CPIQ)
- Professional Associations of Chemical Engineers (specially ACIQ)
- Employers of Graduates of the Program (represented by the External Advisory Committee of the Program – CAE)
- Graduates of the Program
- Active Students of the Program
- Active Professors of the Program

As mainstay among the program constituents, the Universidad Nacional de Colombia, declares:

Mission

As the nation's University, it promotes equitable access to the Colombian educational system, provides the widest range of academic programs, educates competent and socially responsible professionals. It contributes to the elaboration and meaning of the nation project, studies and enriches the cultural, natural and environmental heritage of the country. As such, it advises on scientific, technological, cultural and artistic orders with academic and research autonomy.

Main objective

To edify free citizens and promote democratic values, tolerance and commitment to civil duties and human rights. The University will contribute to national unity, as a center of intellectual and cultural life open to all currents of thought, through academic freedom, and to all the social, ethnic, regional and local sectors. It will study and enrich the nation's cultural, natural and environmental heritage and contribute to its conservation. It will study and analyze the national problems and propose formulations and relevant solutions autonomously. It will share in the benefits of its academic and research activities with the social sectors that constitute the Colombian nation. It will provide support and advice to the State in scientific and technological, cultural and artistic orders, with academic and research autonomy.

Based on the mission and its institutional objectives, basic guidelines were established for the education of students at the Universidad Nacional de Colombia through its curricular programs, as stated in the Agreement 033 of 2007 of the CSU (1). Article I of Chapter I of this agreement describes the principles of students' education at the National University of Colombia:

Article 1. In accordance with the public character of the University and with the Decree 1210 of 1993, the University will edify free citizens and will promote democratic values, tolerance and commitment to civil duties and human rights. It will contribute to national unity, as a center of intellectual and cultural life open to all currents of thought, through academic freedom, and to all the social, ethnic, regional and local sectors. It will study and enrich the nation's cultural, natural and environmental heritage and contribute to its conservation.

It will study and analyze the national problems and propose formulations and relevant solutions autonomously.

It will share the benefits of its academic and research activities with the social sectors that constitute the Colombian nation.

It will provide support and advice to the State in scientific and technological, cultural and artistic orders, with academic and research autonomy. To achieve the above purposes, the educational processes of the students of the University through its curricular programs will be governed by the following principles:

1. ***Academic excellence.*** *In accordance with the purposes established in the Decree 1210 of 1993, the University will foster academic excellence, which is an essential factor for the development of its members and the country, through the promotion of an academic culture that stimulates scientific knowledge, the incorporation of new currents of thought and technologies, the consolidation of disciplines and professions, and interdisciplinary communication. It will introduce new practices that encourage the development of the teaching and learning capacity, of criticism and innovation, of teamwork, of solidarity attitudes, of individual and collective responsibility, for the well-being of the community.*

2. ***Integral Education.*** *The Universidad Nacional de Colombia, as a public university, has acquired the commitment to educate individuals capable of formulating proposals and leading academic processes that contribute to the construction of a democratic and inclusive nation in which knowledge is a fundamental pillar of coexistence and social equity. The university education will promote respect for individual and collective rights, and for differences in belief, thought, gender and culture. The University will form an academic community with a systemic thinking that be expressed in universal languages with a high conceptual and experimental capacity. It will develop aesthetic and creative sensibility; ethical, humanistic, environmental and social responsibility; and the ability to pose, analyze and solve complex problems, thus, generating autonomy, critical analysis, proactive capacity and creativity. The graduates of the Universidad Nacional de Colombia will be prepared to work in disciplinary and interdisciplinary teams integrated in a vast network of local and international communication; and to transversally employ the tools and knowledge acquired in an area of knowledge, legitimately adapting and applying them in other areas.*

3. ***Contextualization.*** *This principle seeks to integrate educational processes with cultural, social, ecological, economic, political, historical, technical and scientific environments. At all levels of education, the University will seek to contextualize the subjects through the articulation of the education, research and specialized consultancy processes with the history of production, creation and application of knowledge.*

4. ***Internationalization.*** *This principle promotes the identification and incorporation of professors, students, the institution and its academic programs into the scientific, technological, artistic and cultural movements that occur at the national and international level, while treasuring local knowledge as factor of our cultural diversity that should contribute to the construction of universal knowledge.*

5. ***Research Education.*** *Research is the foundation of the production of knowledge, develops learning processes and strengthens the interaction of the University with society and its background. Research should contribute to the formation of human talent, artistic creation and technological development for the solution of local, regional and international problems. It is the only way to reduce the gap in scientific production, creation in the arts and postgraduate education in our country. The education of researchers is a permanent and continuous process that starts at the undergraduate level and continues at the different graduate levels.*

6. ***Interdisciplinarity.*** *Today society demands that the University develops its essential functions by articulating different disciplines perspectives from the communication of ideas; concepts, methodologies, experimental procedures; field explorations and insertion in social processes. Interdisciplinarity is, at the same time, a way of integrating the university community since it promotes teamwork and relationships between its various divisions and of these with other institutions.*

7. ***Flexibility.*** *The University adopts the principle of flexibility to respond to the permanent condition of academic transformation according to the needs, situations, dynamics and demands of the environment and the values cultivated within it. Flexibility, which covers academic, pedagogical and administrative aspects, must be a condition of the university processes. Thanks to it, the University has the capacity to satisfy a principle of equity by welcoming the cultural, social, ethnic, and economic diversity of beliefs and intellectual interests of the members that form the university community.*

8. ***Management for Academic Improvement****. The University will strengthen an institutional culture that facilitates the improvement of academic activities and processes for decision-making that contribute to achieve academic excellence. This improvement must be carried out in a systematic, permanent, participative, integral and multidirectional manner among the different members of the academic community.*

The Article 8 of Chapter II of the same Agreement, establishes guidelines that define the educational objectives of the undergraduate programs (1):

> *Article 8. Definition and educational objectives of the undergraduate programs. In addition to the principles described in the Chapter I of this Agreement, the undergraduate curricular programs aim to develop knowledge, skills, practices, abilities, expertise, performance and general competences, typical of a knowledge area, and specific to a discipline or profession, in a way that allows a graduate to argue, synthesize, propose, create and innovate in their academic, social and professional performance and development.*

Additionally, the undergraduate programs must be flexibly structured, taking into account the Foundation, Disciplinary and Free Choice Components. The latter corresponds to at least 20% of the total credits of the Program. The Agreement establishes the special nature of the course Final Work Degree, therefore (1):

> *It permits students to strengthen, apply, employ and develop their research capacity, creativity and work discipline in the treatment of a specific problem, based on the knowledge and methods acquired during the development of the curricular program. The objective of this course is to promote autonomy in the performance of scientific, scientific-technical and creative work, typical of their discipline or profession.*

Another interested party in the educational process of Chemical Engineering professionals is the School of Engineering of the Bogota Campus. The following are the main purpose and the mission declared by the School (16):

The main objective of the School is to lead the construction of an inclusive, equitable and sustainable society through the integral education and scientific research so as to promote innovative solutions that have an impact on technology, society and economy.

The mission of the School is to educate engineers and researchers committed with the technological, economic and social development for the improvement and sustainable transformation of the country. This is achieved by collaborative, inclusive, responsible, ethic and inspirational work as an example of the leadership and entrepreneurship the members of the academic community of the School have.

The mission of the Department of Chemical and Environmental Engineering, as responsible for the resources of the Chemical Engineering Program, is described in the following functions:

- Promote excellence in the education of chemical engineers.
- Contribute to the definition of the structure of undergraduate and graduate curricular programs.
- Assimilate, produce and disseminate the knowledge required by the chemical industry.
- Interact and integrate with society, promoting the edification of citizens that are sensitive to national interests, free, creative, critical, respectful of democratic values, civil duties and Human Rights.
- Address the demand for services of the curricular programs of the School of Engineering.
- Develop relevant research and specialized consultancy with an interdisciplinary nature, focused on the solution of social issues at national and international level.

Likewise, considered as constituent, the Professional Council of Chemical Engineering of Colombia, created in the Law 18 of 1976 and its Regulatory Decree 371 of 1982, issues the licenses and professional cards of the Chemical Engineers of the country, monitors and controls the proper exercise of the profession, collaborates with the university and professional authorities, and supports the activities of labor unions and scientific and professional associations of Chemical Engineering. Some of its functions are:

- Issue the rules of professional ethics, aiming to improve the professional level of the Chemical Engineer, and set clearly and precisely the professionals' obligations to themselves, to their profession, to the country and to the national and universal community;
- Ensure compliance with the current Law and annul the license of those who do not comply with the precepts contained in the Code of Professional Ethics;
- Collaborate with the university and professional authorities in the study and establishment of the academic requirements and curriculum, aspiring to an optimal education of Chemical Engineering professionals;
- Cooperate with labor unions and scientific and professional associations of Chemical Engineering in the promotion and development of the profession and in the continuous improvement of the qualification and function of the Colombian Chemical Engineers, through high professional standards of ethics, education, knowledge, retribution and scientific and technological achievements;
- Present to the Ministry of National Education and other competent authorities the problems that arise on the illegal exercise of the profession and on the compatibility or incompatibility between the degrees conferred in Chemical Engineering and the actual levels of education or suitability of those who hold these degrees.

The needs conveyed by employers and graduates were incorporated in the first version of the Program Educational Project (17) and updated in 2019 out of surveys administered to 227 graduates of the program, graduated during the 2014-2018 period, and the External Advisory Committee (CAE, consisting of 18 employers and distinguished professionals).

The following is a summary of the answers provided in the above-mentioned surveys and in the study known as Characterization of the Professional Development of the Chemical Engineering in Colombia from 2015 to 2017. This study, applied by the CPIQ, was published in the first semester of 2019.

Results of the survey applied to the External Advisory Committee (CAE)

The CAE, comprised of professional experts from different professional field areas of Chemical Engineering, conceived a list of abilities and knowledge future engineers must develop during their studies. This information is shown in Table 1.

Table 1. Abilities chemical engineering professionals must have according to the members of the CAE of the Chemical Engineering Program (survey conducted in March, 2019).

ABILITY	CHARACTERISTICS
Effective communication	Presentation of written reports
	Presentation of projects and business ideas
	Confidence, certainty and assertiveness of their concepts and statements
	Sale of knowledge
Administrative skills	Financial Literacy
	Globalization of economic, political and social knowledge
	Leadership
	Planning, organization and programming
	Analysis and diagnosis of complex situations
	Priority analysis
	Decision Making
	Conflict resolution
	Personnel Management
	Results driven (economic, political)
Project design and management	Project planning, creation, management, monitoring and execution
	Total Productive Maintenance (TPM).
Process Integrity	Risk analysis
	Analysis and solution of operational problems
	Optimization
	Interdisciplinarity (work implications in all areas)
Ethical and professional responsibility	Risk analysis
	Analysis and solution of operational problems
	Optimization
	Interdisciplinarity (work implications in all areas)
	Selection of reliable information sources
Global Impact	Quantitative risk assessment (QRA)
	Safe design
	Occupational safety and health
	Safety and health at work (SH@W)
	Social and environmental impact
	Social and environmental responsibility
Modern technology tools	Use of new technologies
	Digital transformation of the industry
	Appropriate management of technologies and information sources

Research and Innovation	Research for improving competitiveness
	Research for development
	Innovation for sustainability
Real contact with the industry	Engineering implications in all areas
	Real size of plants and equipment.
	Greater work experience.

Source: Information collected from the survey applied to the External Advisory Committee members (CAE)

Additionally and according to the results of the survey applied, for 90% of the members of the CAE, it is important that professionals have the ability of acquiring and applying knowledge in consonance with emerging needs, adopting suitable learning strategies. For 70% of members, the following abilities are essential: to develop and conduct appropriate experimentation, to analyze and interpret data and to use engineering criteria for drawing conclusions. Figure 1 shows other results from the members of the CAE when assessing the importance of the present educational process results.

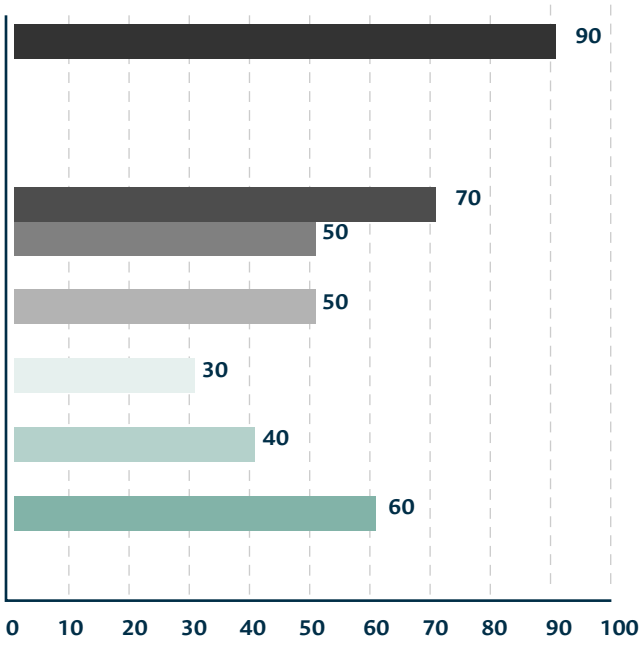


Figure 1. Percentage of members of the External Advisory Committee who consider the ability as important.
Source: information collected from the survey applied to the External Advisory Committee members

Percentage of members of the External Advisory Committee who consider the ability as important (%)

- Ability to identify, formulate and solve complex engineering problems by applying scientific, mathematical and engineering principles.
- Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- Ability to communicate effectively with a range of audiences.
- Ability to recognize ethicaland professional responsabilities in engineering situations and make informed judgments, wich must consider the impact of engineering solutions in global, economic, enviromental, and social contexts.
- Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- Ability to acquire and apply knowledge as needed, using appropriate learning strategies.
- Ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

Results of the survey applied to the graduates from the 2014-2018 period

During the first semester of 2019, another survey was applied to professionals graduated over the 2014-2018 period, having collected 227 answers. This survey inquired about performance sectors of the graduates during 2018, their personal development, most useful knowledge and abilities and which of those were not obtained during their academic years. Figure 2 gives the percentage of graduates distributed according to their performance in different sectors in 2018.

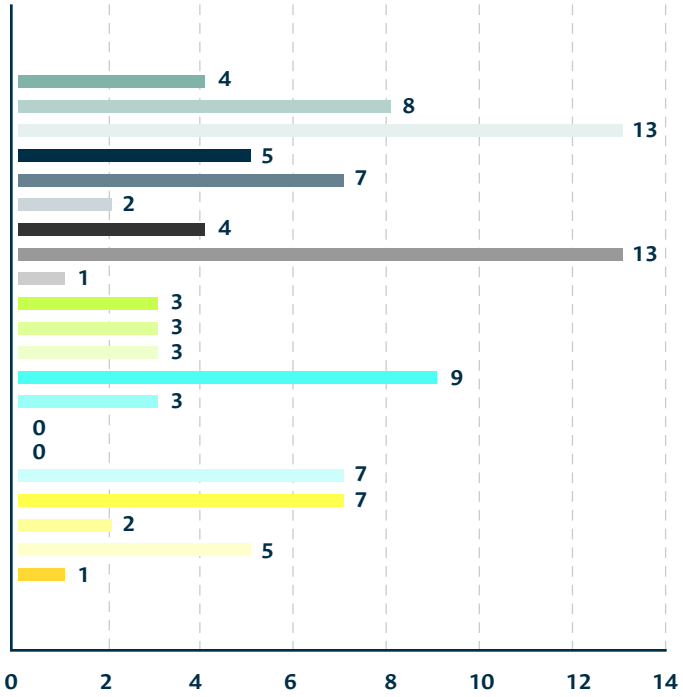


Figure 2. Percentage of graduates distributed according to their performance in different sectors in 2018.
Source: information collected from the survey applied to the graduates of the program.

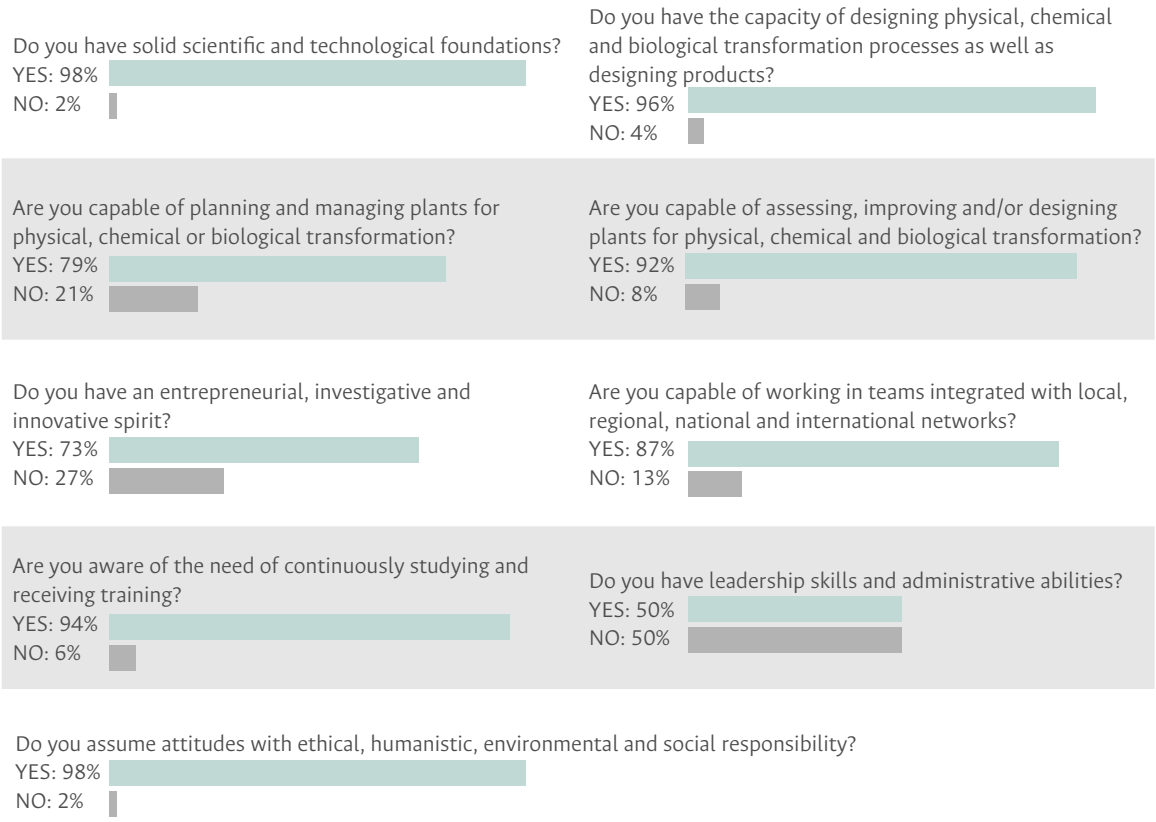
Graduates (%)

- Marketing - sales - commercial
- Unemployed
- Others
- Oil & gas - coke manufacturing - petroleum refining - mines and quarries
- Design and/or construction of plants and equipment
- Assembly - construction - maintenance of plants
- Environment - drinking water - basic sanitation - social management - human health
- Research - design and development of products or processes
- Manufacturing of chemical substances and products
- Manufacturing of non-metal mineral products - ceramics - glass - cement
- Manufacturing of personal care products - cosmetics - pharmaceuticals
- Manufacturing of rubber and plastic products - polymers
- Manufacturing of food and beverage products
- Manufacturing paper, cardboard and cellulose products
- Manufacturing of common metals and metal products
- Manufacturing of fibers and textile products
- Education
- Quality - Logistics - Telecommunications
- Automation - Instrumentation - Technological solutions for plants and laboratories
- Agro-industry - biofuels
- Organizational Management - Financial sector

The sectors in which a great percentage of graduates perform are: research, design and development of products and processes (13%), and design and construction of plants (7%). Meanwhile, the unemployment rates in the country were lower by the time the survey was applied, near a 10% (18).

Table 2 presents the results of the surveys regarding the questions about the graduates' professional development. These questions will be considered for defining the new Educational Objectives of the Program (OEP).

Table 2. Answers of the graduates from the 2014-2018 period to the statement: "concerning their professional development, the graduates of the program"



Finally, when graduates were asked about education results, they believed the most important one was the ability of identifying, formulating and solving complex engineering problems by applying scientific, mathematical and engineering principles. The second in rank was the ability of developing and conducting appropriate experimentation, the analysis and interpretation of data and drawing conclusions based on the engineering judgement. Finally, it was the ability of acquiring and applying appropriate learning strategies when necessary. Other results are depicted in Figure 3.

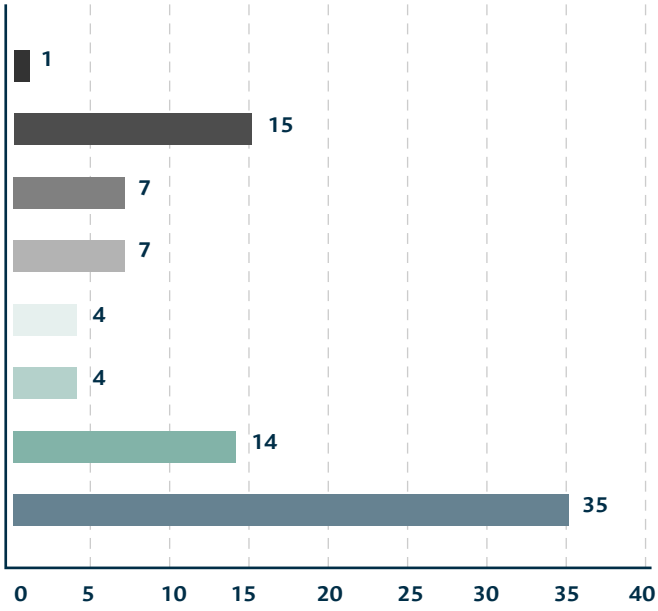


Figure 3. Graduates' most useful knowledge or ability acquired during their education process as chemical engineers in the Universidad Nacional de Colombia brought to their professional practice. Source: Information collected from the survey applied to the graduates of the Program.

Graduates (%)

- Other
- Ability to develop and conduct appropiate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- Ability to acquire an apply knowledge as needed, using appropiate learning strategies
- Ability to function effectively on a teamwhose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- Ability to recognize ethical and professional responsabilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and social contexts
- Ability to communicate effectively with a range of audiences
- Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- Ability to identity, formulate and solve complex engineering problems by applying scientific, mathematical and engineering principles

Characterization of the Professional Development of Chemical Engineering in Colombia from 2015 to 2017

In the first semester of 2019, the Professional Council of Chemical Engineering (CPIQ) presented the study of Characterization of the Professional Development of Chemical Engineering in Colombia 2015-2017. Some of the results will be used to define the new OEP since the CPIQ is one of the constituent members of the program. The overall objective of the study was to identify the academic and employment situation of chemical engineering graduates and enrolled students between 2015 to 2017.

The specific objectives were:

- Analyze predominant sectors, labor areas, salary ranges, job satisfaction and perception, and the time chemical engineers waited before starting their first job sector.
- Identify the highest level of education achieved by the chemical engineers and the types of graduate degrees highly preferred.
- Show associations among different variables of interest.
- Examine business relationships and models the chemical engineers currently manage.

Out of the general results, the following are worth mentioning:

- Although there are more female chemical engineers than male ones, the difference is less than 0.5.
- Most of them live in the country, a 95%, and out of this percentage, 38% lives in Bogota, the capital. 35% works in Bogota and in its area of influence.
- 25% of the chemical engineers who were surveyed, graduated from the Universidad Nacional de Colombia. 66% of the graduates wrote a thesis (Final Work Degree) as degree requirement, 16% coursed postgraduate subjects and 15% did an intership.
- Only 12% of the graduates from 2015 to 2017 are studying a master or doctorate program.
- 80% affirms to be proficient in other language and out of that percentage, 66% speaks English.
- 59% of chemical engineers has an employment as main activity, 27% is looking for a job, 11% is studying and only 2.4% took the initiative of starting a business. 89% is employee of a private company and the other 11% is part of the public sector.
- 70% of the graduates obtained a job in less than six months after graduating.

Figure 4 presents the performance sector of the graduates during the study period.

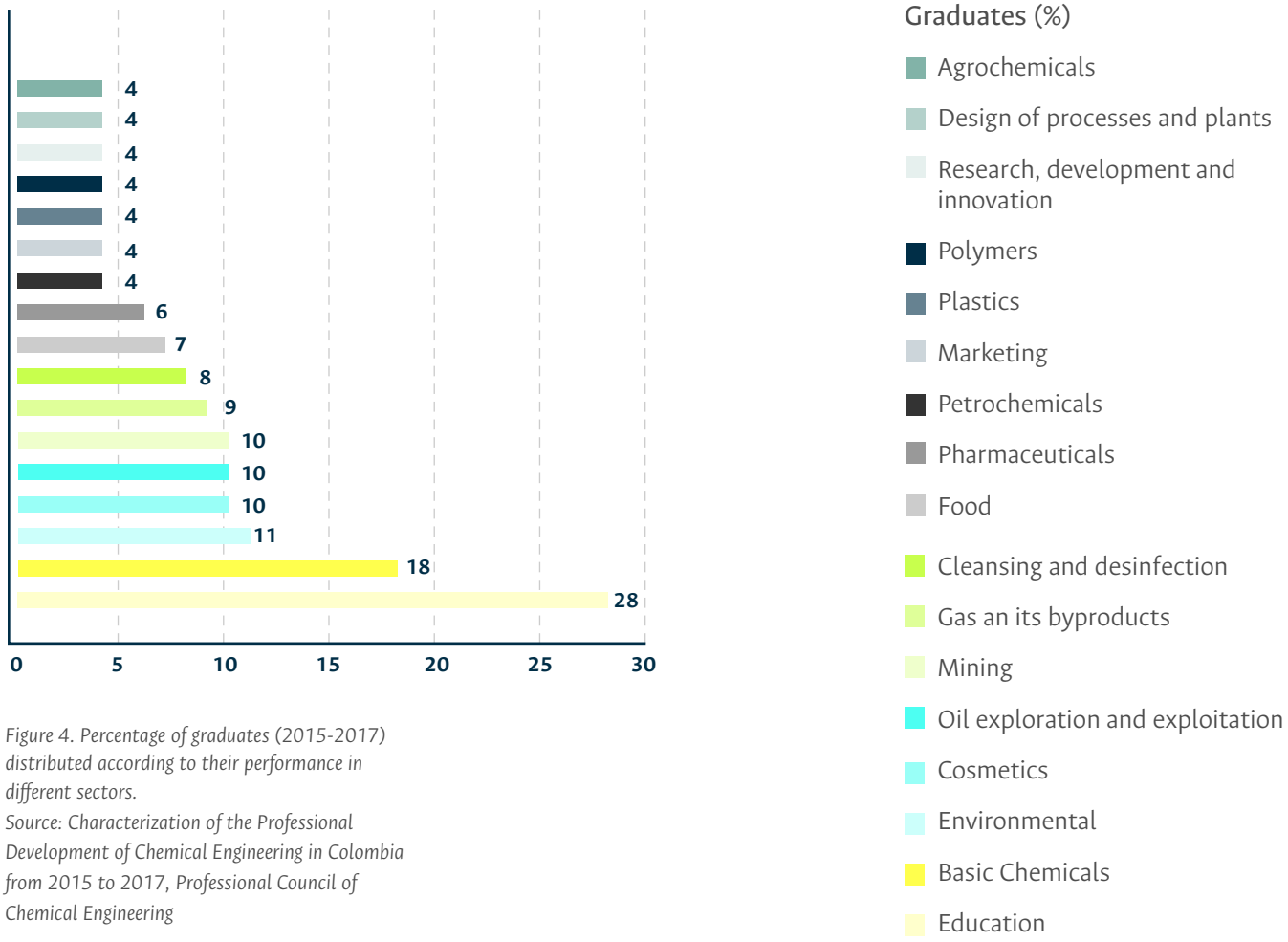


Figure 4. Percentage of graduates (2015-2017) distributed according to their performance in different sectors.
Source: Characterization of the Professional Development of Chemical Engineering in Colombia from 2015 to 2017, Professional Council of Chemical Engineering

Figures 2 and 4 show some clear differences between the performance sectors of the graduates of the University program and the performance sectors of those graduates from other universities. The performance in both food and education sectors is important for the two aforementioned groups, being 9 and 7% respectively for the graduates of the program in comparison to the 28% of the graduates of the country. Clearly, the professional field of the graduates of the program is focused on product design, processes, plants and equipment, and research and development with a 20%.

D. Curriculum Objectives

According to the information collected in the previous sections, the Educational Objectives of the Chemical Engineering Program are the following (19):

The graduates of the Chemical Engineering Program of the Universidad Nacional de Colombia, Bogotá Campus, will be integral citizens and professionals who:

- Will develop their careers applying their scientific, technological, humanistic and administrative knowledge, with social responsibility[2], to positively influence society.
- Will become leading professionals who design, operate, manage or market products, processes or industrial facilities, incorporing sustainability criteria.
- Will use the communication and teamwork skills developed during their educational process, as well as their commitment to life-long learning, to advance their careers.
- Will contribute to the well-being of their communities through their involvement in research, development and innovation projects.

Fields of action of the Chemical Engineer of the Universidad Nacional are[3]:

- Industrial: planning, supervision, design, assembly, control and operation of plants, and process equipment.
- Research: development of products and processes. Formulation and evaluation of basic and applied research projects. Study, management and adaptation of technological changes to improve production methods.
- Administrative: direction, organization, administration and management of industrial and financial companies. Preparation, technical and economic evaluation of industrial projects in enterprises or companies that provide engineering services (engineering firms and consultants).
- Teaching: development of academic, investigative and university specialized consultancy activities related to the areas of chemical engineering and related professions.
- Technical sales: technical support for the commercialization and use of plants, processes, chemical products and equipment.

E. Profile of Applicants

The Chemical Engineering Program of the National University, Bogota Campus, is aimed at high school graduates who have interest in creating industries or companies in the chemical sector or working in them; affinity for mathematics, chemistry, physics, biology, economics and administration; and willingness to apply knowledge in these areas to promote the development of products, processes and services that contribute to the economic growth and social equity of the country.

2 Citizens' ethical behavior with themselves and their environment, beyond the compliance of their legal duty. It is the awareness of how out decisions will have an affect on future society.

3 Law 18 of 1976 (3) defines and regulates the fields of action of the Chemical Engineering professional in Colombia.

F. Profile of Graduates

This Program Educational Project is based on the educational goals of the undergraduate students of the Universidad Nacional de Colombia, the history and development of its Chemical Engineering curriculum, the characteristics of current chemical engineering field and those of the near future, the capacities that the national and international actors related to the profession expect to find in chemical engineers and the fields of action of the chemical engineer. Consequently, it aims to educate professionals with the following profile:

The Chemical Engineer of the Universidad Nacional de Colombia, Bogota Campus is capable of designing, operating, administering and marketing products, processes or industrial facilities apart from having an effective communication and participation in research, development and innovation projects. Besides, these professionals, with a solid scientific, technological, humanistic and administrative education, have an effective impact on the country's development as a result of their leadership and social responsibility.

G. Student outcomes

The Student Outcomes (SO) imply the different abilities, skills and competences that the students of the program must have when graduating. For the Chemical Engineering Program, the following are the ones required:

- Identify, formulate and solve complex engineering problems by applying principles of engineering, science, and mathemathics.
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, environmental, social, and economic factors.
- Communicate effectively with a range of audiences.
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and social contexts.
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- Develop and conduct appropriate experimenttion, analyze and interpret data, and use engineering judgment to draw conclusions.
- Acquire and apply new knowledge as needed, using appropiate learning strategies.
- Participate in research, innovation and entrepreneurship projects.

Table 3 presents the relation between the OEP and the SO.

Table 3. Relation between the Educational Objectives and the Student Outcomes of the Chemical Engineering Program of the Universidad Nacional de Colombia, Bogota Campus.

EDUCATIONAL OBJECTIVE	STUDENT OUTCOMES
GRADUATES OF THE CHEMICAL ENGINEERING PROGRAM OF THE UNIVERSIDAD NACIONAL DE COLOMBIA, BOGOTA CAMPUS, WILL BE INTEGRAL CITIZENS AND PROFESSIONALS WHO:	**BY THE TIME OF THE GRADUATION, THE STUDENTS OF THE CHEMICAL ENGINEERING PROGRAM WILL HAVE AN ABILITY:**
Will develop their careers applying their scientific, technological, humanistic and administrative knowledge, with social responsibility , to positively influence society.	To identify, formulate and solve complex engineering problems by applying principles of engineering, science, and mathemathics. To recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and social contexts.
Will become leading professionals who design, operate, manage or market products, processes or industrial facilities, incorporing sustainability criteria.	To apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, environmental, social, and economic factors. To recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and social contexts. To develop and conduct appropriate experimenttion, analyze and interpret data, and use engineering judgment to draw conclusions.
Will use the communication and teamwork skills developed during their educational process, as well as their commitment to life-long learning, to advance their careers.	To communicate effectively with a range of audiences. To function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. To acquire and apply new knowledge as needed, using appropiate learning strategies.
Will contribute to the well-being of their communities through their involvement in research, development and innovation projects.	To participate in research, innovation and entrepreneurship projects.

H. Curriculum

The curriculum of the Chemical Engineering Program has a total of one hundred eighty (180) credits, distributed as follows:

- Foundation Component: Sixty-nine (69) credits required. The student must approve sixty-three (63) credits of compulsory courses and six (6) of electives.
- Disciplinary or Professional Education Component: Seventy-five (75) required credits. The student must approve sixty-six (66) credits of compulsory courses and nine (9) of elective.
- Free Choice Component: thirty-six (36) credits required, which correspond to 20% of the total credits of the curriculum

Tables 4 and 5 present the distribution of the compulsory and technical elective credits within thematic groups for each component of the curriculum.

Table 4. Distribution of the courses in the curriculum of Chemical Engineering. Foundation Component.

GROUP	COMPULSORY CREDITS	CREDITS FOR TECHNICAL ELECTIVES	TOTAL COMPULSORY CREDITS
Mathematics, Probability and Statistics	23	0	23
Chemistry and Biology	23	0	23
Physics	8	0	8
Economic and Administrative Sciences	6	3	9
Engineering Tools	3	3	6
Total	63	6	69

Table 5. Distribution of the courses in the curriculum of Chemical Engineering. Disciplinary Component.

GROUP	COMPULSORY CREDITS	CREDITS FOR TECHNICAL ELECTIVES	TOTAL COMPULSORY CREDITS
Thermodynamics	10	3	13
Unit Operations	20	0	20
Chemical and Biological Processes	15	3	18
Research and Innovation	18	0	18
Materials	0	3	3
Professional Context	3	0	3
Total	66	9	75

Table 6 shows the classification of the groups per knowledge area and its percentage regarding the total credits number.

Table 6. Classification according to knowledge area.

KNOWLEDGE AREA	GROUP	PERCENTAGE (%)	PERCENTAGE (%)
Basic Sciences and Mathematics	Chemistry and Biology	12.8	30.0
	Mathematics, Probability and Statistics	12.8	
	Physics	4.4	
Engineering Sciences	Basic Engineering Sciences	6.7	6.7
Applied Engineering	Thermodynamics	7.2	38.3
	Unit Operations	11.1	
	Chemical and Biological Processes	10.0	
	Research and Innovation	10.0	
Complementary Contents	Socio-humanistic Area and Complementary Topics	6.3	11.3
	Economics and Administration	5.0	
Free Choice (without including socio-humanistic areas and complementary topics)			13.7

Annex I shows the curriculum of the Chemical Engineering Program in detail. Table 7 shows that throughout the curriculum students must dedicate between 48 and 60 hours per week for their total academic activity, with an average of 54 hours. It can be interpreted as a daily work of 9 hours, 6 days a week.

The courses of the Free Choice Component can be taken in any academic period.

Table 7. Credits distribution per semester in the curriculum of the Chemical Engineering Program.

SEMESTER	FOUNDATION COMPONENT CREDITS	DISCIPLINARY COMPONENT CREDITS	FREE CHOICE CREDITS	TOTAL CREDITS PER SEMESTER	HOURS OF ACADEMIC ACTIVITIES PER WEEK
1	13	3	0	16	48
2	15	3	0	18	54
3	14	3	3	20	60
4	10	7	0	17	51
5	6	10	3	19	57
6	8	10	0	18	54
7	3	12	3	18	54
8	0	12	7	19	57
9	0	9	9	18	54
10	0	6	11	17	51

The credits, groups and subjects of the curriculum components are specified in Tables 8 and 9.

FOUNDATION COMPONENT

Table 8. Group: Mathematics, Probability and Statistics.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
1000004	Differential Calculus	4	YES	Basic Mathematics
1000005	Integral Calculus	4	YES	Differential Calculus
1000006	Calculus of Several Variables	4	YES	Integral Calculus Linear Algebra
1000007	Differential Equations	4	YES	Integral Calculus Linear Algebra
1000013	Fundamentals of Probability and Statistics	3	YES	Differential Calculus
1000003	Linear Algebra	4	YES	Differential Calculus

Table 9. Group: Physics.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
1000019	Fundamentals of Mechanics	4	YES	Differential Calculus
1000017	Fundamentals of Electricity and Magnetism	4	YES	Integral Calculus Fundamentals of Mechanics

Table 10. Group: Chemistry and Biology.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
1000025	Laboratory of Basic Techniques in Chemistry	3	YES	
1000024	Principles of Chemistry	3	YES	
1000026	Principles of Chemical Analysis	3	YES	Principles of Chemistry
1000027	Laboratory of Principles of Chemical Analysis	3	YES	Principles of Chemistry
1000028	Principles of Inorganic Chemistry	3	YES	Principles of Chemistry
1000030	Principles of Organic Chemistry	3	YES	Principles of Chemistry
1000010	Laboratory of Principles of Organic Chemistry	2	YES	Principles of Chemistry
1000025	Molecular and Cellular Biology	3	YES	

Table 11. Group: Economic and Administrative Sciences.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2015703	Engineering Economics	3	YES	Integral Calculus
2015702	Project Management and Administration	3	YES	Engineering Economics
2015698	Business Administration	3	NO	Engineering Economics
2016609	Industrial Safety	3	NO	Fundamentals of Electricity and Magnetism
2016741	Financial Management	3	NO	
2016610	Costing Systems	4	NO	
2015699	Market Administration	3	NO	
2016592	General Economics	3	NO	
2015695	Project Design, Management and Evaluation	3	NO	
2015705	Markets I	4	NO	
2016056	Decision Theory	4	NO	
2015700	Fundamentals of Financial Accounting	3	NO	
2015704	International Marketing	3	NO	
2015694	Labour Law	3	NO	

Table 12. Group: Engineering Tools.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2015734	Computer Programming	3	NO	
2015709	Oral and Written Communication	3	NO	
2015711	Basic Drawing	3	NO	
2015970	Numerical Methods	3	YES	Differential Equations

PROFESSIONAL EDUCATION COMPONENT

Table 13. Group: Thermodynamics.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2015741	Thermodynamics	3	YES	Differential Calculus Material Balance
2015740	Chemical Thermodynamics	3	YES	Thermodynamics Calculus of Several Variables
2015735	Workshop 1	1	YES	Thermodynamics Calculus of Several Variables
2015707	Energy Balance and Chemical Equilibrium	3	YES	Chemical Thermodynamics
2015739	Molecular Thermodynamics	3	NO	Chemical Thermodynamics
2015738	Thermodynamic Cycles	3	NO	Thermodynamics
1000038	Physical Chemistry II	3	NO	Energy Balance and Chemical Equilibrium

Table 14. Group: Unit Operations.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2015708	Mass Balance	3	YES	
2015714	Fluids	3	YES	Fundamentals of Mechanics Thermodynamics
2015726	Solids Handling	3	YES	Fluids
2015743	Heat Transfer	4	YES	Differential Equations Thermodynamics
2015744	Mass Transfer	3	YES	Differential Equations
2015736	Workshop 2	1	YES	Differential Equations
2015731	Separation Operations	3	YES	Mass Transfer Energy Balance and Chemical Equilibrium

Table 15. Group: Chemical and Biochemical Processes.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2015716	Chemical Reaction Engineering	3	YES	Energy Balance and Chemical Equilibrium
2015713	Design of Chemical and Biochemical Processes	3	YES	Energy Balance and Chemical Equilibrium
2015710	Processes Control	3	YES	Numerical Methods Chemical Reaction Engineering
2015712	Design of Plants and Equipment	3	YES	Separation Operations Design of Chemical and Biochemical Processes
2015715	Processes Engineering	3	YES	Design of Chemical and Biochemical Processes

2015729	Modelling and Simulation of Chemical Processes	3	NO	Mass Transfer Chemical Reaction Engineering
2015728	Modelling and Simulation of Biochemical Processes	3	NO	Mass Transfer Chemical Reaction Engineering

Table 16. Group: Research and Innovation.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2015721	Laboratory of Thermodynamic and Transport Properties	3	YES	Energy Balance and Chemical Equilibrium
2015719	Laboratory of Fluids, Solids and Heat Transfer	3	YES	Fluids Solids Handling Heat Transfer
2015720	Laboratory of Separation, Reaction and Control Operations	3	YES	Separation Operations Processes Control
2015737	Interdisciplinary Projects Workshop	3	YES	70% of the total credits required in the disciplinary or professional education component (53 credits)
2015289	Final Work Degree	6	NO	80% of the total credits required in the disciplinary or professional education component (60 credits)
2015290	Final Work Degree – Postgraduate Courses	6	NO	80% of the total credits required in the disciplinary or professional education component (60 credits)

Table 17. Group: Materials.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2015717	Introduction to Materials Engineering	3	NO	Chemical Thermodynamics 108 credits approved out of the total credits of the curriculum
2020326	New Topics in Chemical Engineering	3	NO	108 credits approved out of the total credits of the curriculum
1000040	Introduction to Materials Science	3	NO	108 credits approved out of the total credits of the curriculum
2015727	Materials	3	NO	Chemical Thermodynamics 108 credits approved of the total credits of the curriculum
2024929	Introduction to Polymer Materials Engineering	3	NO	108 credits approved of the total credits of the curriculum
2017348	Materials Technology	3	NO	
2017256	Materials Science and Engineering	3	NO	
2015598	Chemistry of Solids	3	NO	

Table 18. Group: Professional Context.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2015718	Introduction to Chemical Engineering	3	YES	

FREE CHOICE COMPONENT

Table 19. Group: Technical Electives.

CODE	NAME OF THE SUBJECT	CREDITS	COMPULSORY	PRE-REQUISITE(S)
2016762	Student Internship I	3	NO	
2016763	Student Internship II	6	NO	
2016764	Student Internship III	9	NO	
2025725	Colombia Practice I	3	NO	
2025726	Colombia Practice II	6	NO	
2025727	Colombia Practice III	9	NO	
2024647	Introduction to Biochemical Engineering	3	NO	
2024649	Microbiology and Biochemistry of Bioprocesses	3	NO	
2020324	Enzyme Engineering	4	NO	
2020323	Advanced Biochemical Engineering	4	NO	
2020327	Operations of Separation in Bioprocesses	4	NO	70% of the total credits of the curriculum
2014979	Design of Physicochemical and Biological Processes	4	NO	
2023122	Oil and Gas Engineering	4	NO	
2023549	Principles of Heterogeneous Catalysis	4	NO	
2020336	Catalytic Technology and Applications	4	NO	
2023572	Advanced Course in Fuel Chemistry	4	NO	
2020329	Polymerization Processes	4	NO	
2020338	Transformation of Polymers	4	NO	
2020339	Physicochemical Properties of Polymers	4	NO	
2020316	Biorefinery and Biorefining	4	NO	
2020315	Biodiesel and Oleochemistry	4	NO	
2024931	Bioethanol and Alcohol Chemistry	4	NO	
2022897	Energy and fuels	3	NO	Without the requirement of 70%
2020359	Environmental Catalysis	4	NO	
2014984	Integrated Management of Hazardous Waste	4	NO	
2015042	Soil Pollution	4	NO	
2015045	Engineering for Industrial Wastewater Treatment	4	NO	
2015032	Environmental Impact Assessment	4	NO	70% of the total credits of the curriculum
2015033	Environmental Management and Audit for Projects	4	NO	
2015034	Policy, Information and Environmental Management	4	NO	
2014981	Air Pollution	4	NO	
2015029	Stationary Sources of Air Pollution	4	NO	
2015041	Industrial Pollution Prevention	4	NO	
2015040	Green Chemistry and Industrial Ecology Tools	4	NO	

2015035	Water Quality	4	NO	
2014978	Environmental Context in Colombia	4	NO	
2015000	Integral Urban Solid Waste Management	4	NO	
2015017	Workshop: Case Studies I	4	NO	
2015018	Mathematical and Numerical Methods for Environmental Engineering	4	NO	
2015030	Mobile Source of Air Pollution	4	NO	
2015031	Air Quality Modelling	4	NO	
2015036	Water Quality Modelling	4	NO	
2015037	Water Purification Plants and Systems	4	NO	
2015039	Environmental Design of Processes	4	NO	
2015044	Landfill Engineering	4	NO	
2015047	Environmental Microbiology	4	NO	
2015051	Wastewater Treatment Plants and Systems	4	NO	70% of the total credits of the curriculum
2020317	Materials Characterization	4	NO	
2020318	Industrial Context in Colombia	4	NO	
2026490	Applied Electrochemistry Batteries and Fuel Cells	3	NO	
2027022	Talking about Chemical Engineering	3	NO	
2027153	Introduction to Statistical Thermodynamics	3	NO	
2020321	Transport Phenomena	4	NO	
2020337	Advanced Thermodynamics	4	NO	
2020333	Multicomponent Separations	4	NO	
2020330	Heterogeneous Processes	4	NO	
2020328	Process Optimization in Chemical Engineering	4	NO	
2020313	Reactor Analysis	4	NO	
2011393	Bioreactors and Bioseparation Design	4	NO	
2023580	Modern Chromatographic Techniques	4	NO	
2015525	Petroleum Geology	3	NO	Without the requirement of 70%
2023545	Introduction to Food Engineering	3	NO	
2022902	Introduction to Food Chemistry	2	NO	
2025441	Plant-based Food Science	4	NO	
2018407	Meat and Meat Products Science	4	NO	
2023542	Food Processing and Analysis 2	3	NO	
2019451	Food Processing	4	NO	
2019452	Technology for Plant-based Food	4	NO	70% of the total credits of the curriculum
2023540	Fruit and Vegetable Preservation	3	NO	
2018406	Food Biotechnology	4	NO	
2025402	Instrumental Analysis of Sensory Properties in Foods	4	NO	
2018404	Sensory Analysis	4	NO	
2023543	Meat Industry	3	NO	
2017100	Agro-industry of Dairy Products	3	NO	

The offer of technical electives can be annually reviewed and modified at the request of the Program Advisory Committee and the subsequent approval of the School Council. These modifications are made in order to improve the level of flexibility of the curriculum and the articulation with other curricula of the University.

The above mentioned modifications to the curriculum were validated through a School Council resolution, with previous approval of the Program Advisory Committee, the support of the National Directorate of Undergraduate Programs and the review from the Academic Vice-presidence.

English is the foreign language considered fundamental for the professional students' education of the Curricular Program of Chemical Engineering of the School of Engineering in the Bogota Campus. The accreditation of the 12 credits of the English language courses, completed and approved at the University or validated by proficiency, is a requirement for the degree. It is important to clarify that this number of credits is independent of the total amount of credits estimated for the curriculum program.

Students can complete a student internship using their free choice credits. The range of the internship number of credits will be from three to nine, depending on the required dedication and will be approved by the Program Advisory Committee, at the request of the student.

The sum of the students in-person and autonomous activities constitutes their total academic activity. Every 48 hours of academic activity per semester corresponds to one credit. Each academic semester is developed in 16 weeks

The objectives of each group of courses that comprise the curriculum are briefly described below:

Group of Professional Context

The course "Introduction to Chemical Engineering" is the only one of the Group of Professional Context. It is conceived as a course during the first semester, where students get in touch with multiple topics associated with Higher Education, the University, the School of Engineering, the Department of Chemical and Environmental Engineering, the Chemical Engineering Curriculum, the Profession and the Chemical Engineering Professional, among others.

Groups of Mathematics, Probability and Statistics, Physics, Chemistry and Biology

The courses of these groups aim to provide a solid background in mathematics, chemical sciences, physics and biology, which is necessary to address the courses of the Disciplinary and Free Choice Components. The students must approve seven (7) Chemistry courses, including three (3) laboratories, four (4) of Calculus, one (1) of Linear Algebra, one (1) of Probability and Statistics and one (1) of Biology.

Group of Engineering Tools

The courses of this group aim to provide students with some of the tools needed for their professional practice, including communication skills, computer programming, drawing and numerical methods.

Group of Economic and Administrative Sciences

The courses of this group aim to develop skills for the administration and economic evaluation of projects and processes, as well as of companies in which a chemical engineer can perform.

Group of Thermodynamics

The courses of this group aim to present the fundamental concepts of the laws of thermodynamics, the methods for predicting properties and the fundamentals of phase and chemical equilibria, essential for the chemical engineer to design equipment, processes and transformation plants.

Group of Unit Operations

The courses of this group aim to study and present the concepts of momentum, heat and mass transfer phenomena, with an appropriate balance between the phenomenological approach and the unit operation, with emphasis on the development of skills for the design of equipment frequently used in process plants.

Group of Chemical and Biochemical Processes

The courses of this group were conceived to integrate the knowledge of basic sciences and engineering through the design of processes, the design of equipment and plants, and process engineering. To structure this group, the approach of the engineering of process systems was used, considering the life cycle of a process plant.

Group of Materials

In this group, the courses aim to address issues related to the new paradigm of chemical engineering, product design through the characterization, design and performance prediction of polymer, biological and catalytic materials, among others, including the nanoscale.

Group of Technical Electives

This group includes the graduate courses of the study plan of 1994, courses of the Postgraduate Programs of the Curricular Area of Chemical and Environmental Engineering and any other that could be classified among the Free Choice component, according to the definition of Agreement 033 of 2007. In concordance with the flexibility of the curricula of the Universidad Nacional de Colombia, this group is conceived and offered for the student to develop and deepen their knowledge, particularly in the lines of research of the Postgraduate Programs of the Curricular Area. These lines coincide with the interests, experience, academic formation and developments of the academic community associated with the Program. These lines are:

- Catalytic and Petrochemical Processes
- Polymerization Processes and Materials
- Bioprocesses
- Biorefineries - Biofuels
- Basic Sanitation
- Solid and Hazardous Waste
- Air Quality
- Sustainable Processes

Although Food Engineering is not part of the Curricular Area of Chemical and Environmental Engineering, it can be considered as another research line since it has been subject of numerous research and specialized consultancy projects. These projects are developed through the Specialization and Master's programs in Food Science and Technology, usually with the support of the Institute of Food Science and Technology (ICTA by its Spanish acronym).

Based on these lines, the curricular routes presented in Table 20 were defined.

Table 20. Curricular Routes of the Chemical Engineering Program of the Universidad Nacional de Colombia, Bogota Campus.

CURRICULAR ROUTE	DESCRIPTION	CODE	COURSE
Catalytic Processes	The objective of this route is that students acquire the concepts to professionally perform or participate in research or innovation processes in topics related to catalysis, with emphasis on organic and heterogeneous catalysis Topics ranging from the design, preparation and characterization of catalysts to their application in industrial processes are addressed.	2023549	Principles of Heterogeneous Catalysis
		2020336	Catalytic Technology and Applications
Petrochemical Processes	The objective of this route is that students acquire the concepts to professionally perform or participate in research or innovation processes in topics related to the extraction, recovery, separation and transformation of oil and gas.	2024650	Petrochemistry and Refining
		2023122	Oil and Gas Engineering
		2020336	Catalytic Technology and Applications
Biotechnological Processes	The objective of this route is that students acquire the concepts to professionally perform or participate in research or innovation processes in topics related to biotechnological processes to obtain chemical products, waste and wastewater treatment, and apply these concepts in the agroindustrial, food, drink and health sectors.	2024647	Introduction to Biochemical Engineering
		2020324	Enzyme Engineering
		2020323	Advanced Biochemical Engineering
		2020327	Operations of Separation in Bioprocesses
		2011393	Bioreactors and Bioseparation Design
Biorefineries and Biofuels	The objective of this route is that students acquire the concepts to professionally perform or participate in research or innovation processes in topics related to biorefinery and biofuels, focusing on the design of chemical, biochemical and thermal processes found in this type of industrial facilities. Likewise, students will have an approach to the economic, social, technological and political contexts of biorefineries with emphasis on biofuels. Later, there will be a deepening on concepts about biorefineries based on vegetable oils, algae and ethanol.	2020316	Biorefinery and Biorefining
		2020315	Biodiesel and Oleochemistry
		2024931	Bioethanol and Alcohol Chemistry
Polymerization Processes	The objective of this route is that students acquire the concepts to professionally perform or participate in research or innovation processes in topics related to the characterization, production and transformation of polymers.	2020329	Polymerization Processes
		2024652	Transformation of Polymers
		2020339	Physicochemical Properties of Polymers
Environmental Engineering – Air Quality	The objective of this route is that students professionally perform or participate in research or innovation processes in topics related to the emissions of industrial processes, including their controls and effect on the environment, human health and climate.	2014978	Environmental Context in Colombia
		2014981	Air Pollution
		2015029	Stationary Sources of Air Pollution
		2015030	Mobile Source of Air Pollution
		2015031	Air Quality Modelling
Environmental Engineering – Water Quality	The objective of this route is that students acquire the concepts to professionally perform or participate in research or innovation processes in topics related to the treatment of industrial wastewater.	2014978	Environmental Context in Colombia
		2015028	Mathematical and Numerical Methods for Environmental Engineering
		2015036	Water Quality Modelling
		2015051	Wastewater Treatment Plants and Systems
		2020359	Environmental Catalysis
		2015035	Water Quality

Environmental Engineering – Solid and Hazardous Waste	The objective of this route is that students acquire the concepts to professionally perform or participate in research or innovation processes in topics related to segregation, recycling and industrial solid waste recovery.	2014978	Environmental Context in Colombia
		2014984	Integrated Management of Hazardous Waste
Materials	The objective of this route is that students acquire the concepts that allow them to initiate and deepen the knowledge required for the characterization, production and use of different materials with an approximation to the nano scale.	2015717	Introduction to Materials Engineering
		2015727	Materials
		2015598	Chemistry of Solids
Thermodynamics	The objective of this route is that students go in depth in topics related to thermodynamics, strengthen their knowledge obtained in compulsory subjects and broaden the spectrum of possibilities that thermodynamics offers for predicting material properties, chemical balance and phase equilibrium.	2015739	Molecular Thermodynamics
		2015738	Thermodynamic Cycles
		2020337	Advanced Thermodynamics
		2027153	Introduction to Statistical Thermodynamics
Analysis and Design of Reactors	The objective of this route is that students delve into topics related to the analysis and design of reactors with emphasis on transport phenomena: momentum, heat and mass present in this type of equipment. Likewise, there will be an approach to new kinetic models and to the study of real reactors.	2020321	Transport Phenomena
		2020330	Heterogeneous Processes
		2020313	Reactor Analysis
Process Simulation and Modelling	The objective of this route is that students go in depth in the knowledge of techniques, tools and methodologies for the modelling and simulation of processes, including marketing packages and software developed by themselves. Also, it presents the optimization of process modelling and simulation.	2015729	Modelling and Simulation of Chemical Processes
		2015728	Modelling and Simulation of Biochemical Processes
		2020328	Process Optimization in Chemical Engineering
Economics and Administration	The objective of this route is that students broaden their knowledge in economics and administration and develop even more management skills.	2015698	Business Administration
		2015695	Project Design, Management and Evaluation
		2015699	Market Administration
Food Engineering	The objective of this route is that students acquire the concepts to perform professionally or participate in research or innovation processes in topics related to food engineering, including its preservation, transformation and analysis.	2023545	Introduction to Food Engineering
		2026316	Science and Technology of Meat and Meat Products
		2026175	Emerging Technology for Food Industry
		2026910	Diary Science and Technology
Chemical Engineering –Sustainability in Chemical Processes	The objective of this route is that students acquire the concepts to professionally perform and participate in processes regarding the research and innovation of topics related to the prevention and mitigation of environmental impacts in the chemical industry.	2014978	Environmental Context in Colombia
		2015039	Environmental Design of Processes
		2015041	Industrial Pollution Prevention
		2015040	Green Chemistry and Industrial Ecology Tools
		2015017	Workshop: Case Studies I
Master's in Engineering – Chemical Engineering	The objective of this route is that students can advance in postgraduate education, specifically at a Master level. The student that follows this route can take credits of the main component of the Master in Engineering – Chemical Engineering as technical electives. Students must still course academic activities and 20 free choice credits. With these courses, the student will acquire advanced concepts in transport phenomena and thermodynamics and will have an overview of the chemical industry in Colombia.	2020321	Transport Phenomena
		2020318	Industrial Context in Colombia
		2020337	Advanced Thermodynamics
		2025427	Advanced Separation Processes
		2020333	Multicomponent Separations

Master's in Engineering – Environmental Engineering	The objective of this route is that students can advance in postgraduate education, specifically at a Master level. The student that follows this route can take compulsory credits of the main component of the Master in Engineering – Chemical Engineering as technical electives. Students must still course pending academic activities and 20 free choice credits. By taking these subjects, students will obtain basic concepts of physicochemical and biological processes around environmental engineering; learn and apply mathematical and numerical methods used for solving environmental engineering problems; and they will have an overview of the chemical industry in Colombia.	2014979	Dynamics in physicochemical and biological processes
		2014978	Environmental Context in Colombia
		2015028	Mathematical and Numerical Methods for Environmental Engineering

Group of Research and Innovation

The correspondent group comprises the laboratories of the disciplinary component, the Workshop of Interdisciplinary Projects and the Final Work Degree. The objective is that students perform —as members of a team in the first two (Laboratories and Workshop of Interdisciplinary Projects) and individually in the latter (Final Work Degree)— a work of research and critical analysis on properties, operations, processes or products that integrate different components of the curriculum. The scope, degree of responsibility and complexity of these works or projects depend on the position of the courses in the curriculum. Therefore, the ones with the greatest commitment and development are the Interdisciplinary Projects Workshop and the Final Work Degree.

I. Teaching methodologies and strategies

Without ignoring the diversity of courses and contents and, above all, the principle of academic freedom, the following is a brief description of the teaching methodologies, strategies and support systems of the Chemical Engineering Program of the Bogota Campus. This description follows the classification of the curriculum courses according to its modality.

Theoretical and theoretical-practical courses

Considering the characteristics of the courses of theoretical and theoretical-practical nature, the predominant methodology is the lecture. However, with the purpose of strengthening concepts and developing the proposed thematic content, complementary media are often used, e.g. exercises and classroom work, reading controls, teamwork oral presentations, seminars, elaboration of computational tools, use of elements of the virtual platform (Moodle) and visits to companies. These activities involve a direct input from students in their educational process and incorporate elements such as communication, bibliographical search, practicing a second language, exploration of methods and calculation tools and, frequently, teamwork.

Some of these courses, especially those of the group Design of Chemical and Biochemical Processes, are offered in modular scheme. With this, two or three professors develop the contents of the courses in established topics, according to their strengths in research and technological development, as well as to their professional and teaching experience. In some of these courses, the methodology is based on the development of projects, in which the student applies the acquired knowledge.

During the reform process of the curriculum, the professor of the Chemistry Department of the School of Sciences highlighted the impossibility of developing theoretical - practical courses due to the limited capacity of the laboratories. As a consequence, there are only two theoretical- practical

courses in the curriculum. These are offered by the Physics Department of the School of Sciences, Fundamentals of Mechanics and Fundamentals of Electricity and Magnetism, which are developed in three weekly sessions of two hours each: one session for laboratory practice, other for lectures and the final one for a workshop. The lectures are supported by demonstration experiments in the classroom. The Physics Department has sufficient resources to carry out the laboratory activities involved.

Practical courses

From the methodological point of view, the practical courses of the curriculum are divided into the group of Chemistry and Biology (comprised by the Laboratories of Basic Techniques in Chemistry, Principles of Chemical Analysis and Principles of Organic Chemistry) and the disciplinary component (namely, Laboratories of Thermodynamic and Transport Properties, Fluids, Solids and Heat Transfer, and Separation, Reaction and Control Operations).

The laboratory courses of the Chemical and Biology group are programmed for 24 to 32 students, which form teams of two people. Before each practice, students have to review and strengthen the concepts that allow them to understand and successfully perform each of the experiments, under the supervision of the professor. After completing the practice, they prepare the corresponding report, in which they exercise skills of presentation and analysis of results, generation of tables and figures, and formulation and writing of conclusions. Some practices are done through research projects of limited scope. Additionally, the professors propose reinforcement and revision activities (workshops, tasks and complementary readings).

The methodology of the Laboratories of the Disciplinary Component, located in the research and innovation group, aim to develop teamwork skills, strengthen communication competences and integrate economic, environmental and industrial safety aspects. The courses are composed of up to 12 students divided into teams of three or four members. The practices are carried out under the direction of the professor and, although they mostly use the resources offered by the Chemical Engineering Laboratory (LIQ), they also visit laboratories of different Departments and Institutes of the University, such as the Hydraulics Laboratory and the Mechanical and Electrical Engineering Laboratories, as well as the plant and the laboratories of the Food Technology and Science Institute (ICTA).

During the semester, two sessions of guided work for the elaboration of reports are performed. In these sessions, the professor assesses the teamwork strategy of each group and proposes corrective actions if needed.

Workshops

The curriculum includes three workshops that aim to integrate the knowledge and concepts developed in different stages of the education process. They are Workshop 1, Workshop 2 and the Interdisciplinary Projects Workshop, which are strategically positioned in the IV, VI and IX semesters, respectively.

The Workshops intend to be subjects that promote the integration of the knowledge that correspond with specific periods in the curriculum. Although each workshop has a particular methodology, all of them have in common the development of projects throughout the semester. These projects —in addition to the integration of knowledge and the promotion of skills such as the aforementioned teamwork and oral communication, promote the search for information with modern tools, synthesis and text writing, and the contextualization of Chemical Engineering at national and global levels.

Workshop 1 integrates knowledge about energy, and the student has an approach to knowledge of the country, through its conventional and alternative energy resources.

In Workshop 2, students are expected to delve the knowledge in regard to the identification of natural resources of the country, its needs and opportunities for development, and select a raw material to obtain a product that aggregates value, emphasizing on the innovation component.

The Interdisciplinary Projects Workshop is held in teams of students from approximately seven undergraduate programs of the School. It aims to find innovative solutions for problems of different kinds.

Student Internship

The flexible component of the curriculum allows students to carry out a Student Internship. This activity is conceived as an opportunity for students to acquire work experience during their education process. Students internship are also a possibility to build and strengthen links among the University and companies, which can be translated into internships or research, innovation and technological development projects. Students are under the supervision of a professor of the Program during the internship, besides being tutored by an employee of appropriate level designated by the company.

Final Work Degree

All the students must complete a Final Work Degree in any of the modalities established in order to meet the objective defined in the Agreement 033 of 2007 by the CSU (1):

> *Its objective is to promote autonomy in the realization of scientific, scientific-technical and creative works of their own discipline or profession. For planning the Final Work Degree, the undergraduate programs may include courses in the curriculum such as research seminars, academic practices and research or creation practices.*

The following are the modalities that apply for the realization of the Final Work Degree, which were defined in the aforementioned Agreement and approved for the curriculum of Chemical Engineering.

- Research work: participation in research projects and final project.
- Specialized consultancy practices: Participation in teaching-assistance programs, internships, entrepreneurship and social projects.
- Degree Option: Postgraduate courses.

All these modalities imply the supervision of a professor and have different objectives:

Through research projects, students create relations with the research groups of the University and begin their education as researchers, which will continue in postgraduate levels. The activities resulting from this modality must be consigned in a structured document.

Specialized consultancy practices allow students and the University to link with the productive sector or communities through the development of a specific project. The activities resulting from this modality must be consigned in a structured document.

Undergraduate students who take postgraduate courses begin their education process at this level and thus facilitate the transition to graduate programs, especially the Master's degree.

Complementary Contents

The complementary contents include courses from the socio-humanistic area, which are part of the Free Choice Component. These courses can be selected from many offered by the University, including the Institutional Lectures "Manuel Ancízar", "José Celestino Mutis", "Jorge Eliécer Gaitán", "Marta Traba" and "Gabriel García Márquez". This area also comprises the courses from the group of Economics and Business Administration.

Technical visits

The Technical Visits to companies in the chemical and related sectors of different regions of the country are a policy of the Program. The goal is that most of the students have this experience at least once during their degree. These visits have been systematically carried out since the late 1980s. Each semester, three of the following industrial regions of the country are scheduled to visit:

- Barranquilla and Cartagena
- Medellín and the Aburrá Valley
- Cali and Valle del Cauca
- Boyacá
- Coffee Region
- Bucaramanga and Barrancabermeja

To participate in this academic activity, students must elaborate pre-reports and reports related to the visits, which are evaluated by the professors of the Chemical and Biochemical Processes Unit. The grade obtained will be integrated to the evaluation of the correspondent course of the group of chemical and biochemical processes that the student be taking.

Leveling when entering the Program

The Rector's Office, through the Resolution 469 of April 3, 2009, regulated the classification, registration and qualification of students with the need of leveling in mathematics, reading and writing and foreign language proficiency. These regulations were modified one year later by the Resolution 037 of January 15, 2010.

The latter resolution highlights the essential nature of the leveling courses for an adequate insertion in the university and is defined as additional to the curriculum. The courses correspond basically to mathematics and writing and reading comprehension in Spanish and English. The National Directorate of Admissions and the Departments, Units or Centers related to these courses are responsible for the classification tests. Students who do not reach the level of proficiency must take leveling courses in basic mathematics and reading and writing comprehension In particular, the approval in basic mathematics determines the possibility of starting the courses of the Mathematics group which, in turn, are prerequisite of several courses of the Foundation and Professional Component.

As it was mentioned, in terms of Proficiency in English, the University requires the approval of 12 credits. In the first stage, a classification test allows ranking the students, according to their proficiency level, in one of the four levels established. Each level corresponds to a three-credits course. As a result, the students located in level 1 will have the 12-required credits pending, and the students who reach proficiency do not need to take English courses.

The Department of Foreign Languages offers the courses of each level in three modalities: semi-annual, virtual and intensive. Likewise, it conducts the proficiency exams and the homologation of external courses or exams that certificate the intermediate or B1 level of the student (these equivalences are given by International Examinations and their relationship with the Common European Framework of Reference for Languages and the Colombian Technical Standard NTC 5580 of 2007).

Evaluations and its grading

According to Agreement 008 of 2008 of the CSU,

> *the academic evaluation is made through tests that are programmed in each course or activity, in order to determine the achievement of the proposed objectives in the topics and sub-themes. The nature of the academic evaluations of the courses will be determined by their own nature and objectives. The academic evaluations may be: written, oral, practical or virtual. The number of evaluations in a course and its nature must be established in the respective program-calendar. There are three types of evaluations: ordinary, supplementary and validations. At least three ordinary evaluations must be carried out in each course, except for those whose program - course specifies it.*
>
> *In the Universidad Nacional de Colombia, the grades or scores of the courses will be numeric from zero point zero (0.0) to five point zero (5.0), in units and tenths. The minimum grade to approve undergraduate courses is three point zero (3.0). When the minimum attendance required in the program-course is not reached, the course will be graded with zero point zero (0.0). Professors are autonomous when grading the evaluations of their courses, but students will have the right to ask the professor for revision when they do not agree with the grade obtained.*

Student Assistance System

The Student Assistance System (20) is “an articulated set of policies, guidelines, actors, activities and academic and welfare means, based on the recognition of liberties, opportunities and individual differences, which supports and advises undergraduate and graduate students of the Universidad Nacional de Colombia in order to facilitate the adaptation, permanence and successful completion of their professional education”.

A fundamental aspect of the System is the process of academic companion provided to students by a group of professors selected for that purpose, under the name of academic tutors (21). These tutors have similar functions and characteristics to those from the previous figure of teachers as councillors. They are designated by the Basic Unit for Academic and Administrative Management (UBGAA) and must work for two hours weekly.

Additionally, they have the academic advice of the professors of the Department of Chemical and Environmental Engineering, as part of the work attached to classroom teaching. They use about one for every two hours of class to attend students, even if they are not enrolled in their courses.

J. Activities oriented towards the development of the abilities stated in the Student Outcomes

The way in which the abilities stated in the Student Outcomes, in the curriculum courses and the related activities developed, is described as follows:

The Foundation Component courses contribute meaningfully to students' scientific education, promoting the dialogue among different actors and teamwork. Laboratories and workshops are common activities in this Component. Scientific and technological education is a constant feature promoted through readings, presentations, questionnaires, workshops, assessments and projects. Teamwork is also fostered since there are activities that require students to organize groups in order to comply with class objectives within the period established by the professors.

The knowledge, foundation and generation of administrative skills are developed, firstly, in the courses of the Economic and Administrative Sciences group. Then, activities such as informative conferences, preliminary market studies, economic evaluations and planning and management of resources are carried out partially or collectively in disciplinary courses such as Introduction to Chemical Engineering, Chemical and Biochemical Process Design, Chemical Reaction Engineering, Laboratory of Separation, Reaction and Control Operations, Laboratory of Thermodynamic and Transport Properties, Solid Handling, Thermodynamics, Workshop 2 and Interdisciplinary Projects Workshop.

In these courses of the Disciplinary Component, activities aim to generate social responsibility in students, highlighting the social, ethical, economic and environmental commitment of Chemical Engineering and focusing highly on the development of environmental awareness. Additionally, some courses include projects where the social component is a decision criterion.

The capacity to create a company is developed in the courses Introduction to Chemical Engineering, Chemical Reactions Engineering and Business Management, Workshop 2, Interdisciplinary Projects Workshop and Final Work Degree, but also in extracurricular activities that promote entrepreneurship. In addition, the technical electives of the Free Choice Component address contents related to entrepreneurship and business creation. Students must develop blueprints and projects, and some conferences in this subject are offered by experts who belong to government entities, industry, unions and business incubators.

More recently, subjects of the flexible component such as Special Topics in Chemical Engineering, New Topics in Chemical Engineering and the Institutional Lecture for the Graduate are offered due to the great results of the strategy described in the previous paragraph. Consequently, they have fostered the development of administrative, management and humanistic skills since graduates and professionals with industrial expertise share their experiences with students.

As a distinguishing feature of students, leadership is promoted through the collaborative work students perform in institutional activities offered by the School and in Disciplinary Component courses such as: Energy Balance and Chemical Equilibrium, Laboratory of Properties of Thermodynamic and Transport, and the Laboratory of Separation, Reaction and Control Operations. With these activities, students have the opportunity to lead practices or specified exercises.

Research, technological development and innovation are abilities promoted in all the courses of the Disciplinary Component. They are developed through activities and projects that entail some characteristics associated with these abilities such as the research, identification and selection of scientific and technological information, as well as their interpretation and appropriation for solving problems with the freedom of choosing the most suitable solutions.

Courses such as Introduction to Engineering, Workshop I and II develop different topics with the objective of encouraging teamwork and communicative skills, consolidated and evaluated in courses of the group of Design of Chemical and Biochemical Processes. Teamwork and knowledge among students and the national and international community is encouraged since the first semesters. The creation or the incorporation into Work Groups may have academic, environmental, union, social, leisure or sportive objectives.

Designing and improving products and transformation processes is an ability developed throughout the curriculum. In the early stages, the recognition of the elements that contribute to designing is promoted with analysis activities focused basically on processes of physical transformation. Gradually, chemical and biological transformations are introduced and, in the last semesters, the design of chemical and biochemical processes and plants is incorporated, achieving the ability to develop basic designs of processes.

K. Resources

The Program Educational Project of the Chemical Engineering degree of the Universidad Nacional de Colombia, Bogota Campus is under the responsibility of the Curricular Area and the Department of Chemical and Environmental Engineering which are part of the Engineering School of the Bogota Campus of the Universidad Nacional de Colombia.

Article 11 of the General Statute (22) establishes that the Government of the Universidad Nacional de Colombia is constituted by:

- Superior University Council
- Presidence
- Academic Council
- Campus Council
- Vice-Presidents
- The National Financial and Administrative Manager
- Directorate of Campus of National Presence
- The School Councils
- Deans
- Directors of Research Institutes and Centers
- Department Directors, Directors of Curricular Programs and other authorities, bodies and forms of organization established in accordance with the provisions of this Statute

In turn, Article 12 of the General Statute (22) establishes the levels of management and the academic and administrative organization, as follows:

National level

- Superior University Council
- Presidence
- Academic Council
- Academic, General and Research Vice-President's Offices and their divisions
- National Financial and Administrative Management and its divisions
- General Secretariat and its divisions
- Committee of Vice-Presidents

Figure 5 shows a simplified flowchart of the National level of the University.

Campus Level

- Campus Council
- Campus Vice-President's Office its divisions
- Campus Secretariat and its divisions
- Campus Research Institutes
- Campus Centers
- Administrative Academic Committee of the National Presence Campus

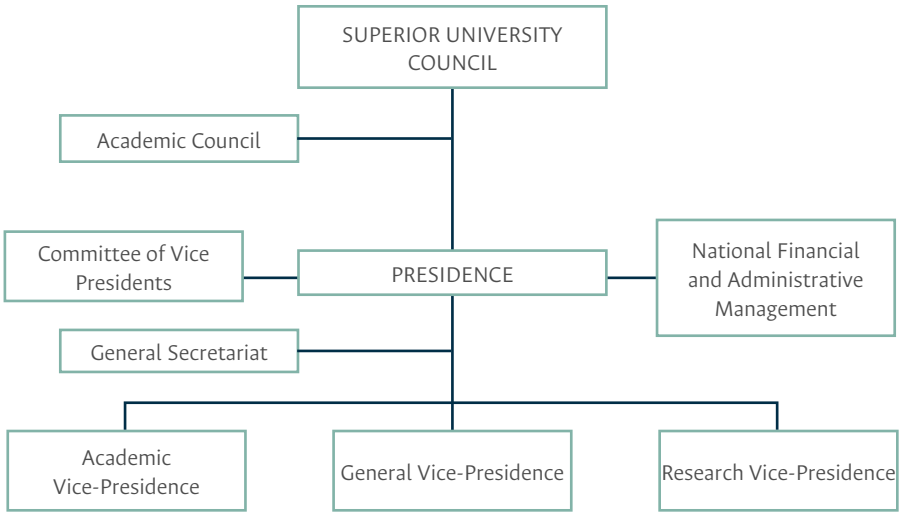


Figure 5. Simplified flowchart of the Universidad Nacional de Colombia, National level.

The simplified Flowchart of the Campus level of the University is depicted in Figure 5 and the School level flowchart in Figure 7.

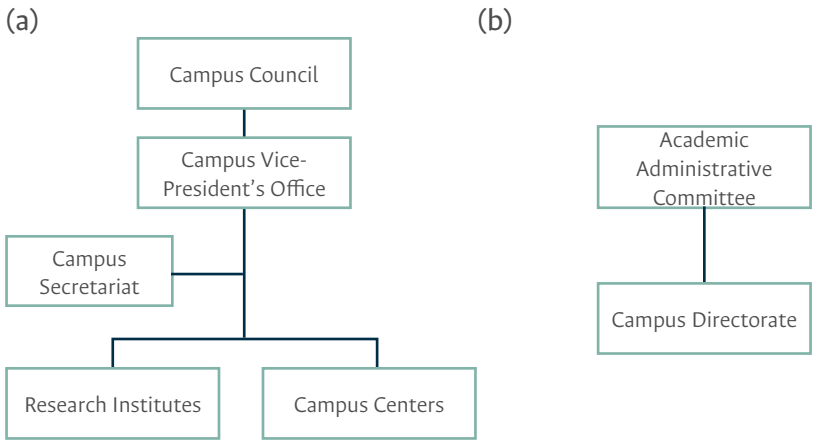


Figure 6. Simplified Flowchart of the Universidad Nacional de Colombia. (a) Campus Level. b) National presence, Campus Level.

The Department of Chemical and Environmental Engineering has the following administrative structure:

- Department Director
- Department Committee
- Unit Coordinators: Thermodynamics, Unit Operations and Chemical and Biochemical Processes
- Head of Laboratory of Chemical Engineering

The Curricular Area of Chemical and Environmental Engineering has the following administrative structure:

- Area Director
- Program Committee
- Program Coordinators (Chemical Engineering Undergraduate Program, Graduate Programs of Chemical Engineering and Environmental Engineering)

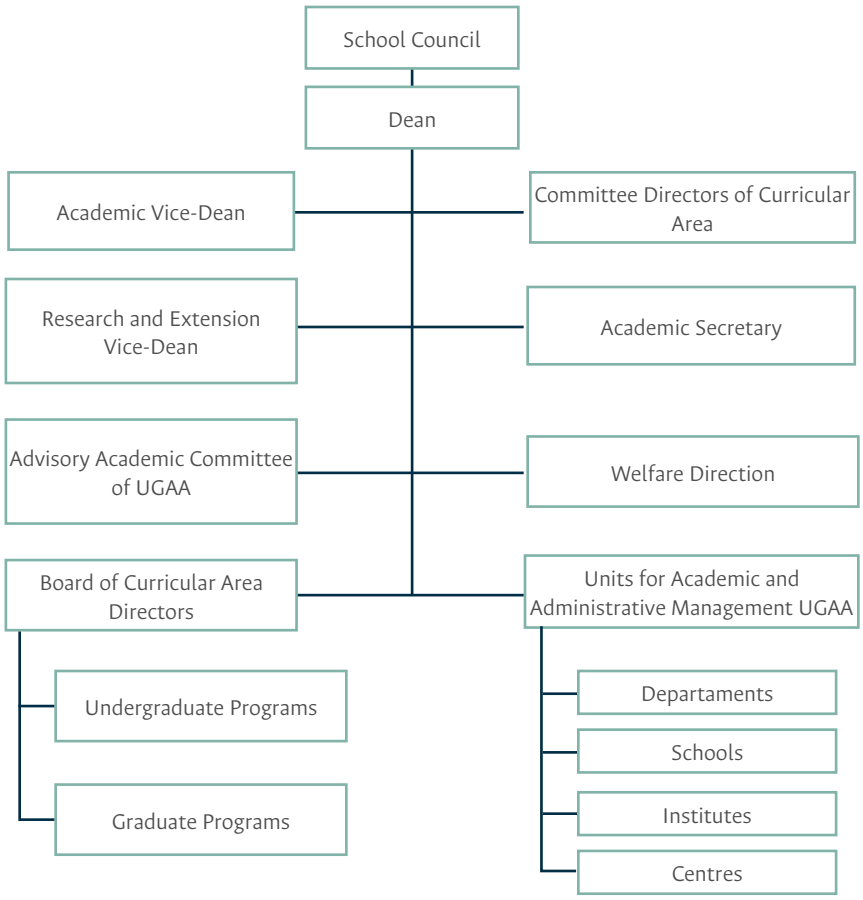


Figure 7. Simplified Flowchart of the Universidad Nacional de Colombia, School Level.

The Universidad Nacional de Colombia is the institution of higher education with the greatest physical infrastructure in the country with an area of almost 2.5 million m², distributed within its nine campuses. Among the approximate 600.000 m² built for academic activities, around 70% is part of the Bogota Campus. The university has academic support systems such as libraries, laboratories and computing resources.

The Universidad Nacional has 667 laboratories. 448 of them are located at the Bogota Campus and 58 of them are part of the School of Engineering (23). Of the latter, 56 are available for teaching practices, 9 exclusively for this matter and the remaining are used for the rest of the mission activities.

For the development of the PEP, the Chemical Engineering Program of the Bogota Campus has specifically the following resources:

Professors

The faculty staff associated to the program corresponds to the professors of the Chemical and Environmental Engineering. This staff has 39 professors, 92% of them working full time or with exclusive dedication which represents 40 and 48 weekly working hours respectively. Besides, it is necessary to bear in mind that the professors of the five departments of the School of Engineering, the departments of Mathematics, Statistics, Chemistry, Biology and Physics of the School of Sciences, and the other Departments and Institutes of the University teach Free Choice Component courses. Additionally, the staff is integrated by associate professors hired every semester and postgraduate students as assistant professors (frequently 7 or 8 respectively).

Infrastructure

The physical infrastructure of the Bogota Campus comprises the University City, the Jorge Eliécer Gaitán Center, the San Agustín Cloister and the Marengo Agricultural Center. The University City, whose construction began in 1936, has 125 buildings, 17 of them have been declared Cultural Patrimony of the Nation.

The physical infrastructure of the School of Engineering of the Bogota Campus for academic activities consists of the following buildings:

- 214: Antonio Nariño Building
- 401: Insignia Building - Julio Garavito Armero
- 406: Institute of Specialized Consultancy and Research, IEI
- 407: Building of Postgraduate in Materials
- 408: Laboratory of Hydraulic Tests
- 409: Hydraulic Laboratory
- 411: Electrical and Mechanical Engineering Laboratories
- 412: Chemical Engineering Laboratory
- 421: Camilo Torres Building – Block 5
- 453: Engineering Classroom Building
- 454: Science and Technology Building

The classrooms, auditoriums and laboratories, where the courses and other activities of the Chemical Engineering Program are developed, are mainly located in the Engineering buildings, the Engineering Classrooms, the Science and Technology Building, Chemistry Building, Hydraulic Laboratory, Electrical and Mechanical Engineering Laboratories, and the Chemical Engineering Laboratory.

The Department of Chemical and Environmental Engineering has at its disposal and for exclusive use:

- Six classrooms at the 453 building, 40 m² each, for a total of 240.
- A 12.9 m² classroom for 10 students and another 21.5 m² classroom for 15 students in the 412 building.

A brief description of each building, where most of academic activities of the program are developed, is presented below:

Insignia Building - Julio Garavito Armero

The 401 building was reopened in 2014 after a thorough renovation. There are three floors and a cafeteria at the back of the building. It has 10 classrooms for 36 students each and other five for 60 students each; three computer rooms with a capacity for 54 people each. Also, it has two studio rooms for 70 people each, and there are other two additional rooms available for postgraduate students of the School. It has two auditoriums with a capacity for 118 people each.

Engineering Classroom Building

Building 453 has four levels and is primarily intended for classrooms and professors' offices. It has 32 classrooms and three lecture halls (one for 160 people and two for 150 people each). As it was mentioned, six of these classrooms are used for teaching the majority of the courses of Chemical Engineering, all the of them equipped with audiovisual media. This building also holds the Five Boards of the Departments of the School.

Science and Technology Building

Building 454 was inaugurated in 2008. It has four floors and a terrace with spaces for the students and professors use. This environment facilitates small work meetings. There is also a operating restaurant. One of the three wings that form the building has 14 classrooms for 20 students each, equipped with overhead projector and an interactive board, two video conference rooms, with capacity for 20 people, and four classrooms with 45 computers each. The auditorium of this building has a capacity for 247 people.

Laboratory of Chemical Engineering

The Chemical Engineering Laboratory (LIQ) (Building 412) has a built area of 3,200 m², on a plot of 2,030 m². The first floor has the specialized laboratories: Pilot Plant (1000 m²), Catalysis (184 m²), Lubricants (55 m²), Instrumental Analysis (66 m²), Polymers (44 m²), Thermodynamic (102 m²), Bio-processes (30 m²), extended with a mezzanine (72 m²). Likewise, it has the Computer Room (46 m²), two rooms for reagents and materials, two sanitary toilet blocks and another room for general services. On the second floor, there are seven professors' offices, a computer room, two classrooms, a room for graduate students (43 m²), the head's office (which includes the secretary's office, a meeting space and a monitor office), a kitchen with two bathrooms, plus two terraces, with areas of 232 and 76 m². On the third level there is another terrace of 435 m².

The northern side of the building has the Industrial Services areas formed by: a general patio (90 m²), where the underground process water storage tank, its pumping systems and the room for chemicals storage are located; a boiler room (78 m²); and a storage room for maintenance materials, where the compressed air systems (16 m²) are located. In addition, the office for the plant operators and the tools room is located between the pilot plant and the boiler room. Above these spaces there is terrace of 55 m².

Moreover, for the Chemistry, Physics and Biology courses, the Program receives the services of the Laboratories of the School of Sciences. Likewise, the Mechanical Engineering Laboratories are used for heat transfer practices; the Laboratories of Hydraulics for fluid handling practices; the Laboratories of the Institute of Food Science and Technology (ICTA) for free choice subjects related to the area of Food Engineering and of some courses of Laboratory and Workshops; and the Laboratories of the Biotechnology Institute for practices of some of the subjects related to the area of Biotechnology and Bioprocesses, among others.

Another important resource in Laboratories for Research and Teaching is the National System of Laboratories of the University. The Interschools Laboratories that are part of this system are:

- X-Ray Fluorescence Laboratory
- Electron Microscopy Laboratory
- Optical Microscopy Laboratory
- Nuclear Magnetic Resonance Laboratory
- Mechanical Testing Laboratory
- Liquid Chromatography Laboratory
- X-Ray Diffraction Laboratory

Support for teaching

For the development of the tasks of their function, professors of the University have the support of administrative, general services and security staff, as well as operators for the laboratories.

The units of national or campus level that support teaching, research and specialized consultancy are:

- National Directorate of Undergraduate Programs.
- Research Division of the Bogota Campus, which supports the processing of research projects financed by the University, and provides support for the participation in calls funded by the Ministry of Science and by other external entities.
- National Directorate of Academic Innovation (DNIA) that analyzes, designs, implements and evaluates technological strategies and tools that promote the use and appropriation of information and communications technologies (ICT). Besides, it develops proposals and coordinates mechanisms for strengthening the teaching-learning processes at different levels and academic programs. Some of its services include: Moodle Virtual Campus, reservation of ICT rooms, ICT training, virtual education solutions and virtual laboratory for dynamic systems.
- Transportation Section that facilitates external academic activities. For instance, there are some technical visits to three regions of the country that last one week and are scheduled every semester. In each of them, students visit almost 8 companies of different industrial sectors. Also, this section supports short visits to nearby companies.
- National Directorate of Information and Communications (DNIC) designs and formulates policies and plans strategies regarding Information and Communication Technologies.

The support units for teaching, research and specialized consultancy at the School of Engineering are:

- Academic Vice-Dean
- Research and Extension Vice-Dean
- Administrative Unit
- Academic Secretary

Likewise, professors of the Department of Chemical and Environmental Engineering have the collaboration of:

- Three secretaries in the Direction of the Department, the Area Board and the Directorate of the Chemical Engineering Laboratory, and
- Five assistants in the Chemical Engineering Laboratory.

Libraries

Access to physical and virtual bibliographic material through libraries, newspaper archives and databases is fundamental for academic education. In the Universidad Nacional de Colombia, these resources are the responsibility of the National Library Directorate (DNBB), which develops and coordinates the National Library System –SINAB (http://www.bibliotecas.unal.edu.co/). Users have remote access to catalogs, databases, online newspapers, books and digital magazines and the University's Digital Library, as well as to the collections of other libraries and other universities. It is also possible to obtain documents by bibliographic exchange with the campuses and with other national and international institutions.

The University has a complete system of newspaper libraries and following the worldwide trend in terms of the transition from paper to electronic media for information access, it has databases, e-books, and other documents in packages of electronic contents, available on the SINAB portal https://bibliotecas.unal.edu.co/. It also has a bibliographical collection of around 1,500.000 volumes, 1,236.833 of which are at the Bogota Campus. The National Library System (SINAB) has 22 libraries properly equipped to offer students a suitable service in all the campuses. 9 of them are located in buildings exclusively constructed for this purpose.

There are 11 libraries in the Bogota Campus whose characteristics go hand in hand with the development of the mission activities. The number of computers and reading places per student substantially increased with the remodelling of the Gabriel García Márquez Library (Central Library), and with the new opening of the Science and Technology Library and the Central Computer Room. The bibliographic sources about contents of the Chemical Engineering Program are available mainly at the Central, and Science and Technology libraries. Their physical infrastructure is described in Tables 21 and 22.

Table 21. Data sheet of the Science and Technology Library (24).

ITEM	NUMBER	ITEM	NUMBER
Reading places at the table	232	Auditoriums	1
Group work cabins	54	Professors' offices	1
Computers for users service	295	Lockers	672
Area		2,500 m²	

Table 22.Data sheet of the Gabriel García Márquez Library (Central Library) (24).

ITEM	NUMBER	ITEM	NUMBER
Area (m²)	10,255	Workstations for people with disabilities different from the visual one	12
Books	312,843	Computers for users service	110
Individual reading points	90	Spaces in the Training Room	20
Reading places at the table	408	Media-library	1
Group work cabins	64	Training rooms	1
Computer workstations for people with visual impairments	12	Music rooms	1
Individual workstations for people with visual impairments	2	Lockers	456

Table 23 presents the electronic resources that contain information about Chemical Engineering available on the website https://bibliotecas.unal.edu.co/.

Table 23. Electronic Resources for the Chemical Engineering Program distributed according to their format (24).

ELECTRONIC RESOURCES ACCORDING TO THEIR FORMAT	TOTAL
Books	165
Journals	164
Reports	60
Thesis	724
Total	1113

Students can access to the bibliography cataloge from the 110 computer terminals in the Central Library, 295 in the Science and Technology Library, 48 in the Newspaper Archive, or from any computer in and outside the Campus by using the web portal https://bibliotecas.unal.edu.co/ which facilitates the search for the existing material, its availability and reservation.

The bibliography borrowing service is useful since it helps locating and exchanging journal articles, books chapters and other materials within the university campuses and other national or international institutions. There are certain agreements established with other institutions to provide more favorable services to the university community. The networks and library systems procured are:

- International Federation of Libraries Associations –IFLA
- American Libraries Association –ALA
- Iberoamerican Science & Technology Education Consortium – Istec
- Colombian Network of University Libraries (Red Colombiana de Bibliotecas Universitarias) – RCBU
- Information Network for Agricultural Science and Technology (Red de Información de Ciencia y Tecnología Agrícola)
- Biblioteca Digital Andina Project
- Ex Libris Users of Colombia
- Regional Networks: high-speed academic networks, library committees of RENATA network (National Academic Network of Advanced Technology): RUMBO (Bogotá), RUAV (Palmira), RADAR (Manizales)
- Other networks: G8, Servinfo (Medellín)

The Universidad Nacional Digital Library contains:

- The University Repository that administrates, preserves and disseminates the monographic works produced in the University throughout its history, including books, work degrees, thesis, professors works, among others. Table 24 presents a summary of the documents that include information for the Chemical Engineering Degree Program.

Table 24. Documents with information for the Chemical Engineering Program available at the University Repository (24).

BIBLIOGRAPHIC RESOURCES IN THE UNIVERSITY REPOSITORY	TOTAL
Articles	33109
Work documents	1612
Papers	48
Thesis	162
Total	34931

- The UN journal portal, that administrates, preserves and disseminates not only the academic journals of the Universidad Nacional de Colombia but also those indexed in Publindex or other international index.
- Data Bases that contain bibliographic resources with academic information of many knowledge areas for supporting research, teaching and specialized consultancy of the Universidad Nacional de Colombia. Table 25 makes reference to some of the SINAB data bases with content about the Multidisciplinary and the Science and Technology Areas.

Table 25. SINAB data bases of the Multidisciplinary and the Science and Technology Areas (24).

MULTIDISCIPLINARY	CIENCIA Y TECNOLOGÍA
Academic Search Complete Doaj - Directory of Open Access Journals	Georef
E-Book Gale Virtual Reference Library	ASTM Standards and Engineering Digital Library
Jstor Colombian Technical Standards and Certification	Alysiinae (Hymenoptera: Braconidae) from Colombia
Oxford Scholarship Online Project Muse	Illustrated cataloge of the Cicadellidae in Colombia
REDALYC Scielo - Scientific Electronic Library Online Science Direct	Scientific Collections of the Natural Sciences Institute
Springer Journal Springer-Books	The Reptile Database (Colombia)
Taylor & Francis Wiley Online Library Nature.com	Suasie - Camino del Sol. Guide of Orb-weaver spiders of the Chingaza Natural National Park

- The Colombian Digital Library that compiles and publishes in digital format the main work contributions to the cultural development of the country throughout its history.

Computing resources for students

The School of Engineering provides computer rooms for students' use and the following is their description, classified by their distribution inside the buildings.

Science and Technology Building – Luis Carlos Sarmiento Angulo

This building has 475 computers with Internet access, 180 of them distributed in four classrooms and other 295 are found in the Science and Technology Library.

Insignia Building - Julio Garavito Armero

It has 162 computers with Internet access distributed in three computing science rooms with 54 computers each. Besides, it has four spaces with ports for wired connection service and battery recharge.

Institute of Specialized consultancy and Research- IEI

The IEI graduates room has 21 computes at the service of graduate students.

Engineering Classroom Building

Building 453 has 95 computers distributed as follows: 24 in the Computer Laboratory, 24 in the Networking and Communications Laboratory, 21 in the Data Bases and Programming Laboratory, 20 in the Linux Room and 30 in the Graduates Room.

Central Computer Room

The Central Computer Room has 370 computers distributed in three rooms.

Table 26 shows the list of computer rooms and software available in the buildings of the School of Engineering at the service of students of the Program.

Table 26. Computer rooms and software available in the School of Engineering at the service of the students of the Program.

BUILDING	ROOM	NUMBER OF COMPUTERS	SOFTWARE AVAILABLE
453 - Engineering Classrooms	119 - Computer Laboratory	24	Netbeans, Eclipse C++, Eclipse Java, Dev Cpp, Proyect 2013, Scilab, QtOctave, Bizagi Modeler, 7-Zip, Code-blocks.
453 - Engineering Classrooms	209 - Networking and Communications Laboratory	24	Configmaker, Packet tracer, Wireschark
453 - Engineering Classrooms	203 - Data Bases and Programming Laboratory	21	Net Beans 8.0.2, Eclipse C++ -JDK, 7-Zip File Manager, Flexsim, Arena, Scilab 5.5.1, Bizagi Studio, Bizagi process, Ethereal, Java, Adobe reader, SQL Developer, Sybase, Oracle, MySQL, R-Studio, Weka 3.7
453 - Engineering Classrooms	205 - Linux Room	20	Free Software
453 - Engineering Classrooms	224 - Graduates Room	30	Scilab, Octave Workshop, Latex, GIMP, R, JabRef
406 - IEI Building	104 - IEI Graduates Room	21	Autocad 2007, Scilab, Dev C++
411 - Electro-Mechanical Laboratory	104B - Users Room	12	Proteus, Xilinx, Matlab, Labview

Source: Coordination of the Computer Rooms of the School

Laboratory of Chemical Engineering

In the Laboratory of Chemical Engineering there are two computer rooms and their resources are described as follows:

Room for analysis and process design

It is used for the Modelling and Simulations of Chemical and Biochemical Processes subject. The software installed on the computers are:

Aspen Engineering Suite V10.0®

Ansys 13.0 ®

Superpro Designer V 8.5®

Bryan Research & Engineering®

AVEVA V 1.2.0 ®.

Table 27 shows the equipment of this room. It is important to mention that between 2019 and 2020 all the community members have access to the Matlab® license.

Table 27. Computer equipment in the Room for Analysis and Design of Processes of LIQ.

NUMBER	CHARACTERISTICS	SOFTWARE AVAILABLE
15	HP M645-SP6001L, Intel Core i7 8th generation CPU M350@ 1.80 GHz, RAM 8.00 GB	Aspen Engineering Suite V10.0® y V8.4®, Ansys 13.0®, Superpro Designer V 8.5®, Bryan Research & Engineering®, AVEVA V1.2.0, Scilab, VMGSim
15	ASUS, Intel i7, RAM 8GB, 2.0 GHz 4MB, Hard Disk 1TB. External Graphics Card NVIDIA N15V-GM.	

Source: Coordination of the Analysis and Process Design Room

Computer room

It is utilized for the collection and processing of the data provided by the process control practices. Besides, it offers the service to borrow thesis, specialized journals in Chemical and Environmental Engineering, becoming a center for documentation. Table 28 presents the equipment and software available there.

Table 28. Equipment in the Computer Room for Analysis and Design of Processes.

NUMBER	CHARACTERISTICS	SOFTWARE AVAILABLE
8	Hewlett- Packard EliteDesk 800. Intel Inside Core i7,3.40 GHz, 16.0 GB RAM.	Matlab, Scilab, Office 2013, Aspen Plus® V 9.0, Win CC
2	Hewlett- Packard EliteDesk 800. Intel Inside Core i7,3.40 GHz, 8.0 GB RAM.	
2	Hewlett- Packard EliteDesk 800. Intel Inside Core i7,3.40 GHz, 16.0 GB RAM.	

Source: Computer Room Coordination

It is important to highlight that the office of the Solid Waste Research Program —located in the Building 421- Block 5 of the Camilo Torres Buildings, has equipment with the ARCGis 9.3 license manager to make improvements in Geographic Information Systems. This license was obtained thanks to the development of different projects.

Finally, it is necessary to emphasize that there is wireless access to the University network in all of the buildings of the School of Engineering, and that those computers in the mentioned rooms have access to wired connection through hotspots arranged in each room.

L. Contact information

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M. References

1. University Superior Council, Universidad Nacional de Colombia. Agreement 033. 2007.
2. Universidad Nacional De Colombia. Chemical Engineering [Internet]. 2018. Available at: https://ingenieria.bogota.unal.edu.co/es/formacion/pregrado/ingenieria-quimica.html
3. Congress of Colombia. Law 18. Colombia; 1976.
4. The National Agency for Quality Assessment and Accreditation (ANECA). White Paper, Degree in Chemical Engineering. 2005.
5. Institute of Chemical Engineers (IChemE). What is Chemical Engineering? [Internet]. 2020. Available at: https://www.icheme.org/education/whynotchemeng/
6. Institute of Chemical Engineers (IChemE). What do chemical engineers do? [Internet]. 2020. Available at: https://www.icheme.org/education/whynotchemeng/what-do-chemical-engineers-do/
7. Allen D, Shornnard D. Green Engineering: Environmentally Conscious Design of Chemical Processes. In: Upper Saddle River (N.J.): Prentice-Hall PTR., editor. 2002.
8. Brundtland GH. Report of the World Commission on Environment and Development: Our Common Future. United Nations Documentation. 1987.
9. Martinez-Hernandez E. Trends in sustainable process design—from molecular to global scales. Curr Opin Chem Eng [Internet]. 2017;17:35-41. Available at: http://dx.doi.org/10.1016/j.coche.2017.05.005
10. Hill M. Chemical Product Engineering-The third paradigm. Comput Chem Eng. 2009;33(5):947-53.
11. McCarthy JJ, Parker RS. Pillars of Chemical Engineering: a block scheduled curriculum. Chem Eng Educ. 2005;38(4):292-301.
12. Riveros M. Una mirada a la evolución de la ingeniería química a través de sus paradigmas. Universidad Nacional De Colombia; 2009
13. Academic Council, Universidad Nacional de Colombia. Agreement 014. 1990.
14. Universidad Nacional De Colombia. Chemical Engineering Degree, Curricular Reform. 1994.
15. Campus Council, Universidad Nacional de Colombia. Agreement 103. 2003.
16. Universidad Nacional De Colombia. Mision and vision of the Engineering School, Bogotá Campus[Internet]. 2018. Available at: https://ingenieria.bogota.unal.edu.co/es/facultad.html
17. Peña Reyes JI, Duarte Velasco OG, Pérez Rodríguez CP, Narváez Rincón PC, Vargas Sáenz JC, Martínez Riascos CA, et al. Program Educational Project, Self-assessment and Monitoring of the Undergraduate Programs Quality, Chemical Engineering. 2015;53(9):1689-99.
18. DANE. Great integrated household survey (GEIH) Labor Market [Internet]. 2020. Available at: https://www.dane.gov.co/index.php/estadisticas-por-tema/mercado-laboral/empleo-y-desempleo
19. Academic Council, Universidad Nacional de Colombia. Agreement 2019. Available at: http://www.legal.unal.edu.co/rlunal/home/doc.jsp?d_i=60932
20. Academic Vice-Presidence, Universidad Nacional de Colombia. Resolution 005. 2010.

21. Academic Vice-Presidence, Universidad Nacional de Colombia. Resolution 006. 2010.
22. University Superior Council, Universidad Nacional de Colombia. Agreement 011. 2005.
23. Office of Strategic Projects, Montoya Castaño D, Abril Contreras PE, Hernández Rodríguez CA, Gómez de Mantilla LT, Cardozo de Martinez CA, et al. Institutional Self-Assessment Report 2019.
24. Universidad Nacional De Colombia. Library Resources and Services - Program: Chemical Engineering Degree -Bogota Campus. 2018.

ANNEX 1 - SYLLABUS

CHEMICAL ENGINEERING PROGRAM

BOGOTÁ CAMPUS | SCHOOL OF ENGINEERING | ACUERDO 02 DE 2013

This curriculum is a proposal that seeks to guide students in the registration of their subjects each semester, taking into account the number of required credits by groups and components.

I	II	III	IV	V	VI	VII	VIII	IX	X
Principles of chemistry 3 — 1000024	Principles of chemical analysis 3 — 1000026	Lab. principles of chemical analysis 3 — 1000027	Principles of inorganic chemistry 3 — 1000028	Principles of organic chemistry 3 — 1000030	Lab. of organic chemistry 2 — 1000010	Economic and administrative sciences (selected elective)* 3	Materials (selected elective)* 3	Interdisciplinary projects workshop 3 — 2015737	Final work degree 6 — 2015289
Lab. basic techniques in chemistry 3 — 1000025	Linear algebra 4 — 1000003	Molecular and celular biology 3 — 1000025	Fundamental probability and statistics 3 — 1000013	Numerical methods 3 — 2015970	Economic engineering 3 — 2015703	Projects management and administration 3 — 2015702	Process control 3 — 2015710	Design of plants and equipment 3 — 2015712	
Differential calculus 4 — 1000004	Integral calculus 4 — 1000005	Calculus of several variables 4 — 1000006	Differential equations 4 — 1000007		Mass transfer 3 — 2015744	Separation operations 3 — 2015731	Lab. of separation, reaction and control operation 3 — 2015720	Process engineering 3 — 2015715	
Engineering tools (selected elective)* 3	Fundamental of mechanics 4 — 1000019	Fundam. of electricity and magnetism 4 — 1000017	Fluids 3 — 2015714	Heat transfer 4 — 2015743	Workshop 2 1 — 2015736	Lab. fluids, solids and heat transfer 3 — 2015719	Chemical and biochemical processes (selected elective)* 3		Free choice election 3
			Workshop 1 1 — 2015735	Solids handling 3 — 2015276	Lab. thermodynamics and transport properties 3 — 2015721				Free choice election 3
Introduction to chemical engineering 3 — 2015718	Mass balance 3 — 2015708	Thermody-namics 3 — 20155741	Chemical ther-modynamics 3 — 2015740	Energy balance and chemical equilibrium 3 — 2015707	Thermodynamics (selected elective)* 3	Chemical reactions engineering 3 — 2015716	Design of chemical and biochemical processes 3 — 2015713	Free choice election 3	Free choice election 3
		Free choice election 3		Free choice election 3	Free choice election 3	Free choice election 3	Free choice election 4	Free choice election 4	Free choice election 4
TOTAL CREDITS 16	18	20	17	19	18	18	19	16	19

BASIC MATHEMATICS 4	READING AND WRITING 4		FOUNDATION Total 69 — Required: 63 — Elective: 6	DISCIPLINARY Total 75 — Required: 66 — Elective: 9	FREE CHOICE Total 36 — Required: 36
ENGLISH 1 3	ENGLISH 2 3	ENGLISH 3 3	ENGLISH 4 3		TOTAL PROGRAM 180

% OF PROGRAM

3% Elective — 38% — 35% Required

5% Elective — 42% — 37% Required

20% — 20% Required

CONVENTIONS

- LEVELING COURSES
- FOUNDATION COMPONENT
- FREE CHOICE COMPONENT
- DISCIPLINARY OR PROFESSIONAL EDUCATION COMPONENT

✻ *The list of optional subjects is presented on the following page, according to the grouping which they belong.*

Prerequisite subject → Name of the subject — Subject code — # Number of Credits — Subject identification — Component color

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CHEMICAL ENGINEERING PROGRAM

BOGOTÁ CAMPUS | SCHOOL OF ENGINEERING | ACUERDO 02 DE 2013

GROUPS

MATHEMATICS, PROBABILITY AND STATISTICS

CODE	NAME OF THE SUBJECT	CRED.
1000004	Differential Calculus	4
1000005	Integral Calculus	4
1000006	Calculus of Several Variables	4
1000007	Differential Equations	4
1000013	Fundamentals of Probability and Statistics	3
1000003	Linear Algebra	4

CREDITS: REQUIRED: 23 | COMPULSORY: 23 | ELECTIVE: 0

CHEMISTRY AND BIOLOGY

CODE	NAME OF THE SUBJECT	CRED.
1000025	Laboratory of Basic Techniques in Chemistry	3
1000024	Principles of Chemistry	3
1000026	Principles of Chemical Analysis	3
1000027	Laboratory of Principles of Chemical Analysis	3
1000028	Principles of Inorganic Chemistry	3
1000030	Principles of Organic Chemistry	3
1000010	Laboratory of Principles of Organic Chemistry	2
1000025	Molecular and Cellular Biology	3

CREDITS: REQUIRED: 23 | COMPULSORY: 23 | ELECTIVE: 0

PHYSICS

CODE	NAME OF THE SUBJECT	CRED.
1000019	Fundamentals of Mechanics	4
1000017	Fundamentals of Electricity and Magnetism	4

CREDITS: REQUIRED: 8 | COMPULSORY: 8 | ELECTIVE:0

ECONOMIC AND ADMINISTRATIVE SCIENCES

CODE	NAME OF THE SUBJECT	CRED.
2015703	Engineering Economics	3
2015702	Project Management and Administration	3
2015698	Business Administration	3
2016609	Industrial Safety	3
2016741	Financial Management	3
2016610	Costing Systems	4
2015699	Market Administration	3
2016592	General Economics	3
2015695	Project Design, Management and Evaluation	3
2015705	Markets I	4
2016056	Decision Theory	4
2015700	Fundamentals of Financial Accounting	3
2015704	International Marketing	3
2015694	Labour Law	3

CREDITS: REQUIRED: 9 | COMPULSORY: 6 | ELECTIVE:3

ENGINEERING TOOLS

CODE	NAME OF THE SUBJECT	CRED.
2015734	Computer Programming	3
2015709	Oral and Written Communication	3
2015711	Basic Drawing	3
2015970	Numerical Methods	3

CREDITS: REQUIRED: 6 | COMPULSORY: 3 | ELECTIVE: 3

DEEPENING

The subjects of this grouping and their information are presented in Table 19 of the of the Program Educational Project (PEP). It is suggested to take them as part of the Free Choice component. In the technical electives subjects there is the option of doing Student Practice.

108 credits approved of the total credits of the curriculum

THERMODYNAMICS

CODE	NAME OF THE SUBJECT	CRED.
2015741	Thermodynamics	3
2015740	Chemical Thermodynamics	3
2015735	Workshop 1	1
2015707	Energy Balance and Chemical Equilibrium	3
2015739	Molecular Thermodynamics	3
2015738	Thermodynamic Cycles	3
1000038	Physical Chemistry II	3

CREDITS: REQUIRED: 13 | COMPULSORY: 10 | ELECTIVE: 3

UNIT OPERATIONS

CODE	NAME OF THE SUBJECT	CRED.
2015708	Mass Balance	3
2015714	Fluids	3
2015726	Solids Handling	3
2015743	Heat Transfer	4
2015744	Mass Transfer	3
2015736	Workshop 2	1
2015731	Separation Operations	3

CREDITS: REQUIRED: 20 | COMPULSORY: 20 | ELECTIVE: 0

MATERIALS

CODE	NAME OF THE SUBJECT	CRED.
2015717	Introduction to Materials Engineering	3
2020326	New Topics in Chemical Engineering	3
1000040	Introduction to Materials Science	3
2015727	Materials	3
2024929	Introduction to Polymer Materials Engineering	3
2017348	Materials Technology	3
2017256	Materials Science and Engineering	3
2015598	Chemistry of Solids	3

CREDITS: REQUIRED: 3 | COMPULSORY: 0 | ELECTIVE: 3

108 credits approved of the total credits of the curriculum

CHEMICAL AND BIOCHEMICAL PROCESSES

CODE	NAME OF THE SUBJECT	CRED.
2015716	Chemical Reaction Engineering	3
2015713	Design of Chemical and Biochemical Processes	3
2015710	Process Control	3
2015712	Design of Plants and Equipment	3
2015715	Process Engineering	3
2015729	Modelling and Simulation of Chemical Processes	3
2015728	Modelling and Simulation of Biochemical Processes	3

CREDITS: REQUIRED: 18 | COMPULSORY: 15 | ELECTIVE: 3

PROFESSIONAL CONTEXT

CODE	NAME OF THE SUBJECT	CRED.
2015718	Introduction to Chemical Engineering	3

CREDITS: REQUIRED: 3 | COMPULSORY: 3 | ELECTIVE: 0

RESEARCH AND INNOVATION

CODE	NAME OF THE SUBJECT	CRED.
2015721	Laboratory of Thermodynamic and Transport Properties	3
2015719	Laboratory of Fluids, Solids and Heat Transfer	3
2015720	Laboratory of Separation, Reaction and Control Operations	3
2015737	Interdisciplinary Projects Workshop*	3
2015289	Final Work Degree	6
2015290	Final Work Degree** – Postgraduate Courses**	6

CREDITS: REQUIRED: 18 | COMPULSORY: 12 | ELECTIVE: 6

** 70% of the total credits required in the disciplinary or professional education component (53 credits)*

*** 80% of the total credits required in the disciplinary or professional education component (60 credits)*

CONVENTIONS

- FOUNDATION COMPONENT
- DISCIPLINARY OR PROFESSIONAL EDUCATION COMPONENT
- FREE CHOICE COMPONENT
- REQUIRED SUBJECT