PROGRAM EDUCATIONAL PROJECT

SELF-ASSESSMENT AND MONITORING OF THE UNDERGRADUATE PROGRAMS QUALITY

Chemical Engineering

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Introduction

The Program Educational Project (PEP) of Chemical Engineering incorporates minor modifications made in 2013 and those that resulted from the reform process of the programs of study of the Universidad Nacional de Colombia, Campus Bogotá. This reform process was carried out to adapt the curricula to Agreement 033 of 2007 of the Higher University Council (CSU), which defines the basic guidelines for the students' education, as well as its main principles: academic excellence, comprehensive education, contextualization, internationalization, research education, interdisciplinarity, flexibility and management for academic improvement. This PEP recognizes the scientific and technological realities 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 staff, technical and administrative. This university community has contributed to the education of around 4,500 chemical engineers, who exercise their professional work in different fields of action in Colombia and in other countries.

Initially, this document presents a historical review of the curriculum, in order to show its evolution. Then, Chemical Engineering is defined as a profession and a brief description of its development is outlined through three paradigms: the unitary operations, the continuous or scientific foundations and the product design. 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 education and, finally, the resources to materialize this PEP.

A. PROGRAM IDENTITY

A.1 General Information

Program name: **Chemical Engineering – Bogotá**
Level: **Professional – Undergraduate**
Title: **Chemical Engineer**
SNIES Code: **29**
SIA Code: **2549**
Year of creation: **1939**
Campus: **Bogotá**
School: **Engineering**
Curricular Area: **Chemical and Environmental Engineering**
Basic Academic Unit: **Department of Chemical and Environmental Engineering**
Estimated Duration: **10 semesters**
Delivery mode: **On-campus daytime classes**
Credits: **180**
Foundation Component: 69
Disciplinary Component: 75
Free Choice Component: 36
Year of the first graduation ceremony: **1951**
Number of graduates in the first generation: **3**

A.2 Department History

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 study 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 faculties that included chemistry courses in its programs. In fact, in a few years this Department created the Chemistry and Chemical Engineering programs and became a Faculty.

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 Faculties and Schools of the University under one direction". With the rapid success of this Department, the Directives of the University strengthened it and organized 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 Faculties and by the Director of the School of Pharmacy. On February 10, 1938, Professor Antonio García Banús, Spanish professor at the University of Barcelona, was appointed as the first Special Director.

Creation of the Chemistry and the Chemical Engineering Programs

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 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 with 23 courses and a fifth year of optional specialization. In this Agreement, students could complete the compulsory 4 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 National University of 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 its first stage were developed as planned, which allowed 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. Thus, in 1948 the studies were regulated when the installations of semi-industrial and industrial type were acquired. The first graduate of the program was Ramiro Lobo Sanjuán, who received his diploma on November 12, 1951. Subsequently, on December 14 of the same year, José María Brossa and Gonzalo de Valera Ruiz obtained the title. In 1952, three students graduated, in 1953 and in 1955 a student graduated, and in 1954, none.

Chemistry and Chemical Engineering Faculty

The relevance and development of the Department of Chemical Sciences, its services to the different careers and, especially, the boom of the Chemistry Program motivated the Board Council of the University to convert it into a Faculty, in the Agreement 147 of 1940. This supported the initiatives of Professor García Banús to consider the studies of Chemical Sciences not simply as an auxiliary science but as a special career, fundamental for the development of the country, that had to be provided with the basic elements for its existence and progress.

Structure of the Chemical Engineering Program

With the adequate academic structure and the semi-industrial teams (Laboratory of basic unit operations), the Faculty could fulfill the original purposes of the Agreement 26 and initiate the complementary courses for the education of Chemical Engineers. The study plan 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 Chemist, specific courses of the Chemical Engineering in different levels were added: Statics, Dynamics, Mechanics of fluids, Resistance of materials, Electricity and Economy. The fifth year, specific for Engineers, corresponded to the courses of Inorganic Industrial Chemistry, Electrical Engineering and Laboratory, Water Treatment, Economy, Metallurgy and Chemical Engineering and Projects.

Evaluation of the curriculum of 1953

The arrival of Professor Zbigniew M. Broniewski, Military Engineer and Chemical Engineer of the Polytechnic University of Warsaw 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 liberty to choose 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 the 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. By this time, the formation of the Chemical Engineers had a strong orientation towards the Chemical Sciences and the analysis, as a result of its common origin with the Chemistry program. However, the areas of plant design, assembly and operation were gradually strengthened, and economy and administration courses were incorporated.

The integration of 1965

In 1965, the Rector José Félix Patiño proposed and carried out an integration of some Faculties and Departments, which gradually produced new academic adjustments. The Faculty of Chemistry and Chemical Engineering became the Department of Chemistry, which was integrated to the new Faculty of Sciences. As a result, the career of Chemical Engineering was overshadowed, but shortly after, at the request of professors and students, the University Superior Council (CSU), through the Agreement 188 of August 19, 1965, created the Department of Chemical Engineering, attached to the Faculty of Engineering. The program was transferred to this Faculty, which was integrated then by the Departments of Civil Engineering, Electrical Engineering, Mechanical Engineering and Chemical Engineering, each one with their respective careers.

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 courses for the first semester in common with the other engineering programs. This reform was evaluated by the Academic Council and formally approved by the University Superior Council, through the Agreement of January 8, 1966. Besides dividing the annual courses to two semesters and relocating others that were already semiannual, some common courses were introduced, such as Castellano 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 the student had to perform during his last semester of studies.

The program comprised eighty-six courses, theoretical and practical (laboratories), with a weekly intensity of 35 hours. The program assessment allowed to identify the need to reduce the academic load, the number of courses and their contents and gave the student more time for consultation in the 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, which is described below.

The Reform of 1973

As a consequence of the previous situation, a new study plan was submitted for consideration to the Faculty Board of Directors, which accepted and sent it for analysis and approval to the Academic Council and the CSU. The result was the Agreement 166 of November of 1973, where the curricula for the careers of the Engineering Faculty were approved. The curriculum of the Chemical Engineering Program comprised sixty-four courses for 10 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, in order to leave the student free to enroll 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, valid until 1994, was permanently evaluated by the Curricular Committee and the Board of Directors, to identify aspects that required updating or restructuring.

The reform of 1994

The Agreement 14 of 1990 of the Academic Council outlined the general criteria to structure the curricular programs of the Universidad Nacional de Colombia. The objectives were

- to integrate teaching, research and specialized consultancy more intensively,
- to make study plans more flexible to promote the integral and pluralistic formation of students,
- to increase autonomy and commitment to educate,
- 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 were opening at that time.

The most important aspects of this reform were the flexible and the discipline components in the design of the programs. The flexible component included technical electives and context courses. The aim was to focus on the engineering sciences, which meant strengthening the concepts and foundations of the Basic Sciences.

A study plan was designed consisting of 58 academic activities programmed in 10 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 Petrochemical, 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.

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. In the Agreement 001 of 2005 of the CSU and the Resolution 114 of the same year of the Engineering Faculty Council, the Final Work Degree was modified and regulated, defining the following topics:

- Qualification: 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.

From the reform of 2008 to today

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 students through the curricular programs, as well as the principles of education, namely: academic excellence, comprehensive education, contextualization, internationalization, research education, interdisciplinarity, flexibility and management for academic improvement. The guidelines of this reform are summarized in the Agreement 41 of the Academic Council (2009). According to this Agreement, the number of credits required for the program is 180, whose distribution is described in section C2 of this document.

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 Faculty Council. Likewise, it established that the modality of Final Work Degree can correspond to investigative work, specialized consultancy practices or postgraduate courses. Finally, 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 Faculty 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 the technical electives in thermodynamics, administration and materials.

B. PERTINENCY AND PROGRAM OBJECTIVES

B.1 Program Objectives

B.1.1 *General Objective*

To educate chemical engineers capable of innovating, researching, team working, creating a company, designing and improving products and processes of physical, chemical or biological transformation and dialoguing permanently with the national and international specialized community. Provide society with professionals who have solid scientific and technological education, leadership, social responsibility and administrative skills, which effectively affect the development of the country.

B.1.2 *Specific Objectives*

According to Resolution 146 of 2010 of the Engineering Faculty Council, the specific objectives of the Chemical Engineering Program that integrate its mission, are as follows:

- To educate chemical engineers with a solid scientific and technological foundation, able to design products and physical, chemical or biological transformation processes; as well as to plan, efficiently manage, evaluate, improve and / or design the plants in which those processes are carried out, based on an entrepreneurial, research and innovative spirit.
- To foster the participation of the students of chemical engineering in disciplinary and interdisciplinary teams, integrated into local, regional, national and international networks.
- To promote in its students and graduates the awareness of constant study and education, leadership and the development of administrative skills, as well as ethical, humanistic, environmental and social responsibility, so that they effectively affect the identification, study and presentation of proposals for the solution of specific problems that contribute to the development of the country and the well-being of the communities.

B.2 Program Vision

The Chemical Engineering Program will generate the knowledge that will allow the Colombian chemical industry to be competitive and position itself in the global context. It will contribute to the formation of individuals, based on the scientific, technological, ethical and aesthetic codes of modernity, apt for professional development, research, innovation and entrepreneurship and capable of team working and adaptation to change thanks to their abilities and skills to update their knowledge.

B.3 Profile of Applicants

The Chemical Engineering Program of the National University, Bogotá 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.

B.4 Profile of Graduates

This PEP 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 and those of the near future, the capacities that the national and international actors related to the profession expect to find in the chemical engineers and the fields of action of the chemical engineer. Consequently, it aims to educate professionals with the following profile (CA, Agreement 041 of 2009):

> *The chemical engineers of the Universidad Nacional, Bogota campus, are able to innovate, research, team work, create a company, design and improve products and processes of physical, chemical or biological transformation and dialogue permanently with the national and international specialized community. They are professionals with solid scientific and technological education, leadership, social responsibility and administrative skills, which effectively affect the development of the country.*

According to the Profile of Graduates, it is expected that at the time of graduation the students of the Chemical Engineering program of the Universidad Nacional de Colombia have the following student outcomes:

1. Ability to apply knowledge of mathematics, science, chemical and biological sciences, in Chemical Engineering.

2. Ability to use the techniques, skills, and modern engineering tools necessary for the Chemical Engineering practice.

3. Ability to design and conduct experiments, as well as to analyze and interpret data.

4. Ability to design systems, components, products and/or processes to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety manufacturability, and sustainability.

5. Ability to function on teams.

6. Understanding of professional and ethical responsibility.

7. Ability to communicate effectively in Spanish.

8. Ability to communicate effectively in English.

9. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

10. Recognition of the need for, and an ability to engage in life-long learning.

11. Knowledge of contemporary issues.

12. Ability to participate in research, innovation and / or entrepreneurship processes.

Table 1 presents the relationship of the educational objectives of the program to the student outcomes.

Table 1. Relationship of the program educational objectives of the Chemical Engineering Program to the student outcomes

Educational Objective	**Student Outcomes**
Educate chemical engineers with solid scientific and technological foundations (...)	- Ability to apply knowledge of mathematics, science, chemical and biological sciences, in Chemical Engineering.
Educate chemical engineers (...) able to design products and physical, chemical or biological transformation processes; as well as to plan, efficiently manage, evaluate, improve and/or design the plants in which those processes are involved.	- Ability to design and conduct experiments, as well as to analyze and interpret data. - Ability to use the techniques, skills, and modern engineering tools necessary for chemical Engineering Practice.
Educate chemical engineers (...) based on an entrepreneurial, research and innovative spirit.	- Ability to participate in research, innovation and / or entrepreneurship processes.
Fostering the participation of the students of chemical engineering in disciplinary and interdisciplinary teams, integrated into local, regional, national and international networks.	- Ability to function on teams.
Promote in their students and graduates the awareness of constant study and educating (...).	- Recognition of the need for, and an ability to engage in life-long learning.
Promote in their students and graduates (...) leadership and the development of administrative skills (...).	- Ability to function on teams.
Promote in their students and graduates (...) ethical, humanistic, environmental and social responsibility, so that they effectively affect the identification, study and presentation of proposals for the solution of specific problems (...).	- Ability to design systems, components, products and/or processes to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety manufacturability, and sustainability. -Understanding of professional and ethical responsibility. - Knowledge about contemporary issues.
(...) contribute to the development of the country and the well-being of the communities.	- Ability to design systems, components, products and/or processes to meet desired needs within realistic constraints such as economic,

	environmental, social, political, ethical, health and safety manufacturability, and sustainability. - The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. - Knowledge about contemporary issues.

B.5 Program Prospective

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 Institute that needs this knowledge and means (CRC, Law 18 of 1976).

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. 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 and by others that appeared more recently (ANECA, 2005).

The Institution of Chemical Engineers (IChemE) of Great Britain, establishes that Chemical Engineering is the design, development and management of a wide and varied spectrum of industrial processes (IChemE, 2006). The University of Worcester, in turn, expresses that Chemical Engineering is a discipline related to processes that involve the transformation of matter and energy in useful ways to humanity, economically and without compromising the environment, safety or finite resources (WPU, 2004).

On the one hand, when explaining why chemical industries hire chemical engineers, Towler and Sinnot (Towler & Sinnott, 2008) accurately describe the mission of the profession:

> Starting from a vaguely defined problem statement such as a customer need or a set of experimental results, chemical engineers can develop an understanding of the important underlying physical science relevant to the problem and use this understanding to create a

plan of action and set of detailed specifications, which, if implemented, will lead to a predicted financial outcome.

On the other hand, the fields of action of the Chemical Engineer of the Universidad Nacional, in accordance with Law 18 of 1976, are (CRC, Law 18 of 1976):

• Industrial: planning, supervision, design, assembly, control and operation of plants, and process equipment.

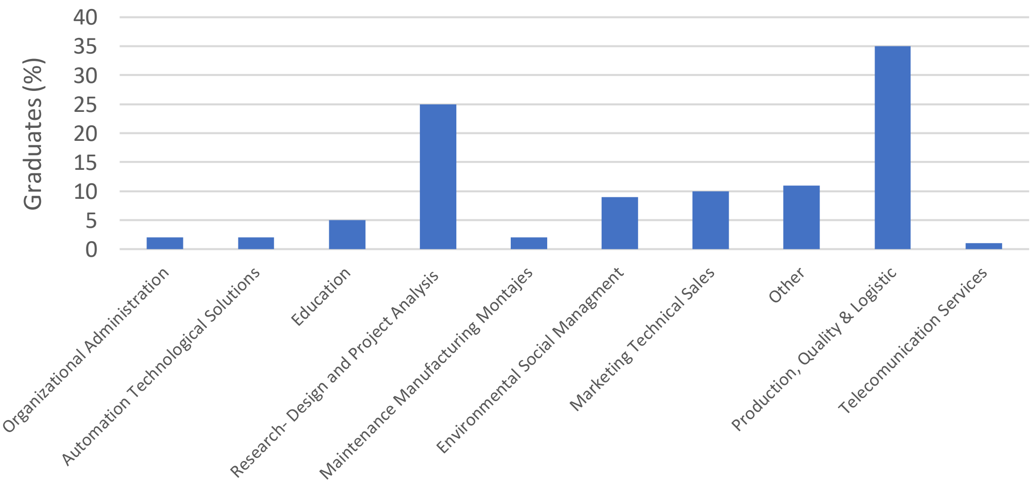
• Research: development of products and processes. Formulation and evaluation of basic and applied research projects. Study, management and adaptation of technological changes to improve production methods.

• 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.

• Commercial: technical support for the commercialization and use of chemical products, equipment, plants and processes.

Figure 1 shows the distribution of graduates of the Chemical Engineering Program by areas of employment. Most of them work in two of them: 1) production, quality and logistics; and 2) research, design and analysis of projects. About 10% of the graduates work in the area of marketing and technical sales, and 5% in education.



Source: Information generated from the information provided by the Graduate Information System in 2010.

Figure 1. Areas of employment of graduates of the Chemical Engineering Program

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 (Allen & Shonnard, 2002):

• 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 in production, but throughout the life cycle of the product, which includes transportation, use, recycling and disposal.

In the development of the profession, three paradigms are distinguished, according to Kuhn in his book *The structure of scientific revolutions are the specific ways of seeing scientific reality* (Hill, 2009). These paradigms mark the evolution of the Chemical Engineering (McCarthy & Parker, 2005). First, at the beginning of the 20th century, in 1915, Arthur D. Little presented the concept of unitary operations, accepted and extended (Riveros, 2009) 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 programs of Transport Phenomena courses and strengthened with the publication, in 1960, of the book *Transport Phenomena*, by R. Bird, W. Stewart, and E. Lightfoot. Nowadays, the paradigm of design and product engineering is rising: Macroscopic variables are designed and controlled through the manipulation of the fundamental units, that is, the molecules.

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 mathematical treatment to maximize the benefit, because it will depend, to some extent, on a complex set of properties that may not be identified. Consequently, product design and the solution of new engineering problems require to strengthen the scientific basis and use specialized engineering tools. A new suite of knowledge is necessary, which is the reason why, since 1988, engineering and product design have been recognized as the third paradigm of Chemical Engineering (Hill, 2009).

In the near future, it is expected that the Chemical Engineering program will incorporate the design of products as a fundamental part of the process design. For this purpose, a research process started in 2014, involving two doctorate theses and another one already completed in 2011. Additionally, as an essential part of product design, the topics related to science and technology of materials will be consolidated, as well as modern design trends in engineering, where the decision criteria include the dimensions of sustainability: economic, environmental and social. Within the social dimension, industrial safety and occupational health are included and must be increasingly studied in the different activities of the curriculum. It also must enhance the identification, analysis and search for solutions to the great problems of humanity, especially the accelerated deterioration of the environment, scarcity of water and food, and the growing needs of energy and economic dependence on non-renewable natural resources. Thus, environmental issues, the intensification and optimization of processes, bio-based products and biorefineries must be key issues in the evolution of the curriculum. Fortunately, these issues have been developing for more than a decade.

Finally, education in Chemical Engineering has changed radically (Felder, 2004):

> From the late 19th century through the 1950s, engineering education was a combination of lecture and hands-on instruction closely tied to industrial practice, and the faculty consisted primarily of experienced engineers and consultants to industry. (...) In the years that followed, external funding opportunities for basic research skyrocketed, faculty started to be hired primarily for their potential as researchers, and most laboratory and field experiences disappeared from the engineering curriculum to be replaced by lectures on applied math and science. (...) In the 1990s, a rising chorus of complaints from industry about the inadequate preparation of new engineering graduates for industrial jobs started to be acknowledged inside the academy. In addition, evidence began to emerge from both cognitive science and empirical classroom research that the prevailing instructional model (...) was ineffective for promoting learning and the acquisition of critical thinking and problem solving skills".

This problem and the new developments in education generated a movement in the United States toward a more active, cooperative and project-based educational model, which, unfortunately, is not yet dominant.

Within the framework of project-based education, Mitchell Waldrop (Waldrop, 2015) stated that the educational approach based on work teams solving problems that simulate reality, independently of the specific methodology implemented, generates significantly better results in the understanding of the science. In contrast with the traditional approach where students listen to the answers, it allows the intersection of political, technological, economic, social and environmental aspects. Thus, some courses of the curriculum of chemical engineering have implemented a model based on projects where students perform a job similar to what they would do as engineers, as part of a work team. Some of those are Workshops 1 and 2, Mass Transfer, Design of Chemical and Biochemical Processes, Process Engineering and Design of Plants and Equipment. In fact, in the last three courses, strategies are designed for students to carry out a project during two or three semesters. This project covers the design cycle in chemical engineering (conceptual design of the process, including energy and mass integration, optimization and activities of the process engineer in the conceptual and basic engineering) and an approach to the work of other specialties in the detail engineering of a chemical transformation plant. It is expected that, in the future, these types of teaching strategies continue to be incorporated, which would undoubtedly facilitate the fulfillment of the program objectives and the achievement of the educational results.

C. ORGANIZATION AND CURRICULAR STRATEGY

C.1 Basic guidelines for the student education

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

- Universidad Nacional de Colombia
- Faculty of Engineering.
- Department of Chemical and Environmental Engineering.
- Curricular Area of Chemical and Environmental Engineering.
- Professional Council of Chemical Engineering.
- Professional Associations of Chemical Engineers.
- Employers of graduates of the program.
- Graduates of the program.
- Active students of the Program.
- Active Professors of the Program

As mainstay among the program constituents, the mission declared by the Universidad Nacional de Colombia is:

> *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.*

And its main objective is 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 Higher University Council. Article I of Chapter I of this agreement describes the principles of student education at the National University of Colombia, which are transcribed below:

> ***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 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. 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 stablished 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.*** *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 employ transversally the tools and knowledge acquired in an area of knowledge, adapting and applying them legitimately 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.*

In Article 8 of Chapter II of the same Agreement, guidelines are established to define the educational objectives of the undergraduate programs. It is indicated that the educational objectives of curricular programs must include the principles described in Chapter I, and additionally establishes that the undergraduate education aims at:

> 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 structured flexibly, 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 033 of 2007 of the CSU establishes that as the nature of the course Final Work Degree is special, as

> *it allows 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 in their 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 Faculty of Engineering of the Bogotá Campus. The following is the mission declared by the Faculty:

> *To educate the engineering and postgraduate professionals demanded by society, based on the commitment to scientific research and the country's technological and social development. The purpose is to contribute to the transformation of the country, through the generation, conservation and transmission of knowledge, expressed in the transfer of expertise and technological innovation, produced by the members of the academic community of the Faculty for both the public and private sectors.*

The essential work of the Department of Chemical and Environmental Engineering (DIQyA), as responsible for the resources related to the Chemical Engineering Program, is described in the following functions (Ingeniería, 2015):

- 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 Faculty of Engineering.
- Develop relevant research and specialized consultancy of an interdisciplinary nature, focused on the solution of society's problems at national and international level.

Likewise, considered as constituent, the Professional Council of Chemical Engineering of Colombia (CPIQ), 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. As an interested party in the Chemical Engineers' educational process, some of its functions are (CPIQ, 2015):

- *Issue the rules of professional ethics, aiming to improve the professional level of the Chemical Engineer, and set clearly and precisely the professional's obligations to himself, to his profession, to the country and to the national and universal community.*
- *Ensure compliance with the 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*

Based on the aforementioned and taking into account the needs of the interested parties, the accumulated experience and the collective knowledge, the objectives of the program and the profile of the graduate were defined, as well as the expected results of the academic education presented previously, and the curriculum that will be described in the next section.

C.2 Structure Organization – Curriculum

The curriculum of the Chemical Engineering Program is defined in the Resolution 146 of 2010 and in Agreements 002 and 016 of 2013 of the Council of the Faculty of Engineering It has a total of one hundred eighty (180) credits, distributed as follows:

a. Foundation Component: Sixty-nine (69) credits required. The student must approve sixty-three (63) credits of compulsory courses and six (6) of electives.
b. 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.
c. Free Choice Component: thirty-six (36) credits required, which correspond to 20% of the total credits of the curriculum.

The credits, groups and courses of the components of the curriculum are specified in Tables 2 – 17.

Foundation Component

Table 2. Mathematics, Probability and Statistics Group

Code	Course name	Credits	Required	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	Fundamental Probability and Statistics	3	YES	Differential Calculus
1000003	Linear Algebra	4	YES	Differential Calculus

Credits required in Mathematics, Probability and Statistics: twenty-three (23)

Table 3. Physics Group

Code	Course name	Credits	Required	Pre-requisite(s)
1000019	Fundamentals of Mechanics	4	YES	Differential Calculus
1000017	Fundamentals of Electricity and Magnetism	4	YES	Integral Calculus Fundamentals of Mechanics

Credits required in Physics: eight (8)

Table 4. Chemistry and Biology Group

Code	Course name	Credits	Required	Pre-requisite(s)
1000025	Laboratory: Basic Techniques in Chemistry	3	YES	
1000024	Principles of Chemistry	3	YES	
1000026	Principles of Chemical Analysis	3	YES	Principles of Chemistry
1000027	Laboratory: 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: Principles of Organic Chemistry	2	YES	Principles of Chemistry
1000025	Molecular and Cellular Biology	3	YES	

Credits required in: Chemistry and Biology: Twenty-three (23)

Table 5. Group of Economic and Administrative Sciences

Code	Course name	Credits	Required	Pre-requisite(s)
2015703	Economic Engineering	3	YES	Integral Calculus
2015702	Projects Management and Administration	3	YES	Economic Engineering
2015698	Business Administration	3	NO	Economic Engineering
2016609	Industrial Safety	3	NO	Fundamentals of Electricity and Magnetism
2016741	Financial Management	3	NO	
2016610	Fundamentals of costs accounting	4	NO	
2015699	Market Administration	3	NO	
2016592	General Economy	3	NO	
2015695	Projects Design, Management and Evaluation	3	NO	
2015705	Markets I	4	NO	
2016056	Decision – Market Theory	4	NO	
2015700	Fundamentals of Financial Accounting	3	NO	
2015704	International Marketing	3	NO	
2015694	Laboral Law	3	NO	

Credits required in Economic and Administrative Sciences: nine (9)

Table 6. Group of Engineering Tools

Code	Course name	Credits	Required	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

Credits required in Engineering tools: six (6)

Disciplinary Component

Table 7. Group of Thermodynamics

Code	Course name	Credits	Required	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	Thermodynamics of Cycles	3	NO	Thermodynamics
1000038	Physical Chemistry	3	NO	Energy Balance and Chemical Equilibrium

Credits required in Thermodynamics: thirteen (13)

Table 8. Group of Unit Operations

Code	Course name	Credits	Required	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

Credits required in Unit Operations: Twenty (20)

Table 9. Group of Chemical and Biochemical Processes

Code	Course name	Credits	Required	Pre-requisite(s)
2015716	Chemical Reactions 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 Reactions 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 Simulations of Chemical Processes	3	NO	Mass Transfer
				Chemical Reactions Engineering
2015728	Modelling and Simulations of Biochemical Processes	3	NO	Mass Transfer
				Chemical Reactions Engineering

Credits required in Chemical and Biochemical Processes: Eighteen (18)

Table 10. Group of Research and Innovation

Code	Course name	Credits	Required	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 professional education component (53 credits)
2015289	Final Work Degree	6	YES	80% of the total credits required in the professional education component (60 credits)
2015290	Final Work Degree – Postgraduate Courses	6	NO	80% of the total credits required in the professional education component (60 credits)

Credits required in Research and Innovation: eighteen (18)

Table 11. Group of Materials

Code	Course name	Credits	Required	Pre-requisite(s)
2015717	Introduction to Materials Engineering	3	NO	Chemical Thermodynamics 108 credits approved of the total credits of the curriculum
2020326	New Topics in Chemical Engineering	3	NO	108 credits approved of the total credits of the curriculum

1000040	Introduction to Materials Science	3	NO	108 credits approved 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 the Polymeric Materials Engineering	3	NO	108 credits approved of the total credits of the curriculum
2017348	Materials Technology	3	NO	108 credits approved of the total credits of the curriculum
2017256	Materials Science and Engineering	3	NO	108 credits approved of the total credits of the curriculum
2015598	Chemistry of Solids	3	NO	108 credits approved of the total credits of the curriculum

Credits required in Materials: three (3)

Table 12. Group of Professional Context

Code	Course name	Credits	Required	Pre-requisite(s)
2015718	Introduction to Chemical Engineering	3	YES	None

Credits required in the Group of Professional Context: three (3)

Table 13. Group of Technical Electives

Code	Course name	Credits	Required	Pre-requisite(s)
2016762	Student Internship I	3	NO	70% of the total credits of the curriculum
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 the Biochemical Engineering	3	NO	
2024648	Control Operations and Bioprocesses Purification	3	NO	
2024649	Microbiology and Biochemistry of Bioprocesses	3	NO	
2024650	Petrochemistry and refining	3	NO	
2023122	Oil and Gas Engineering	4	NO	
2024651	Catalytic Organic Processes	3	NO	
2023549	Principles of heterogeneous catalysis	4	NO	
2020329	Polymerization Processes	4	NO	
2024652	Transformation of polymers	4	NO	

Credits required in the Group of Technical Electives: zero (0)

The offer of technical electives can be reviewed and modified at the request of the Program Advisory Committee and the subsequent approval of the Faculty 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. In fact, as mentioned above, the courses of the Master's Degree in Engineering - Chemical Engineering, Master's Degree in Engineering - Environmental Engineering and Doctorate in Engineering - Chemical Engineering can be part of the group of technical electives of the Free Choice Component.

English is the foreign language considered fundamental for the professional education of the students of the Curricular Program of Chemical Engineering of the Faculty of Engineering of the Bogotá 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.

The modalities of Final Work Degree for the students of the Curricular Program of Chemical Engineering of the Faculty of Engineering of the Bogotá Campus will be: Research Work, Specialized Consultancy Practices and Postgraduate Courses. In order to register Final Work Degree, the student must have approved sixty (60) credits of the Disciplinary Component (80% of the total credits required for this component).

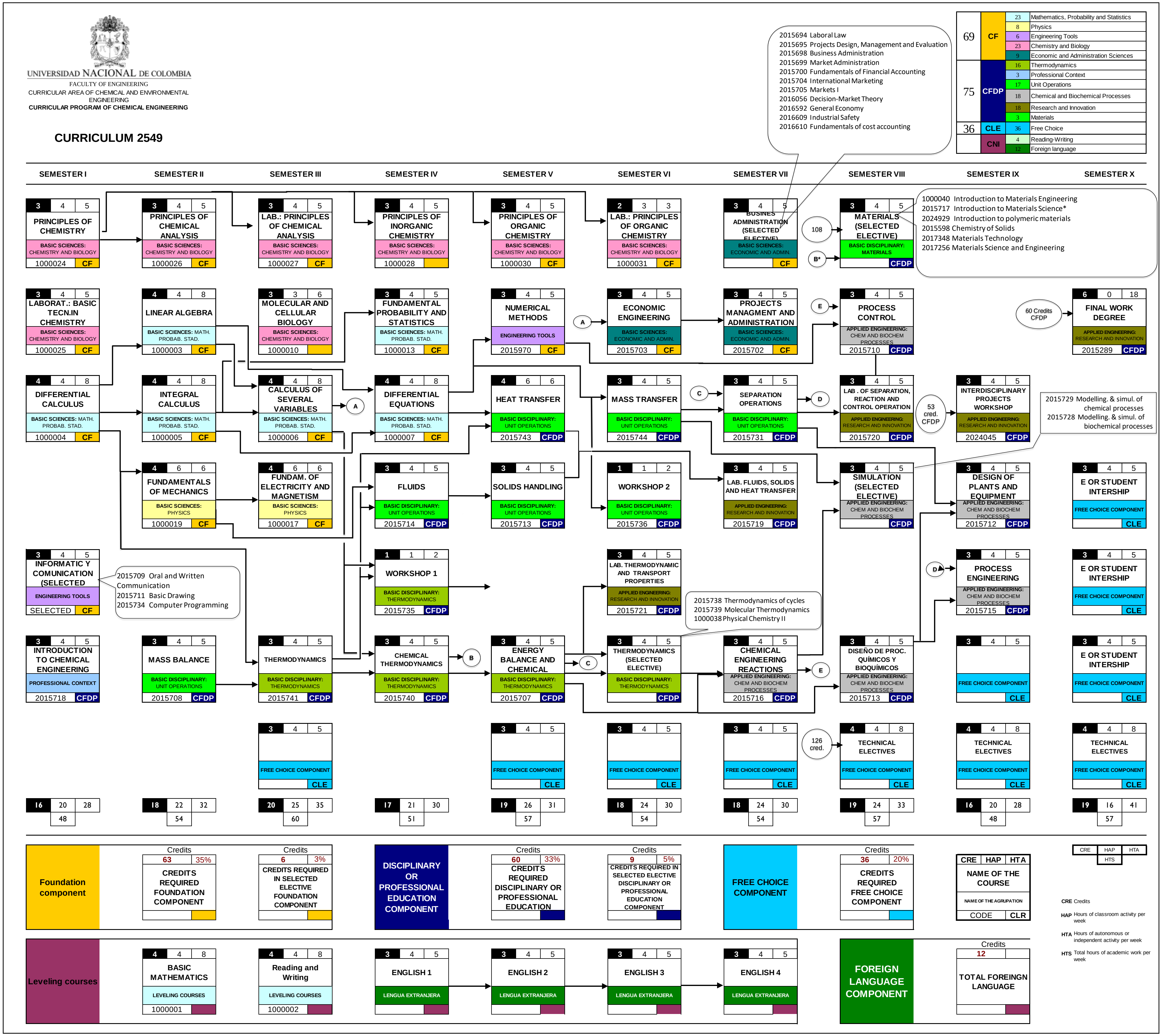


Figure 2. Curriculum of Chemical Engineering

Students can complete a student internship, using their free choice credits. The internship credits will be in the range of 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 in-person and autonomous (outside the classroom) activities of a student constitutes their total academic activity. Each academic semester is developed in 16 weeks. Every 48 hours of academic activity per semester corresponds to one credit. Tables 14-15 show the percentage distribution of the required and elective credits, by thematic group for each component of the curriculum.

Table 14. Distribution of the courses of the Chemical Engineering Curriculum – Foundation Component

Group	Required Credits	Technical Electives Credits	Total Credits Required
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 15. Distribution of the courses of the Chemical Engineering Curriculum – Disciplinary Component

Group	Required Credits	Technical Electives Credits	Total Credits Required
Thermodynamics	10	3	13
Unit Operations	20	0	20
Chemical and Biochemical Processes	15	3	18
Research and Innovation	18	0	18

Materials	0	3	3
Professional Context	3	0	3
Total	**66**	**9**	**75**

Tables 16 show the group classification per knowledge area and its percentage regarding the total credits number.

Table 16. Group Classification According to Knowledge Area

Knowledge Area	Group	Curriculum Percentage (%)	Total Curriculum 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 Biochemical Processes	10.0	
	Research and Innovation	10.0	
Complementary Contents	Socio-humanistic area and complementary topics	6.3	11.3
	Economy and Administration	5.0	
Free Choice (without socio-humanistic area and complementary topics)			13.7

Table 17 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 17. Credits Distribution in the Curriculum of the Chemical Engineering Program per Semester

Semester	Foundation Component Credits	Professional Component Credits	Free Choice Credits	Total Credits per Semester	Total 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 students of the Program, as all the students of the University, can obtain a second undergraduate degree at the University, or participate in a national or international double degree, in the institutions with signed agreements. The requirements for the double undergraduate degree at the University are defined in Article 48 of the Agreement 8 of 2008 and in Agreement 155 of 2014 of the CSU. In the case of international institutions, besides the student statute, the students must comply the conditions defined in the double-degree agreement. Currently, the program has a double degree agreement with the Higher School of Chemical Engineering (ESIC) of the University of Lorraine (Nancy, France) and process agreements with the Polytechnic Institute of Milan (Milan, Italy), the group of Paris Technology Schools (Paris, France) and the National Institute of Applied Sciences - INSA (Lyon, Rennes, Rouen, Strasbourg, Toulouse and Center Val de Loire, France).

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

a) **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 Faculty of Engineering, the Department of Chemical and Environmental Engineering, the Chemical Engineering Career, the Profession and the Chemical Engineering Professional, among others, in order to initiate their approach to student life and to the work of the chemical engineer

b) **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.

c) **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.

d) **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

e) **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.

f) **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 (Table 5-10).

g) 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.

h) 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 polymeric, biological and catalytic materials, among others, including the nanoscale (Table 5-13).

i) Group of Technical Electives

Besides the courses listed in Table 3, this group includes the graduate courses 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. The current lines of research are:

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

Additionally, 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). Based on these lines, the curricular routes presented in Table 18 were defined.

Table 18. Curricular Routes of the Chemical Engineering Program

Route	Objective	Courses
Catalytic and Petrochemical Processes	To acquire the concepts to perform professionally 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	Catalytic Technologies and Applications
		Principles of Heterogeneous Catalysis
		Oil and Gas Engineering
		Environmental Catalysis
Biotechnological Processes	To acquire the concepts to perform professionally or participate in research or innovation processes in topics related to biotechnological processes for obtaining chemical products and the identification of other applications in agro-industry and in sectors such as food, beverages and health.	Introduction to the biochemical Engineering
		Enzymatic Engineering
		Modelling and Simulation of Biochemical Processes
		Operations of Control and Separation in Bioprocesses
		Advanced Biochemical Engineering
Biorefineries and biofuels	To acquire the concepts to perform professionally or participate in research or innovation processes in topics related to biorefineries and biofuels, focusing on the design of chemical, biochemical and thermal processes that are used in	Biorefineries and Biorefining
		Biodiesel and Oleochemistry

	this type of industrial facilities. The student has an approach to the economic, social, technological and political context of biorefineries, with emphasis on biofuels and chemical products.	Bioethanol and Alcoholchemistry
		Catalytic Technologies and Applications
		Environmental Process Design
Materials – Polymeric Materials	To acquire the concepts to perform professionally or participate in research or innovation processes in topics related to the characterization, synthesis and transformation of polymers. To acquire the concepts to begin and develop the required knowledge for the characterization, production and use of different material, with an approach to the Nano-scale.	Introduction to the Engineering of Polymeric Materials
		Polymerization Processes
		Polymers Transformation
		Physiochemistry of Polymers
Materials – Inorganic Materials	To acquire the concepts to begin and develop the required knowledge for the characterization, production and use of different material, with an approach to the Nano-scale. To perform professionally or participate in research or innovation processes in topics related to the emissions of industrial processes, including their controls and effects on the environment, the human health and the climate.	Introduction to the Materials Engineering
		Catalytic Technologies and Applications
		Materials Characterization

Environmental Engineering – Air Quality	To perform professionally or participate in research or innovation processes in topics related to the emissions of industrial processes, including their controls and effects on the environment, the human health and the climate. To acquire the concepts to perform professionally or participate in research or innovation processes in topics related to the treatment of industrial wastewater.	Colombian Environmental Context
		Mathematical and Numerical Methods in Environmental Engineering
		Atmospheric Pollution
		Emissions from fixed sources
		Emissions from mobile sources
		Air Quality Modelling
Environmental Engineering – Water Quality	To acquire the concepts to perform professionally or participate in research or innovation processes in topics related to the treatment of industrial wastewater. To acquire the concepts to perform professionally or participate in research or innovation processes in topics related to the management of hazardous and non-hazardous waste (generation, classification, transport, utilization, treatment and disposition).	Colombian Environmental Context
		Mathematical and Numerical Methods in Environmental Engineering
		Environmental Catalysis
		Water Quality
Environmental Engineering - Wastes	To acquire the concepts to perform professionally or participate in research or innovation processes in topics related	Colombian Environmental Context

	to the management of dangerous and non-dangerous waste (generation, classification, transport, utilization, treatment and disposition). To perform professionally or participate in research or innovation processes in topics related to the mitigation and prevention of the environmental impacts of the chemical industry.	Mathematical and Numerical Methods in Environmental Engineering Integral Management of Dangerous Waste Pollution Prevention
Environmental Engineering – Sustainable Chemical Processes	To perform professionally or participate in research or innovation processes in topics related to the mitigation and prevention of the environmental impacts of the chemical industry. To deepen the topics related to the thermodynamics, consolidate the acquired knowledge in the courses and expand the spectrum of possibilities that thermodynamics offers for the estimation of properties, the equilibrium in systems with chemical reactions and the equilibrium of phases in separation processes.	Colombian Environmental Context Colombian Industrial Context Environmental Processes Design Pollution Prevention Case-Studies Workshop 1
Thermodynamics	To deepen the topics related to the thermodynamics, consolidate the acquired knowledge in the courses and expand the spectrum of possibilities that thermodynamics offers for the estimation of properties, the equilibrium in systems with chemical reactions and the equilibrium of phases in separation processes. To deepen the topics related to the analysis and design of reactors, with emphasis on phenomena of *momentum*, heat and mass transfer that occur in this	Molecular Thermodynamics Thermodynamics of cycles Physiochemistry of Polymers Advanced Thermodynamics

	type of equipment. Likewise, it gives an approach to new kinetic models and to the study of real reactors.	
Analysis and Design of Reactors	To deepen the topics related to the analysis and design of reactor, with emphasis on phenomena of *momentum*, heat and mass transfer that occur in this type of equipment. Likewise, it gives an approach to new kinetic models and to the study of real reactors. To deepen the knowledge of concepts, techniques, tools and methodologies of analysis, modeling, simulation, optimization and process control.	Transport Phenomena
		Heterogeneous Processes
		Reactors Analysis
Process System Engineering	To deepen the knowledge of concepts, techniques, tools and methodologies of analysis, modelling, simulation, optimization and process control.	Modelling and Simulation of Chemical Processes
		Modelling and Simulation of Biochemical Processes
		Process Control Engineering
		Process Optimization in Chemical Engineering
Economy and Administration	To expand the knowledge in economy and administration and develop advanced management skills.	Modern Management Tools
		Design, Management and Evaluation of Projects
		Market Research

Food Engineering	To acquire the concepts to perform professionally or participate in research or innovation processes in topics related to food engineering, including conservation, transformation and analysis of food.	Introduction to Food Engineering
		Sensory Analysis
		Milk Science and Technology
Master's in engineering – Chemical Engineering	To advance in the postgraduate education. The student that follows this route can take credits of the main component of the Master in Engineering – Chemical Engineering as technical electives. With these courses, the student will acquire advanced concepts in transport phenomena and thermodynamics and will have a general vision of the Colombian chemical industry.	Transport Phenomena
		Colombian Industrial Context
		Advanced Thermodynamics
Master's in Engineering – Environmental Engineering	To advance in the postgraduate education. The student that follows this route can take credits of the central component of the Master in Engineering – Environmental Engineering as technical electives. With these courses,	Dynamics of Physicochemical and Biological Processes

	the student will acquire advanced concepts of physicochemical and biological processes involved in the environmental engineering. The students will also learn mathematical and numerical methods applicable to the environmental engineering issues and will have a general vision of the environmental overview in Colombia.	Colombian Environmental Context
		Mathematical and Numerical Methods in Environmental Engineering

j) Group of Research and Innovation

The description corresponding to this group is presented in section D.3.

C.4 Curriculum actualization

Planning, self-evaluation and continuous improvement are an essential part of the institutional policies of the National University of Colombia (Curricular Area of Chemical and Environmental Engineering, 2010). In Agreement 033 of 2007, the CSU establishes the Management for Academic Improvement, as a principle for the processes of student education, which implies to

> *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.*

Likewise, Article 33 establishes that

> The curricular programs must be evaluated periodically, with the participation of the university community. This evaluation should lead to the preparation of plans of improvement, within the framework of the global development plan of the Universidad Nacional de Colombia.

Agreement 151 of 2014 standardized the process of self-evaluation and monitoring of the quality of the curricular programs of the institution (Curricular Area of Chemical and Environmental Engineering, 2015). It establishes that annual monitoring of the quality of the program will be carried out based on indicators, previously defined by the National Undergraduate Programs Directorates, and defines the responsible areas of this process.

In the specific case of the Chemical Engineering Program, three self-assessment processes have been carried out in the last 15 years. The first one, in 2003, was in the framework of the University's assessment process. The second one, in 2005, resulted in the high-quality accreditation of the Program for a period of 6 years by the National Accreditation Council (CNA). The third one was made in 2010, for a period of 8 within the framework of the 2009 Call for the Mercosur University Career Accreditation. As a result, the Undergraduate Program in Chemical Engineering obtained the High-Quality Accreditation by the CNA for 8 years, and the international recognition of the Iberic-American Network for the Accreditation of the Quality of Higher Education (RIACES). In 2015, the program evaluation was made based on 22 indicators distributed in the factors of students, professors, academic processes, graduates, and national and international visibility.

In the case of the first the curriculum modifications emerge generally from the analysis and proposals of the professors of the Program and are presented to the Advisory Committee. They analyze them and elaborate a second proposal to submit it to the Committee of Area Directors, who approve it for its presentation to the Faculty Council. The modifications are divided into significative and non-significative. The first type includes changes related to credits, components and groups and require the approval of the Campus Academic Direction. The second type involve requirements and courses of the Free Choice component. In this case, the approval of the Faculty Council is enough for its implementation.

In 2014, the program initiated the self-assessment process within the framework of the Accreditation Board for Engineering and Technology (ABET), which involves the implementation of a continuous assessment system for compliance with the educational results defined by the program. This system will allow to know whether the goals are fulfilled or not with respect to these educational results. Through this analysis, the aim is to identify successes and failures, and propose actions for improvement or reinforcement. The assessment system began to be implemented in the second half of 2015.

C.5 Pedagogical 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 Campus Bogotá. The courses that integrate the Study Plan are classified according to its modality.

a) 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 expositions, 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 a modular scheme. With this scheme, 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 for the design of processes, equipment and plants, as well as for its integration and optimization, with a scope close to the professional practice as processes engineer. This methodology allows them to carry out from the conceptual design of a chemical transformation process, including the thermal and mass integration and its optimization, the realization of the conceptual and basic engineering of a process plant, including approximation, to the detailed design made by other engineering specialties.

The theoretical - practical courses correspond to those offered by the Physics Department of the Faculty of Sciences, Fundamentals of Mechanics and Fundamentals of Electricity and Magnetism, which are developed in three weekly sessions of 2 hours each: one corresponds to laboratory practice, another one to lectures. and the final session to an exercise workshop. The lectures are supported by demonstration experiments in the classroom. The Physics Department has sufficient resources to carry out the laboratory activities involved.

b) Practical courses

From the methodological point of view, the practical courses of the curriculum are divided into the group of Chemistry and Biology (e.g. *Laboratories of Basic Techniques in Chemistry*, *Principles of Chemical Analysis* and *Principles of Organic Chemistry*) and the Core 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.

c) Workshops

The Curriculum includes three workshops that aim to integrate the knowledge and concepts developed in different stages of the education process, strengthen oral and written communication skills and develop teamwork. These are Workshop 1, Workshop 2 and the Interdisciplinary Projects Workshop (TPI), which are strategically located in the IV, VI and IX semesters, respectively.

Although each workshop has a particular methodology, all have in common the development of projects throughout the semester as the main component. In these projects, in addition to the integration of knowledge and the promotion of skills such as the aforementioned teamwork and oral communication, it promotes the search for information with modern tools, the synthesis and writing of texts, and the contextualization of Chemical Engineering at the 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, the student is expected to approach the knowledge of the political, social and economic conditions of the country, delve the identification of natural resources, the needs and opportunities of regional development, and select a raw material to obtain a product that aggregates value, emphasizing on the experimental component and on innovation.

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

d) Final Work Degree

All the students of the Universidad Nacional must complete a Final Work Degree, in any of the modalities defined, in accordance with the requirements of Agreement 033 of 2007 of the CSU[1]:

> *It is a special course where the students strengthen, apply, employ and develop their research capacity, creativity and work discipline in the treatment of a specific problem, through the application of knowledge and methods acquired in the development of the study plan of their curricular program. Its objective is to promote autonomy in the realization of scientific, scientific-technical and creative works of their own discipline or profession. For the planning of the work of degree, the undergraduate programs may include in the curriculum courses such as research seminars or academic, research or creation practices.*

The modalities of the Final Work Degree defined in this agreement are:

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

For the Chemical Engineering curriculum, the following are considered applicable:

[1] See CSU, Agreement 033 of 2007: http://www.legal.unal.edu.co/sisjurun/normas/Norma1.jsp?i=34245

• Research work: Participation in research projects and final project.

• Specialized consultancy practices: Participation in teaching-assistance programs, internships, business entrepreneurship and social projects.

• Degree Option: Postgraduate courses.

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

Through research projects, the students link with the research groups of the University and begin their education as a researcher, which will continue in the postgraduate level. 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 also be recorded 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.

e) 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" and "Marta Traba".

f) 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 needs of leveling in mathematics, reading and writing and foreign language sufficiency. 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 study plans. The courses correspond basically to mathematics and writing and reading comprehension in Spanish and English. The DNA 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 comprehension. In particular, the approval in basic mathematics determines the possibility of starting the courses of Mathematics which, in turn, are prerequisite of several courses of the Foundation and Disciplinary Components of the Curricular Program.

In terms of Proficiency in English, the University requires the approval of 12 credits. In the first stage, a classification test is carried out, which allows ranking the students 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).

g) 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 National University, 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 aprove 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 in the grading of 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. "

h) Student Assistance System

The Student Assistance System (CA, Agreement 028 of 2010) 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 (CA, Agreement 028 of 2010). Thus, students of the program have a tutor, who they meet since the Induction week to the University and can consult when needing advice on curricular subjects. 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.

A fundamental strategy of the accompaniment system is the course Introduction to Engineering, which in addition to the aforementioned objectives, allows that the professors of the program attached to the Department of Chemical and Environmental Engineering know the students from the first semester, and identify strengths and possibilities for improvement. In addition, in this course, the initial phase of the "Program of Promotion of Formative Character: Communication between the Physical and the Emotional" (COMFIE) is developed. This program began in 2008 and its central objective is that the participating student

> *be empowered, from the recognition of their own conception of health and personal experiences, from the management of their well-being, to impact in a positive way their academic performance and strengthen a culture of promotion in this matter*

i) Relationship between the curriculum courses and the profile of the graduate

The profile of the graduate and the education outcomes introduce the need to generate or strengthen diverse capacities, abilities and competences in the students. The following is a description of the way in which these competences are addressed in the courses of the Curriculum and in the activities associated with it.

The courses of the Foundation Component contribute significantly to the scientific education and promote dialogue with different partners and teamwork. Laboratories and workshops are common in this component. Scientific and technological education is constant, and is promoted through lectures, exhibitions, questionnaires, workshops, evaluations and projects. In these, teamwork is fostered in activities that frequently involve the formation of work groups, where an adequate organization is required to meet the proposed objectives, within the deadlines defined 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 Reactions 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 ability to create a company is developed in the courses Introduction to Chemical Engineering, 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.

Research, technological development and innovation are promoted in all courses of the Disciplinary Component and consolidated in the Final Work Degree. It comprises projects and activities that involve some characteristics associated with these abilities, such as search, identification and selection of scientific and technological information, as well as its interpretation and appropriation for the solution of problems with different constraints.

There is a continuous dialogue with the national and international specialized community. From the Introduction to Chemical Engineering course, talks are offered, and students are invited to involve early in research groups and student work groups, and to attend conferences, seminars, meetings, technical weeks and specialized lectures.

Throughout their education process, students can participate in the technical visits scheduled by the Chemical Engineering Department, three per semester, to visit local, regional and national industries.

They can also attend the Defenses of Master's and Doctorate Thesis of the different programs of the Curricular Area and have access to technic specialized documentation. Once a year, they can take the International Course of the Faculty of Engineering that bring international researchers and expositors of known prestige. Some students participate in academic exchanges or double-degrees with universities and institutions in countries such as Germany, France, Italy, the United States, Mexico and Spain.

Teamwork and knowledge among students and the national and international community is encouraged since the first semesters. The creation of or the incorporation into work groups by students may have academic, environmental, union, social, leisure or sportive objectives. For instance, there are: The Student Chapter of the AIChE of the Universidad Nacional de Colombia - Bogotá Campus, the Student Group of Chemical Engineering-UN (Geiqun), the National Encounters of Chemical Engineering Students (Eneiq), the University Olympiads of Engineering (OUT-UN), the Colombian Association of Chemical and Processes Engineering (Aceiquip) and the Latinamerican Congresses of Chemical Engineering Students (Colaeiq).

Designing and improving products, equipment, processes and transformation plants is an ability developed in the courses of the Disciplinary Component. In the early stages, the recognition of the elements that contribute to the design 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.

Figure 3 presents the relation between the student outcomes and the courses of the Disciplinary Component of the curriculum.

	Thermodynamics						Professional Context	Unit Operations							Chemical and Biochemical Processes							Research and Innovation				
Conventions: 3 (Green)- Main component (<25%), 2 (Orange)-Important component (10-25%), 1(Red)-Minority component (5-10%), I(blue)-Occasional(<5%) component,	Thermodynamics (2015741)	Chemical Thermodynamics (2015740)	Workshop 1 (2015735)	Energy Balance and Chemical Equilibrium (2015707)	Molecular Thermodynamics (2015739)	Thermodynamics of cycles (2015738)	Introduction to Chemical Engineering (2015718)	Mass Balance (2015708)	Fluids (2015714)	Solids Handling (2015726)	Heat Transfer (2015743)	Mass Transfer (2015744)	Workshop 2 (2015736)	Separation Operations (2015731)	Chemical Reaction Engineering (2015716)	Design of Chemical and Biochemical Processes (2015713)	Process Control (2015710)	Modelling and Simulation of Chemical Processes (2015729)	Modelling and Simulation of Biochemical Processes (2015728)	Process Engineering (2015715)	Design of Plants and Equipment (2015712)	Lab. thermodynamics and Transport Properties (2015721)	Lab. Fluids, Solids and Heat Transfer (2015719)	Lab. Separations, Reaction and Control Operations (2015720)	Interdisciplinary Projects workshop (2024045)	Final Work Degree (2015289)
Ability to apply knowledge of mathematics, science, chemical and biological sciences, in Chemical Engineering	3	3	2	3	3	3	1	3	3	3	3	3	1	3	3	3	3	3	3	1	3	3	3	1	1	3
Ability to use the techniques, skills, and modern engineering tools necessary for the Chemical Engineering practice	1	2	1	1	2	2	I	1	2	2	2	I	I	2	3	2	3	3	3	3	1	2	3	2	1	3
Ability to design and conduct experiments, as well as to analyze and interpret data	1	2	1	2	2	3	I	1	3	1	1	1	2	1	1	1	1	2	2	2	1	3	3	3	1	3
Ability to design systems, components, products and/or processes to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety manufacturability, and sustainability	0	I	1	0	I	1	I	1	1	3	1	2	1	1	2	3	2	1	1	3	3	1	2	3	2	3
Ability to function on teams	1	1	3	1	1	1	3	1	2	1	2	1	3	2	I	2	1	1	1	2	2	3	3	3	3	1
Understanding of professional and ethical responsibility	2	1	2	1	1	1	2	1	2	0	1	1	2	2	I	2	I	1	1	1	2	2	2	1	1	3
Ability to communicate effectively in Spanish	2	1	3	1	1	1	2	2	2	1	1	1	2	2	1	1	1	1	1	1	1	2	2	1	2	3
Ability to communicate effectively in English	1	I	I	I	1	I	I	I	I	I	I	I	1	1	I	1	1	1	1	2	1	1	0	2	0	1
The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	2	I	3	2	I	1	1	1	2	1	1	2	3	2	I	2	1	1	1	2	3	2	2	1	2	3
Recognition of the need for, and an ability to engage in life-long learning	1	1	2	1	1	1	I	2	2	I	1	1	1	2	1	2	0	1	1	1	1	2	2	1	I	3
Knowledge of contemporary issues	2	I	2	I	I	2	2	1	I	I	1	1	2	2	I	I	I	1	1	I	1	1	0	0	2	1
Ability to participate in research, innovation and / or entrepreneurship processes.	I	I	1	I	I	I	I	I	I	I	1	1	1	I	I	I	0	0	0	0	0	2	I	I	3	3

Figure 3. Relation between the student outcomes and the courses of the Disciplinary Component of the curriculum

D. ARTICULATION WITH THE MEDIUM

D.1 Academic Mobility

The academic mobility of the program comprises outgoing and incoming, national and international exchanges. In outgoing national mobility, students of the program can have an academic experience in the other campuses of the University or in national universities with signed agreements, where they can take courses or participate in research projects. In the national incoming mobility, students of other chemical engineering programs or related programs from other campuses or universities with signed agreements can take courses of the curriculum. The same description applies to international mobility, but with foreign institutions.

Since 2005, the international mobility of students has been a fundamental objective of the Faculty of Engineering. For this reason, the Office of International Relations of the Faculty has developed the Best Averages Program, which aims to (ORI, 2015):

"support engineering students to participate in exchanges and other international academic activities and to define strategic alliances with national and international higher education institutions. In the medium and long term, it will accentuate and verify the academic quality of engineering graduates of the UN and its undergraduate and graduate curricular programs in an international environment, through an international education in accordance with the demands of today's world ".

This program has allowed students to carry out international exchanges or participate in double degree agreements. Some of the institutions where students perform these types of activities are: the University of Purdue, New Mexico, Oklahoma and Wisconsin in the United States; the ParisTech Schools Group, the INSA Group, the University of Lorraine (double degree with the ENSIC) and the INP of Grenoble in France; the Polytechnic of Milan in Italy; Hochschule Offenburg, the Universities of Stuttgart and Duisburg Essen, the TU München, Dresden, Cottbus and Darmstadt, in Germany. Likewise, a framework agreement is negotiated aiming to double degree with the University of Santiago de Chile. In the period 2010 - 2015, more than 150 students, from the Chemical Engineering Program, had experiences of this type.

Other activities that allow the internationalization of students are the International Seminar of Engineering and the International School, which allow students who can not leave the country to have an internationalization experience and receive specific courses on current issues in chemical engineering, by professors and international experts who visit the University in the inter-semester periods at the beginning and the middle of the year. Table 19 presents the courses associated with the chemical engineering program in the period 2010 - 2015.

Table 19. Courses associated with the Chemical Engineering program in the framework of the International Course of Engineering and the International School in the period 2010 – 2015

Year	Course	Event Framework
2010	*Material Science of Polymer for Engineering*	IV International Seminar of Engineering
2010	*Nonomaterials: Synthesis, Characterization and Applications*	IV International Seminar of Engineering
2010	*Biorefineries: Principles and Applications*	IV International Seminar of Engineering
2010	*Innovation Engineering and Marketing*	IV International Seminar of Engineering
2010	*Science and Engineering of Climate Change*	IV International Seminar of Engineering
2011	Engineering and Marketing of Innovation: From idea to market	V International Seminar of Engineering
2011	Security in Process Engineering	V International Seminar of Engineering
2011	Advances in Polymers Science and Engineering: Biomaterials, engineering, simulation and polymerization	V International Seminar of Engineering
2012	Lignocellulosic Ethanol	VI International Seminar of Engineering
2012	Advanced Separation Operations	VI International Seminar of Engineering
2013	Advanced Separation Operations: Technologies of Separation in Biorefineries	VII International Seminar of Engineering
2013	Engineering and Marketing of Innovation: From idea to market	VII International Seminar of Engineering
2014	Advanced Separation Operations: Technologies of Separation in Biorefineries	VII International Seminar of Engineering
2014	Electricity Production and Storage Technologies for Mobile and Residential Applications	VII International Seminar of Engineering

2014	*Enhanced Oil Recovery: Techniques, Practices and Simulation*	VII International Seminar of Engineering
2014	*Process Control Engineering*	International School 2014
2014	*48 Heures pour Faire Emerger des Idées dans la Salle de Classe*	International School 2014
2015	*Process Synthesis, Optimization and Control*	International School 2015
2015	Advanced Separation Operations: Technologies of Separation in Biorefineries	VIII International Seminar of Engineering

D.2 Student Practices and internships

a) Student practice

The flexible component of the curriculum allows students to carry out a Student Practice. This activity is conceived as an opportunity for the student to acquire work experience within their education process. Student practices are also a possibility to create links between the University and companies, which can be translated into internships or projects of research, innovation and technological development. Besides being tutored by an employee of appropriate level, designated by the company, the student is under the supervision of a professor of the Program during the practice. Some of the companies where the students of the program carry out student practices include Ecopetrol, Equion, Brinsa, Family Products, Polar Food, Belstar, Bavaria, Carbones del Cerrejón, Casa Luker, Quala, Soya and Firmenich, among others.

b) Internship

As mentioned in section C.5, the syllabus contemplates the completion of a Final Work Degree. One of its modalities is specialized consultancy practices, and among them, internships are one of the most popular activities for students. Unlike student practices, the internship allows students to develop a specific project of interest to the company, where they apply their knowledge, ability to plan, teamwork, communication and participation in research processes, innovation or entrepreneurship, for the solution of a problem. As in student practices, the student has the tutoring of a professor of the Program and of a responsible employee in the company.

c) 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 career. 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 chemical and biochemical processes group that the student be taking.

D.3 Articulation of research

The articulation of research is carried out in the courses of the correspondent group, which comprises the laboratories of the Professional component, the Workshop of Interdisciplinary Projects (TPI) and the Final Work Degree. The objective is that the students perform, as members of a team in the first two (Laboratories and TPI) and individually in the last (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 location 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

Additionally, students of the program can be linked to research groups since the first semesters. Table 20 presents the research groups that belong to the Department of Chemical and Environmental Engineering, including the classification according to the Call for Recognition and Classification of Colciencias Groups of 2014, and a summary of the academic products generated by each one of them.

Table 20. Research groups of the Department of Chemical and Environmental Engineering including their productivity in the period from 2010 to 2014, and the classification according to the Call for Measurement of Research Groups of 2014.

Research Group	Classification	Product	#
Air Quality	Recognized	Papers	21
		Courses given	2
		Conferences	52
		Books	2
		Projects	31
Research Group on materials, catalysis and environment	D	Papers	15
		Book Chapter	3
		Projects	5
Research group on chemical and biochemical processes	A1	Papers	73
		Book Chapter	3
		Courses given	7
		Scientific Event	21
		Books	7
		Projects	34
Process Systems Engineering	c	Papers	7
		Projects	5

D.4 Articulation with graduates

The policies for the follow-up of graduates are detailed in Agreement 014 of 2010 of the CSU, "By which the Graduate Program of the Universidad Nacional de Colombia is restructured and consolidated". The objectives of the Graduate Program are:

• Consolidate and continuously improve the Graduate Information System for communication among them, the University and society in general.

• Support the participation of graduates in the development and updating of the academic programs offered by the University, in research and specialized consultancy activities, as well as in other processes belonging to the University.

• Establish alliances with graduate associations of the University in order to carry out events of various kinds that contribute to fulfilling the mission and goals of the University.

• Encourage, stimulate and contribute with the documentation of the history of the Universidad Nacional de Colombia through the realization of their graduates and their impact on society.

• Strive for establishing mechanisms that allow the strengthening and expansion of closer relations between the University and its graduate.

• Promote studies on the impact and conditions of graduate at the local, regional, national and international levels.

• Strengthen the graduates' sense of belonging to the University, in order to revert to their interest in it.

The execution of the program is in charge of the Vice-Rectors' Office of the Campus and the Directorates of National Presence, with the support of the dependency of of welfare in each Campus articulated with the Faculties. For this purpose, each Dean will designate a responsible for the Graduates Program in its Faculty.

Since 2003, the Chemical and Environmental Engineering Department and Area have been organizing each year the Colloquium of Chemical Engineers of the Universidad Nacional de Colombia. It is a space designed for meeting graduate, professors and students. Graduates share their knowledge and experience with other members of the academic community of the program; professors present their advances in teaching and research; and students expose their research and their curricular activities different from courses.

Another space for the articulation of graduate is the inclusion of one of them in the Program Committee and their active participation in the different self-assessment processes of the Chemical Engineering program (the most recent in 2010), as well as in other programs of the Area (2012, 2013 and 2015).

Additionally, since 2015, the UN Graduates Seminar and the course *Special Topics in Chemical Engineering* have been implemented. In these academic activities, the graduates design and develop a course, in coordination with the professors of the Department, to share their knowledge with other graduates, students and teachers. Table 21 lists the courses taught in the framework of this program.

Table 21. Courses of the Chemical Engineering program in the framework of the articulation with the graduates in 2015

Year	Course	Participants
2015	UN Graduates Seminar: for the UN – Refining Industry and Process Engineering	Antonio Joya López (Tipiel), Gerardo Villamizar Plata (Tipiel), Marcelo Cavallazzi (IST Internacional), Óscar Peñaranda (IST Internacional), Jorge G. Vásquez (Tipiel),

		Andrés Saavedra Salinas (Tipiel), Jaime Rodríguez Acevedo (Equion Energy)
2015	*Special Topics in Chemical Engineering – Security in Process Plants*	Gerardo Villamizar Plata (Tipiel)

For this articulation, in 2016, the course *Let's Talk about Chemical Engineering* will begin, where graduates who work in a specific sector will share their experience about their professional and personal practice, with students and professors.

E. SUPPORT TO CURRICULUM MANAGEMENT

The Chemical Engineering Program of the Universidad Nacional de Colombia, Campus Bogota, is responsibility of the Curricular Area and the Department of Chemical and Environmental Engineering of the Faculty of Engineering. The administrative organization of the University and the Faculty are described below, as well as the resources available to the program for the development of its activities.

E.1 Administrative organization

The National University of Colombia is a higher education institution, public and state, autonomous and independent, whose complexity is reflected in the intensity of its basic functions: teaching, research and specialized consultancy. Currently, it has eight active campuses: Bogotá, Medellín, Manizales, Palmira, Amazonia, Orinoquia, Caribe and Tumaco.

In accordance with Article 1 of the General Statute (CSU, Agreement 011 of 2005),

> The Universidad Nacional de Colombia fulfills, on behalf of the State, non-administrative functions aimed at promoting the development of higher education to its highest levels, promote access to it and develop teaching, research, science, artistic creation and the specialized consultancy , to reach excellence and the aims indicated in article 2 of the Extraordinary Decree 1210 of 1993 and in this Statute

Article 11 of the General Statute (CSU, Agreement 011 of 2005) establishes that the Government of the Universidad Nacional de Colombia is constituted by:

- The Superior University Council.
- The Campus Councils.
- The Vice Rectors.
- The National Financial and Administrative Manager.
- Campus Directors of National Presence.
- The Faculty Councils.

- The 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 establishes the levels of management and the academic and administrative organization, as follows:

- National level
    - Superior University Council.
    - Rectory.
    - Academic Council.
    - Academic, General and Research Vice-Rector's Offices and their divisions.
    - National Financial and Administrative Management and its divisions.
    - General Secretariat and its divisions.
    - Committee of Vice Rectors.

Figure 4 shows a simplified flowchart of the National level of the University.

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

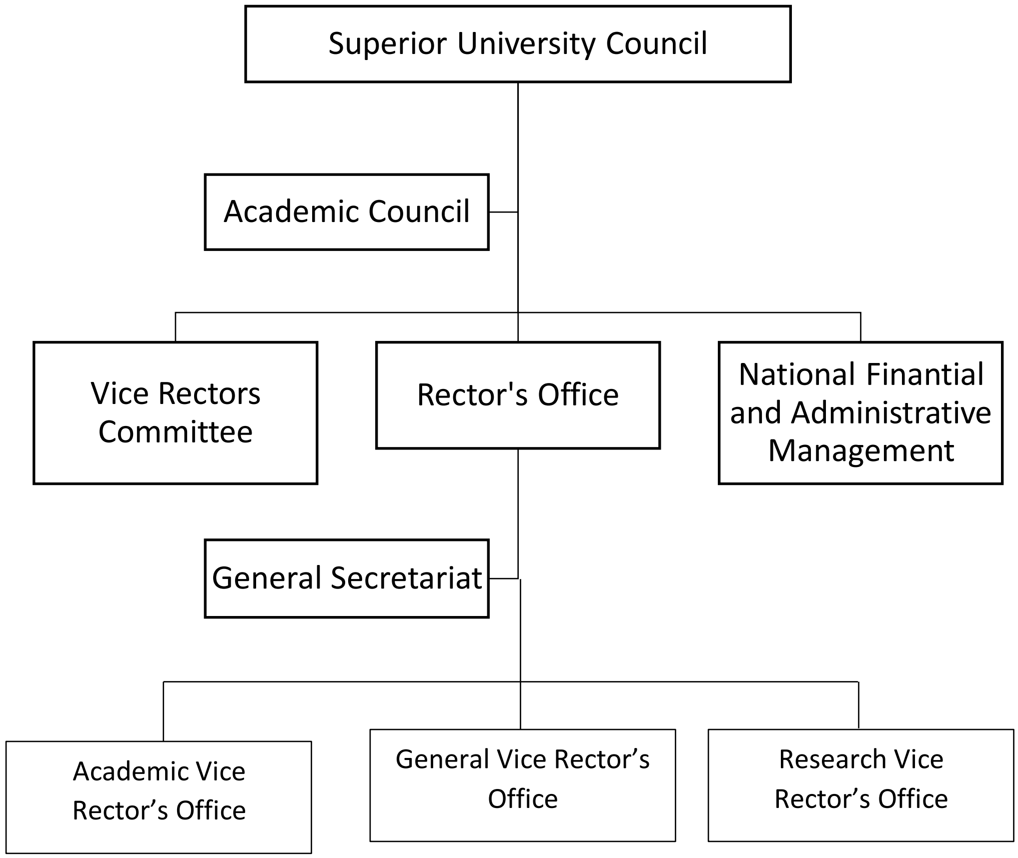


Figure 4. Simplified Flowchart of the National level of the Universidad Nacional de Colombia

The simplified flowchart of the Campus level of the University is depicted in Figure 5.

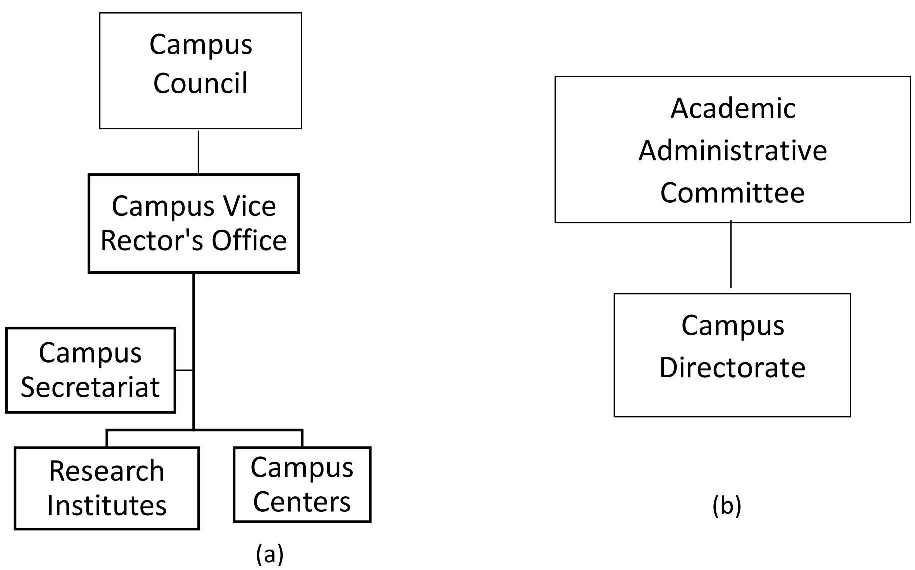


Figure 5. Simplified Flowchart of the Universidad Nacional de Colombia. (a) Campus Level. B) National Presence Campus Level

Figure 6 show the flowchart of the Faculty of Engineering

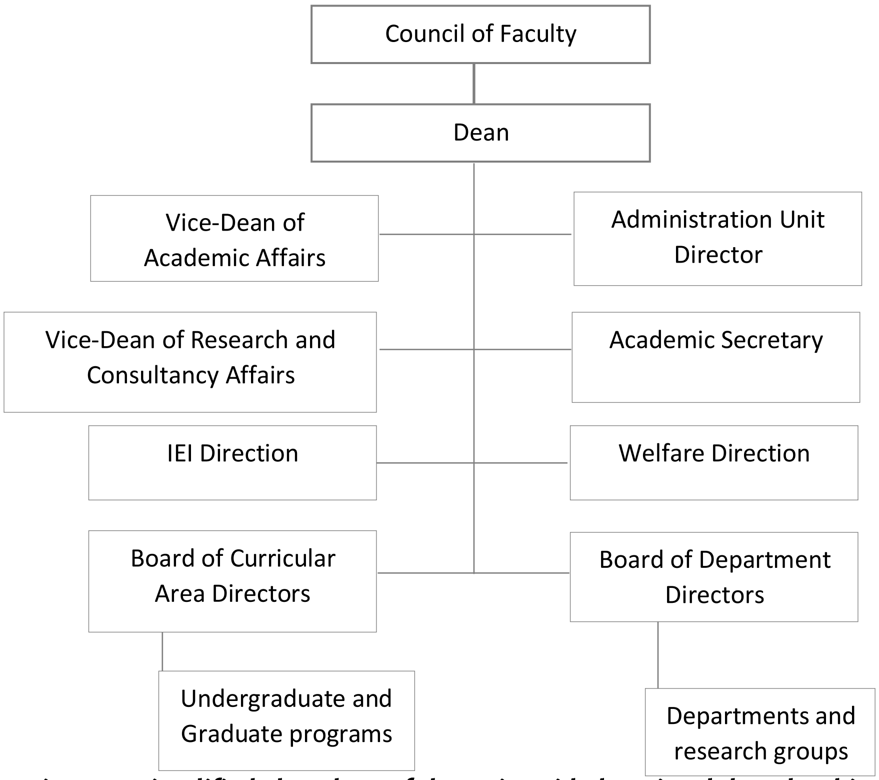


Figure 6. Simplified Flowchart of the Universidad Nacional de Colombia. Level of faculty

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
- Director of the Chemical Engineering Laboratory

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

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

E.2 Professors

The teaching staff associated to the program correspond to the professors of the Faculties of Sciences (Departments of Mathematics, Statistics, Chemistry, Biology and Physics), Economics and Engineering, who teach courses of the curriculum. In particular, the teaching staff assigned to the Department of Chemical and Environmental Engineering are responsible for the courses of the disciplinary component. Professors from the other faculties of the University, who offer free choice courses, are also included.

Currently, the Department of Chemical and Environmental Engineering has 41 professors: 32 of them have Exclusive Dedication (78%), five are full-time (12.2%) and four are lecturers (9.8). This distribution represents 44.6 full-time equivalents. 51.2% (21) of them have the maximum Phd. education, 36.6% (15) have a master's degree, 4.9 (2) have a specialization and 7.3 (3) are engineers. With respect to their categories, 14.6% (6) are full professors, 51.2% are associate professors, 26.8% (11) are assistant professors and 7.3% (3) instructors.

E.3. Physical resources and support for teaching

E.3.1 Physical resources

The Universidad Nacional de Colombia is the institution of higher education with the largest physical plant in the country: it has about 2.5 million m2, distributed in its eight campuses. From 606,241 m2 built for academic activities, 398,173 (67.7%) are located in Bogotá. Since 2012, the campuses of the University have occupied the first place as environmentally sustainable campus in the GREENMETRIC (Greenmetric, 2014) at national level, fourth place in Latin America and 107 worldwide. It also has excellent academic support systems, such as libraries, laboratories and computer resources. The University also has a bibliographic collection of about 1,500,000 volumes, from which 1'119,552 correspond to the Bogota Campus. To provide adequate attention to all students and professors in its different locations, the National Library System (SINAB) has twenty-two (22) fully equipped libraries; nine (9) of them have exclusive buildings and thirteen (13) are located in different Faculties and Institutes.

The Universidad Nacional also has 646 laboratories: 480 of them are located in Bogota Campus and 72 in the Faculty of Engineering (ONP, 2009). In Bogota, 49% of the use time of use of laboratories corresponds to teaching functions, 38% to research functions and 13% to specialized consultancy . The practical courses of the disciplinary component of the program are mostly developed in the Chemical Engineering Laboratory, which has 3,200 m2 built, 7 laboratories and 2 computer rooms.

The Chemical Engineering Program of the Bogotá Headquarters has, specifically, the following resources:

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 Faculty of Engineering of the Bogota Campus for academic activities consists of the following buildings:

- 401: Insignia Building - Julio Garavito Armero
- 406: Institute of Specialized consultancy and Research - IEI
- 407: Building of Postgraduate in Materials
- 409: Hydraulic Laboratory
- 411: Electrical and Mechanical Engineering Laboratories
- 412: Chemical Engineering Laboratory
- 421: Camilo Torres Buildings
- 453: Engineering Classroom Building
- 454: Science and Technology Building - Luis Carlos Sarmiento Angulo

The classrooms, auditoriums and laboratories, where the courses and other activities of the Chemical Engineering Program are developed, are mainly located in the Insignia Building - Julio Garavito Armero, the Engineering Classrooms, the Science and Technology Building and the Chemical Engineering Laboratory.

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

Five classrooms in building 453, 40 m2 each, for a total of 200 m^2.

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

a) Insignia Building - Julio Garavito Armero

The 401-building was reopened in 2014 after a thorough renovation. It has three floors with two auditoriums for 118 people each, 16 classrooms (13 of them for 36 students and three for 60 students each) and three computer rooms, with 52 computer each. This building houses the board offices of the Faculty of Engineering: Dean, Academic Vice-Dean, Research and Consultative Vice-Dean and Welfare Offices.

b) 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). Five of these classrooms are used for teaching the majority of the courses of the Curricular Area of Chemical and Environmental Engineering. All the classrooms have audiovisual media. This building also holds the Five Boards of the Departments.

c) Science and Technology Building

Building 454 was inaugurated in 2008. It has four floors and a terrace with a cafeteria and spaces for students and professors use. One of the three wings that form the building, has 14 classrooms for 20 students each, equipped with overhead projector and interactive board; two video conference rooms, with capacity for 20 people; and four classrooms with 45 computers each. It has an auditorium with a capacity for 247 people. The Science and Technology Library is loated in this building.

d) Chemical Engineering Laboratory

The Chemical Engineering Laboratory (LIQ) (Building 412) has a built area of 3,200 m^2, on a plot of 2,030 m^2. The first floor has the specialized laboratories: Pilot Plant (1000 m^2), Catalysis (184 m^2), Fuels and Lubricants (55m^2), Instrumental Analysis 1 and 2 (66 m^2), Polymers (44 m^2), Thermodynamic and Transport Properties (102 m^2), HPLC and Bio-processes (60 m^2), extended with a mezzanine (72 m^2). On the second floor, there are seven professors' offices, two computers rooms as classrooms and for tutoring in courses that require computational tools, a room for graduate students (43 m^2), the LIQ coordination office (which includes the secretary's office, a meeting space and a monitor office), plus two terraces, with areas of 232 m^2 and 76 m^2. On the third level there is another terrace of 435 m^2[2]. The western side of the building has the Industrial Services areas, formed by: a general patio (90 m^2), where the underground process water storage tank, its pumping systems and the room for chemicals storage are located; a boiler room (78 m^2); and a storage room for maintenance materials, where the compressed air systems (16 m^2) are located.

On the other hand, for the Chemistry, Physics and Biology courses, the Program receives the services of the Laboratories of the Faculty of Sciences. Likewise, the Mechanical Engineering Laboratories are used for heat transfer practices, the Laboratories of Hydraulics for fluid handling practices, the Laboratories

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[2] López F. y Contreras O. *Elaboración de los Documentos Técnicos del Laboratorio de Ingeniería Química y Replanteamiento de los Sistemas de Distribución de Servicios Industriales*. Degree Project to obtain the title of Chemical Engineer, Universidad Nacional de Colombia, 2003.

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 Interfaculty Laboratories comprise the following:

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

E.3.2 Support for teaching

For the development of the PEP, Professors can use the services of the National Directorate of Virtual Academic Services for the design and implementation of virtual strategies for education, specialized consultancy and research. Some of those services are (DNIA, 2015):

•Support and Advice in MICT: It aims to facilitate the use of information and communication media and technologies, aimed at supporting teaching-learning processes.

• MICT Education: It aims to edcuate in media and information and communication technologies, aimed at supporting teaching-learning processes.

• Virtual Production: It aims to develop educational material, through the review and pedagogical adaptation and the graphic-multimedia proposal.

• Development in MICT: Development of customized applications.

• Production of Audiovisual Academic Content: It aims to register, edit and process audiovisual material generated from content, events and academic activities.

• ICT Classroom Loan: It provides spaces prepared with equipment (video conference codec, interactive boards, computers, video beam and sound) for the development of academic activities.

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 Direction 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 Colciencias and by other external entities.
- National Direction of Virtual Academic Services, which supports the design of virtual courses and the implementation of virtual aids in face-to-face courses.
- Transportation Section, which facilitates external academic activities.
- Help Desk, attached to the National Directorate of Information Technology and Communications (DNIC), which is responsible for the installation, updating and maintenance of software in equipment throughout the Campus.

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

- Academic Vice-Dean.
- Vice-Dean of Research and Specialized Consultancy.
- Administrative unit.
- Academic secretary.

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

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

The bibliographic material related to the Chemical Engineering Course is mainly found in the Central and Science and Technology libraries and in the Newspaper library. The physical facilities of the three libraries are described in Tables 22, 23 and 24.

Table 22. Data sheet of the Central Library (SINAB, 2010)

Item	Number	Item	Number
Area (m^2)	10,255	Workstations for people with disabilities different from the visual	12
Books	312,843	Computers for users service	110
Individual reading points	90	Places in the education room	20

Reading places at the table	408	Media-library	1
Group work cabins	64	Education Room	1
Computer workstations for people with visual impairments	12	Music Room	1
Individual workstations for people with visual impairments	2	Lockers	456

Table 23. Data sheet of the Science and Technology Library (SINAB, 2010)

Item	**Number**	**Item**	**Number**
Area	2,500 m^2	Auditoria	1
Reading points	448	Academic Staff Rooms	1
Computers for users service	295	Lockers	672

Table 24. Data sheet of the Newspaper Library (SINAB, 2010)

Item	**Number**	**Item**	**Number**
Area	12789 m^2	Auditoria	1
Reading points	88	Exposition Hall	1
Computers for users service	48	Event Hall	1

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.sinab.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 and access to the digital library of the University or to graduate services.

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 74 databases, 198,931 e-books, 27,959 titles of online journals and 54,467 titles of other documents in packages of electronic contents, available on the SINAB portal (SINAB, 2010).

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