

Strategy for professionalizing technologists in petrochemical plant operation

Estrategia para profesionalizar tecnólogos en operación de plantas petroquímicas

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Abstract

Colombia's educational policy is now embracing a new approach to undergraduate formation based on propaedeutic cycles. This study presents the design of a system that efficiently links the study program offered by SENA for technicians in petrochemical plant operation with the undergraduate program of chemical engineering offered by the University of Cartagena, using as basis the concept of learning under the modality of propaedeutic cycles. The proposal to link both programs involved the designing of bridging (or validation) modules that addressed those concepts not covered by the technology study program regarding each of the subjects of the basic engineering cycle. The total number of credits validated through this system was defined as well as the way these modules would be offered and other features that enabled the successful interlinking of both programs. The administrative requirements to carry out this type of alliance were also defined.

Key words: Alliances; propaedeutic cycle; undergraduate formation; technology

Introduction

The concerns posed by the knowledge society, particularly the productive sector, can be addressed by competency capacity-building and propaedeutic cycles (Unidades Tecnológicas del Santander, 2006). Formation cycles allow students to enter the work force at each level of formation as different levels of capacity building are offered and students can go back to school and continue their formation in cycles ranging from technical to postgraduate in scope.

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Since 2006, Colombia's National Learning Service (SENA, its Spanish acronym) has made an effort to establish overarching agreements with other higher education institutions (HEIs) in the country. These agreements mainly seek to link the technical and technological programs offered by SENA with different professionalization programs of HEIs, as reflected in SENA's document on sequential education programs (SENA, 2008). This type of interlinking or sequential education—as called by SENA—has had greater acceptance by HEIs of the private sector than those of the public sector.

Sequential education responds to the need to integrate the vocational training provided by SENA, in coordination with Colombia's Ministry of Education, and undergraduate programs offered by HEIs so that SENA graduates can continue their cycle of professionalization and academic formation, thus becoming better qualified to join the work force (SENA, 2014). This study addresses the search for a bridging or validation system to link one of the technological programs offered by SENA, specifically petrochemical plant operation, with the presential program in chemical engineering of the Universidad de Cartagena.

Theoretical Framework

For several decades, continuing education has ranked high on agendas worldwide, together with the challenges of ensuring access to education, adequate coverage, relevance, and quality. The concept of continuing education stems from the work of Philips Coombs (1968) and particularly that of Edgar Faure *et al.* (1972), carried out at a time when traditional education systems were under deep scrutiny.

Looking at the strategies used by other countries to ensure a cohesive continuing education system revealed that higher education in European countries is designed to be carried out in three cycles: bachelors, masters, and doctorate (Asociación Colombiana de Universidades, 2010). Other countries have organized credit-based systems and competency certification in flexible curriculum frameworks that acknowledge previous learning and experience. These experiences not only indicate that there is a strong link between the different components of higher education systems, but that there is also a need to harmonize degree

systems (Asociación Colombiana de Universidades, 2010).

For example, the non-university higher education offered in Argentina is equivalent to the technical and technological education offered in Colombia by teacher training colleges and technical training institutes that offer professional degrees and it is also linked both horizontally and vertically with universities (UNESCO-Argentina, 2010). University education, on the other hand, is offered by well-known universities and academic, scientific, and professional institutions. Universities grant degrees at the undergraduate, graduate (masters), post-graduate, specialization, and doctoral levels (UNESCO-Argentina, 2010).

In Spain, university education is organized in cycles with very specific educational objectives and independent academic value. There are basically four types of university education: (1) short-term, lasting 3 years and leading to a degree of licentiate, for example technical engineer or technical architect; (2) long-term, consisting of two cycles and lasting 4, 5, or 6 years, leading to a degree of licentiate, for example engineer or architect; (c) only a second 2-year cycle leading to a degree of licentiate, such as engineer or architect; (4) a third 1–2 year cycle, after which students receive a diploma of advanced studies (DEA, its Spanish acronym), which is a prerequisite for the preparation of the PhD proposal and the commencement of Ph.D. research. However, in 2007 a new regulatory framework was introduced that established that all curricula must be adjusted to the new structure of university education, which consists of three different levels: grade degrees (undergraduate studies) with a minimum of 240 credits; graduate studies leading to a masters degree with a credit requirement between 60 and 120; and postgraduate studies leading to a doctoral degree (UNESCO-Spain, 2010).

In Mexico, higher education includes short professional, undergraduate or licentiate, and postgraduate programs at regular, technological, and university level. Short-term studies for professional careers last from 2 to 3 years and lead to an advanced technical degree or professional associate degree. These degrees can be credited towards a licentiate degree, thus linking these two levels of higher education (UNESCO-Mexico, 2010).

In the case of Colombia, after Law 749 of 2002 and Law 1188 of 2008 were passed, many public and private universities and HEIs began to design their undergraduate programs based on propaedeutic cycles. All over the country there are educational institutions that offer different programs under this modality, for example the Electrical Engineering program of the Universidad Distrital Francisco José de Caldas (2011); the Pure Chemistry and Pharmaceutical Chemistry programs of the Universidad de Ciencias Ambientales y Aplicadas–Bogotá Campus (2011a; 2011b); the Agroenterprise Management and Financial Management programs of the Universidad del Tolima (2011a; 2011b); and the Business Administration, Public Accounting, Systems Engineering, and Industrial Engineering programs of the Corporación Universitaria Centro Superior (2011a; 2011b; 2011c; 2011d).

At the regional level, in the department of Bolívar, the Technological Center of Virtual and Distance Learning (CTEV, its Spanish acronym, formerly CREAD) of the Universidad de Cartagena, now offers programs in farm management and tourism and hotel management (Universidad de Cartagena, 2011a; 2011b). The Fundación Universitaria Tecnológica of Comfenalco, a family welfare fund, also offers programs in business administration and systems engineering (Fundación Universitaria Comfenalco, 2011a; 2011b). This shows that both public and private HEIs nationwide have supported this type of education in recent years, and several educational programs based on propaedeutic cycles have been offered.

In addition, as a result of the committed lobbying of the regional directors of SENA, over the past few years several HEIs throughout Colombia have been participating in sequential learning endeavors, linking the technical and technological programs offered by SENA with the professional and technological programs HEIs offer. Up to 2008, around 409 such endeavors had been successfully implemented (SENA, 2011b).

In Bogota, for example, the EAN University offers programs in business administration, international business, manufacturing engineering, marketing, modern languages, systems engineering, and environmental engineering and it has participated in sequential learning endeavors with SENA. Up to 2008, 75 SENA graduates at the technological level

had participated in this sequential learning program and had received their professional degrees from EAN University (SENA, 2011b).

The Open and Distance National University (UNAD, its Spanish acronym) has also participated in sequential learning efforts with SENA in the careers of business administration, industrial engineering, electronic engineering, and systems engineering. Up to 2008, 102 SENA graduates at the technological level had received their professional degrees from UNAD. The Fundación Universitaria Los Libertadores has also established sequential learning programs with SENA in the careers of accounting, business administration, industrial engineering, and mechanical engineering. Up to 2008, a total of 427 SENA graduates at the technological level had received their professional degrees from this university (SENA, 2011b).

Methodology

To design an appropriate bridging or validation system to link the Chemical Engineering (CE) program of the Universidad de Cartagena and SENA's technological program in petrochemical plant operation (TOPP, its Spanish acronym), both study programs were analyzed in detail in a series of workshops held with representatives of both entities.

A matrix was also designed that allowed the concepts covered by SENA's TOPP curriculum to be compared with the contents of all electives, free courses, and required subject courses of semesters I to IV of the University's CE program. The schemes to interlink both educational programs were accordingly designed as well as the corresponding bridging modules, which were based on the concepts seen in each course of the basic cycle of engineering that SENA students had not seen during their studies, as evidenced by the aforementioned comparison matrix.

Results

The SENA-Universidad de Cartagena working group initially established that the duration of SENA's technological program was two years, including internships. By consensus, the working

group proposed that the bridging of both educational programs begin with SENA students entering semester V of the University's CE program. At the time, two arguments justified this decision:

- (1) It made no sense for the bridging program to last more than two years or four semesters. Otherwise, SENA graduates would not be motivated to continue their professionalization because they would be starting practically from zero and their previous studies and knowledge acquired would not be taken into account when entering the university program.
- (2) SENA students could not enroll beyond semester V because this is the semester in which chemical engineering students begin taking courses that are key requisites for

their professional formation (Universidad de Cartagena, 2012).

The working group first compared the curricular content of the University's CE program with that of SENA's TOPP program, using as basis the concepts covered by the TOPP curriculum and the micro-curriculums of all electives, free courses, and required subject courses of the CE program. Comparison matrices were subsequently designed for each subject course of the CE program regarding concepts covered in the TOPP program and submitted to the SENA-Universidad de Cartagena working group for approval. Table 1 illustrates one such comparison matrix for the subject of differential calculus. Similar matrices were obtained for all subject courses of the CE program, semesters I to IV. These matrices helped identify those concepts of the basic cycle of CE that SENA graduates have or have not mastered.

Table 1. Example of a comparison matrix of concepts covered by SENA's TOPP program and the subject course of Differential Calculus of the CE program of the Universidad de Cartagena.

CE Subject Course	Competencies in the TOPP Curriculum					
	1	2	3	4	5	6
Differential calculus		Functions Absolute value Lineal and quadratic inequalities Limits				
Concepts pending development						
Functions. Real numbers. Order theorems. Linear and quadratic inequalities. Absolute value. Cartesian plane. Functions. Trigonometric functions. Limits. Limit theorems. Limits of polynomial functions. Limits of rational functions. Infinite limits. Limits at infinity. Limits of exponential functions. Limits of trigonometric functions. Continuity. Asymptotes. Derivatives. Definition of derivative. Geometric interpretation. Derivative of algebraic functions. Product derivatives. Quotient derivatives. Derivatives of exponential functions. Derivatives of logarithmic functions. Derivatives of trigonometric functions. Derivative of inverse trigonometric functions. Chain rule. Higher order derivatives. Implicit derivation. Derivative applications. Related rates. Problems. Rectilinear motion. Instantaneous velocity. Tangent line. Rolle's theorem. Mean value theorem. L'Hopital's theorem. Maxima and minima. Problems.						

Proposed pedagogical methodology

Pedagogic forms were prepared based mainly on the results of the comparison matrices and served to define and generate validation modules that would ensure that SENA students would have access to curricular content in certain subjects that were fundamental for them to successfully fulfill the basic cycle in CE. Analysis results indicated that SENA students are not knowledgeable in many of the basic concepts of each of the required subject courses of the first four semesters of the CE program. Each pedagogical scheme accordingly strives to eliminate

the shortcomings of students' previous technological education so they can successfully begin semester V of the CE program. Therefore a propaedeutic component was designed, which consisted of bridging modules created based on the results of the comparative matrix analysis of each semester's subject courses.

Table 2 indicates which subject courses per semester are completely validated and which are not and, as a result, students must take the corresponding bridging module that covers fundamental concepts of interest.

Table 2. Analysis of comparison matrixes for semester I of the Chemical Engineering Program of the Universidad de Cartagena.

Semester	Validated subject courses	Validated credits	Non-validated courses	Pending credits
I	Communications I	11	Differential Calculus	6
	General Chemistry		Student Life	
	Descriptive Geometry		Introduction to Chemical Engineering	
	Basic Math			
II	Communications II	10	Integrated Calculus	10
	Physics I and Laboratory		Lineal Algebra	
	Organic Chemistry and Laboratory		Inorganic Chemistry and Laboratory	
III	Stoichiometry	7	Vector Calculus	12
	Informatics II		Physics II and Laboratory	
			Physical Chemistry I and Laboratory	
IV	Probability and Statistics	11	Differential Equations	8
	Thermodynamics I		Physics III and Laboratory	
	Analytical Chemistry			
	Research Methodology			

After analyzing matrix results of each semester's subject courses, the joint working group proposed, by consensus, the development of bridging modules for each semester (Table 3), which would enable

students graduating from SENA to continue their education with the same level of competency in academic concepts and semester credits as students currently enrolled in the University's CE program.

Table 3. Bridging modules per semester proposed by the SENA-Universidad de Cartagena working group.

Semester	Module	Content
I	Management of Institutional Concepts and Chemical Engineering	Program content will cover all concepts addressed in the courses on Student Life and Introduction to Chemical Engineering. Research skills will be monitored in all course work carried out.
	Integrated Math I	Program content will address all concepts that students are currently not familiar with but need in order to successfully complete their course in Differential Calculus.
II	Integrated Math II	Program contents of the subject courses of Integrated Calculus and Lineal Algebra.
	Inorganic Chemistry and Stoichiometry	Program contents and competencies pending development of the course on Inorganic Chemistry as well as those of the semester III course on Stoichiometry.
III	Mathematics III	Program contents and skills pending development of the course on Vector Calculus.
	Integrated Physics I	Program contents and skills pending development of the courses on Physics I and Laboratory I and Physics II and Laboratory II.
	Physical Chemistry I and Thermodynamics	Program contents and skills pending development of the course on Physical Chemistry I and Thermodynamics I.
IV	Differential Equations	Program content and skills required for the course on Differential Equations.
	Physics III and Laboratory III	Program content and skills required for the course on Physics III and Laboratory III.

Figure 1. Percentage distribution of validated and non-validated courses by the SENA-Universidad de Cartagena working group for SENA graduates in petrochemical plant operation .

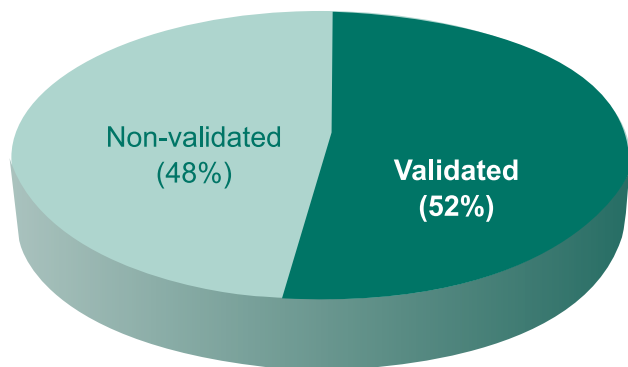


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The analysis of the TOPP and CE curriculums revealed that technologists graduating from SENA’s petrochemical plant operation program know and manage all program contents of certain free courses and electives within the CE program. Therefore the joint working group decided to validate these subject courses. Table 4 indicates those free courses and electives validated in the bridging system.

Table 4. Free courses and electives validated by the SENA-Universidad de Cartagena working group for SENA graduates in petrochemical plant operation.

Free courses	Credits validated
Industrial Hygiene and Safety	2
Industrial Safety	2
Basic Informatics	2
Entrepreneurship	2
Global Effects of Contamination, Man, and Environment	2
Civism	2
Total credits	12
Electives	Credits validated
Industrial Safety	2
Quality Control	2
Total credits	4

Two courses seen by SENA students, Industrial Chemical Processes and Introduction to Polymers, were not validated as the current study was based only on the first four semesters by decision of the joint working group.

The joint working group decided to handle certain concepts, such as research methodology, across the different bridging modules during the validation semester, taking into consideration that SENA students do internships throughout their entire technological formation. Informatics was handled the same way as classes at SENA are held using ICTs so student competencies in this area are strong. Communications I and Communications II of the CE program were also offered across the different bridging modules, reinforcing oral and written communication skills.

After taking and passing the bridging modules proposed in this validation system, SENA graduates can enroll in semester V of the Universidad de Cartagena’s CE program with the suggested adjustments. To opt for the degree of chemical engineer, students must take 78 credits to complete the 169 required by the CE program. In addition, they must necessarily take three electives as two electives were validated by the system. If they chose to do so, however, students may take up to five electives, maximum. Students are not required to attend any free course as six free courses and their pertinent program contents were fully validated.

Proposal for implementing the bridging modules

Taking advantage of the methodology typically used by SENA, the proposal consisted in defining the number of class hours of each of the nine bridging modules depending on the number of academic credits as follows:

- Number of class hours of 2-credit modules = 32
- Number of class hours of 4-credit modules = 64
- Number of class hours of 6-credit modules = 96

The nine bridging modules were designed to be taken in one semester (16–20 weeks; 8 hours a day). Students were allowed to simultaneously take a maximum of three bridging modules; after their successful completion, they could immediately take the next group of three. This is similar to the methodology used by the University’s Faculty of Engineering for summer courses, abiding by students rules and regulations regarding retaking courses or

exams, summer courses, and so forth.

Grading system of subject courses semesters I to IV

Most of the students' course grades in semesters I-IV will be given in the bridging modules for each semester. SENA must issue the corresponding transcript to certify all validated subject courses.

By consensus, the SENA-Universidad de Cartagena working group also proposed that the grades of all validated free courses and electives must be previously certified by SENA.

Interlinking both programs

Figure 2 shows the approach used by the SENA-Universidad de Cartagena working group to interlink both programs after the curriculums of each one were studied, comparison matrices developed, pedagogical schemes designed for each semester, and a series of pertinent decisions taken.

Origin	Positive aspects	Negative aspects
Internal	Strengths	Weaknesses
External	Opportunities	Threats

Figure 2. Approach used to interlink SENA's technological program on petrochemical plant operation with Universidad de Cartagena's chemical engineering program.

Admission to the validation program was based on the results of a specially designed admissions exam and an interview conducted by the Coordinator of the SENA-Universidad de Cartagena validation initiative. Enrollment was on a semester basis, with a maximum of 10 students per semester.

Candidates aspiring to the validation program must fulfill the following requisites:

- Degree of technologist in petrochemical plant operation.
- Pertinent internships.

- Certificate of military service (men).
- Maximum two years after graduation from SENA.

After defining how the system would operate and admission requisites, a SWOT matrix was used to objectively analyze the proposed validation system (Figure 3). The SWOT matrix was divided into internal and external factors. Internal factors (strengths and weaknesses) can be controlled efficiently, whereas external factors generally have little room for manipulation, usually being accepted as facts and the system must be operational under these conditions. Each of these factors was then assessed.

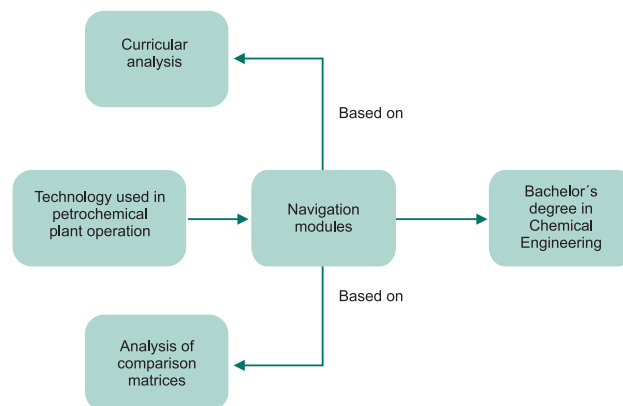


Figure 3. Swot matrix used to analyze the validation system proposed by the SENA-Universidad de Cartagena working group.

SWOT matrix

Strengths

- It is feasible to interlink the curriculums of both the CE and TOPP programs using propaedeutic cycles.
- This initiative was endorsed by the Vice-Rectorate of Academic Affairs of the Universidad de Cartagena, the directors of SENA's Regional Office in Bolívar, in particular SENA's Center for the Petrochemical Industry, and the national government, which endorses this type of project.
- The proposed validation system not only improves the curriculum flexibility of both programs, but also promotes a strong collaborative relationship between the two institutions—SENA and the Universidad de Cartagena—enabling professors

and students to take advantage of their facilities, equipment, and laboratories.

- The proposed validation system expands the coverage of the University's CE program.

- The methodology used to design the validation system is highly pertinent as it addresses the different aspects of a joint endeavor of this type.

Weaknesses

- There could possibly be a lack of acceptance of this new scheme of propaedeutic cycles, as proposed in this strategic alliance between SENA and the Universidad de Cartagena, by the student community of the CE undergraduate program as well as by some professors of the Faculty of Engineering.

- The level of preparation of students of the technological program in the area of basic sciences is low, which extends the duration of bridging modules.

- There could be a lack of budget availability within the Universidad de Cartagena to execute and satisfy the initial needs of the proposed validation system in terms of classrooms, professors, and so forth.

- Students in the validation system may not be able to adapt easily given their shortcomings in pedagogical aspects pertinent to bridging modules.

- The dropout rate of students entering the validation system could be high.

Opportunities

- The approach to education by propaedeutic cycles, in this case engineering, could be used to establish a strategic alliance between SENA and the Universidad de Cartagena.

- The validation system proposed could earn the recognition of Colombia's Ministry of Education and the academia, enabling SENA graduates at the technological level to continue their professional studies as presential students at the Universidad de Cartagena.

- The relationship between the Faculty of Engineering of the Universidad de Cartagena and the Center for the Petrochemical Industry of SENA's Regional Office in Bolívar would be strengthened,

significantly benefitting both institutions.

Threats

- SENA graduates as technologists in petrochemical plant operation could show little interest in participating in the proposed validation system, which would affect the system's sustainability.

- Substantial changes could occur in either SENA's or the University's curriculums, which would make it necessary to adjust the pedagogical schemes and the micro-curriculums of the bridging modules and the validation system as a whole.

- Even after conducting the SWOT analysis for implementing the proposed validation system at the Universidad de Cartagena, a number of administrative requirements could be needed to overcome potential weaknesses arising during the implementation of this joint initiative, despite the creation of the Coordinator's Office for the SENA-Universidad de Cartagena initiative, which is ascribed to the University's Faculty of Engineering, more specifically to the CE program. This Office is responsible for designing the admissions exam to the validation program, conducting the interview for the student screening process, as well as providing academic accompaniment to students in the program.

- Enrolled students could drop out of the SENA-Universidad de Cartagena validation program so the University was asked to provide special accompaniment to these students in aspects related to student life to ensure their opportune adjustment to university life. Also, seeking to ensure that the transition of SENA students to the CE program be as smooth as possible, new faculty members were hired to ensure an excellent learning environment, use of efficient teaching methods within the classroom, and accountability for the program content of all bridging modules.

Conclusions

- By creating a joint SENA-Universidad de Cartagena working group, it was possible to analyze the curriculums and program contents of the programs of both institutions, establish comparison matrices, and determine what SENA students know

or don't know in relation to each subject course of semesters I-IV of CE at the University.

- Based on the information generated by the comparison matrices, pedagogical schemes were designed to validate the credits and knowledge of each of the subject courses of semesters I-IV. As a result, an efficient validation mechanism was obtained for the semesters under study. The total number of credits validated using this system was established, as well as the origin of the grades of validated subject courses, how bridging modules would be taught, and other aspects that allowed the successful interlinking of both programs.

- Administrative requirements necessary to ensure the viability and functionality of the validation system were defined, for example the creation of a administrative department ascribed to the CE program and the endorsement of this initiative by the University's central administration, faculty members, and the Department of Student Life.

- It is recommended to implement the proposed validation system at the Universidad de Cartagena at a pilot-scale, taking into account all its administrative requirements. The system would not only serve as model for other similar initiatives in the region, but also demonstrate that this type of joint endeavor is feasible provided that the curriculums of both programs are very similar and that both institutions are committed and show a willing disposition.

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