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INTEGRATING ESSENTIAL COMPETENCIES FOR SUGAR-ALCOHOL-CHEMICAL BIOREFINERIES

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INTRODUCTION

The search for alternative feedstock from renewable sources to replace crude oil has become a worldwide concern. Among the known alternatives, the ethanol produced in Brazil from sugarcane is the most competitive on a global scale.

The sugar-alcohol sector has seen a constant increase in demand and production, mainly due to three factors that are taking place simultaneously: increased ethanol consumption on the domestic market caused by growing sales of flex-fuel vehicles; the potential growth of the foreign market due to concerns with global warming, leading to the use of renewable energy; and the increased consumption of sugar by the foreign market due to reduced subsidies by the European Union and other countries (CARMO and TANNOUS, 2007).

It is in this context that Brazil has been a leader in producing ethanol from sugarcane. The 2008-2009 crop produced 572,738,489 tons of sugarcane (MAPA (a), 2010), generating 27,681,239 m^3 of ethanol (18,050,758 m^3 of hydrated ethanol and 9,630,489 m^3 of anhydrous ethanol) (MAPA (b), 2010) and 31,297,612 tons of sugar (MAPA(c), 2010). This places Brazil among the leaders in the world ranking.

The sugarcane ethanol produced in Brazil is the worldwide leader in terms of production costs, making it competitive with gasoline obtained from crude oil. This leadership position has been achieved through technological innovation both agriculturally and industrially.

In terms of industry, we can point out incremental progress in the optimization of the production processes and the energetic integration obtained through the co-generation of the sugarcane bagasse, with production of steam and electricity to feed the ethanol and sugar production processes, in addition to generating surplus energy to supply the network. We should also like to point out improvements in the integrated management of the production chain.

However, these gains are reaching their limits, considering the current production processes, therefore a disruptive innovation that provides a new technological plateau is now necessary. The so-called second-generation technology makes use of other feedstock with much lower production costs, such as: agricultural residues, sugarcane bagasse, wood and other sources from cellulosic materials.

For this reason, a convergence and synergy should occur between the production processes for conventional petrochemical refineries and the production processes of the new biorefineries obtaining a variety of similar products to those of the petrochemical chain.

In order, for the supply the ethanol market's growing demand, new investments will be necessary, both towards stimulations the creation of a new technology and by the creation of new venture business. Thereby new incentive and financing mechanisms for producers, equipments and process suppliers, new investors and research institutions can represent a competitive advantage that will allow the country to remain the leader of this import production chain.

On the other hand, the petrochemical sector's production chain also represents a significant portion of the national production, with 23.1% of the Brazilian GDP, both in the production of fuel oils and in producing feedstock for other production chains, such as for plastics, textiles, packaging, auto parts and electro-electronics, among others.

This chain is considered a point of reference in the process of technological innovation for the fuel energy sector in Brazil, therefore it was chosen as a benchmark for this analysis, despite this chain's complexity, with innumerous possibilities for ramifications, it is possible to identify a sequence of transformation processes that begin with a small quantity of feedstock and obtain a variety of intermediary and final products.

In this sequence of processes, it is possible to see that the critical competencies necessary to establish competitive advantages are constantly changing. In other words, the initial stages of the process the fundamental elements the access to feedstock, the economies of scale and production costs, and advanced stages, there are innovation and differentiation capacities (FURTADO, 2003).

This article seeks to identify the essential competencies necessary for technological innovation and their stages on the business management of the sugar-alcohol-chemical chain. In this proposal, concepts from Project-based Learning are used as tools to assist in the methodology for managing competencies and providing collaborative learning.

ESSENTIAL COMPETENCIES

Businesses are becoming increasingly concerned with developing and managing their competencies, since in the current context organizations must have a competitive advantage, holding on to the intelligence of their processes and obtaining economy of scale in their production and logistics. Other wise, it is essential for there must be an integration to take place of all the essential processes held by each business in their production chain (ROSS, 1998).

This integration is an important factor towards gaining a competitive advantage and can occur in a variety of ways, from the verticalization of activities, the acquisition of companies across the chain, alliances with clients, suppliers and competitors (FURTADO, 2003). In order, resources to implement that, in addition to information technology resources, a standard of competencies that permeates all critical processes is necessary.

According to NOKATA and TAKEUSHI (1998), this knowledge can be classified as tacit or explicit. The first is related to the knowledge of employees in obtaining restrictive and individual results. The second has to do with the restructuring of information – both individual and collective – in routine work or in new projects, transmitted in a standardized language.

This being so, tacit knowledge should be avoided, since the biggest challenge faced by organizations lies exactly in transforming that knowledge into explicit knowledge, in other words, avoiding the organization's vulnerability and making it possible to manage and disseminate technological information.

Towards this transformation, those authors proposed four interconnected classifications within a continuous process, namely: externalization, internalization, combination and socialization (Figure 1).

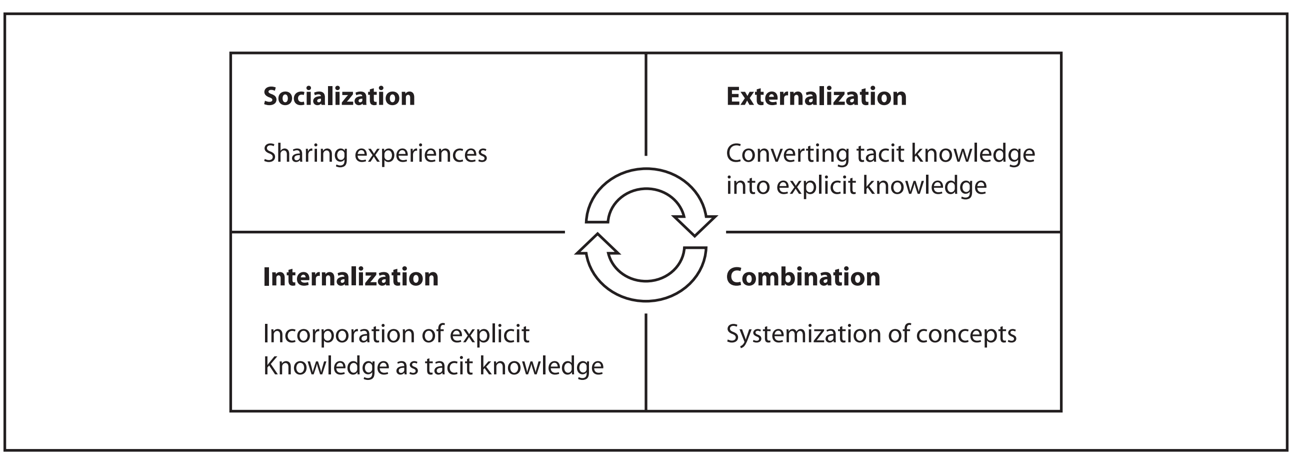


FIGURE 1 Knowledge Spiral.

TABLE 1 Essential competencies corresponding to each stage.

Stage	Example	Type of Competency	Essential Innovative Competency
1	Increase sugarcane processing capacity	Business	Management of manufacturing process performance
		Technical-professional	Development of equipment and engineering
		Social	Centralization of decisions
2	Sugar and alcohol production process optimization	Business	Knowledge of operating costs and performance control
		Technical-professional	Knowledge and maximum process performance
		Social	Decentralization, delegation
3	Sugar and alcohol production process energetic optimization	Business	Process control and strategic planning
		Technical-professional	Knowledge about energy efficiency
		Social	Systemic, holistic vision, autonomy
4	Agricultural and industrial integration (management and logistics)	Business	Complete view of supply chain, integrated management systems and performance indicators
		Technical-professional	Ability to operate in a multifunctional and integrated manner in the organization's many different processes and use of integrated management systems
		Social	Leadership in negotiation, articulation and persuasion in the production chain and community

Source: Table constructed using data from FLEURY and FLEURY (2001).

Socialization is the process that promotes the interaction between the tacit knowledge, where the sharing of experiences takes place. Externalization is where the tacit knowledge is transformed into explicit knowledge, while internalization represents the inverse process. Finally, there is a combination, in which a generation of new knowledge occurs through the systemization of concepts. With this interaction, a business can carry out collective and systemized tasks.

Through this fact, along with the choice of a competitive strategy and the application of a specific management model will make it possible to increase productivity and generate technological innovation. A business innovates when it is able to offer the market a competitive product, services or processes that did not exist previously.

Businesses, once they have incorporated this environment into their organizational culture, should have "intelligence" in a systematic way, in order to facilitate management and the development of essential competencies that will facilitate innovation and provide advantages over the competition. Table 1 shows the essential competences with innovation stages, respectively. Each stage has there types of competencies: business, technical-professional and social (FLEURY and FLEURY, 2001).

The first stage refers to organizational management with emphasis on the performance of its production processes. In this stage, the technological innovation of the sugar-alcohol chain is related to the need for increased quantities of sugarcane processed for alcohol production (Pro-alcohol government program) and the performance of the equipment used in the sugarcane preparation and extraction processes (OLIVÉRIO, 2004).

In the second stage, it is prioritizes the management focuses on optimizing the costs of manufacturing and related services.

In the third stage, management a focus is energy efficiency planning, involving all the internal processes that participate in the resources necessary for production.

In the fourth stage, a strategic vision of the entire supply chain makes it possible to plan and operate the production processes in an integrated manner (agriculturally and industrially) and with minimum resources.

TABLE 2 Types of strategies and essential competencies.

Competitive strategy	Operations	Product development function	Sales/marketing
Operational Excellence	World-class manufacturing/lean production	Incremental innovation	Convince the market that the quality/price ratio of the products/services is optimal
Product Innovation	Scale-up and primary production	Radical (Disruptive) Innovation	Prepare the market and educate potential clients towards adopting innovation
Client-oriented	Agile manufacturing	System development (products; specific services)	Develop client relationships to understand needs and sell solutions

Source: FLEURY and FLEURY, 2001.

Each stage can be related to the organization's essential competitiveness, which are classified by types of competencies: business, technical-professional and social. Examples of each stage are presented in Table 1 (FLEURY and FLEURY, 2001). We can see the development from an initial stage, in which the technical competencies are individual and specific to the production process, towards an advanced stage, where these become integrated in the different processes of the production chain. During this stage, it becomes even more important to use techniques and methods that facilitate the management competencies.

In this sense, aiming at identifying the processes which are essential for the development of competencies for a new plateau of innovation, this study chose the competitive strategy called "Product Innovation".

Table 2 shows the types of strategies and their related essential competencies

This kind of competitive strategy, product innovation, is characterized by the "scaling up" of the primary production and preparation of the market for radical innovation.

TECHNOLOGICAL DEVELOPMENT AND NEW PRODUCTION PROCESS TRENDS FOR THE SUGAR-ALCOHOL-CHEMICAL CHAIN

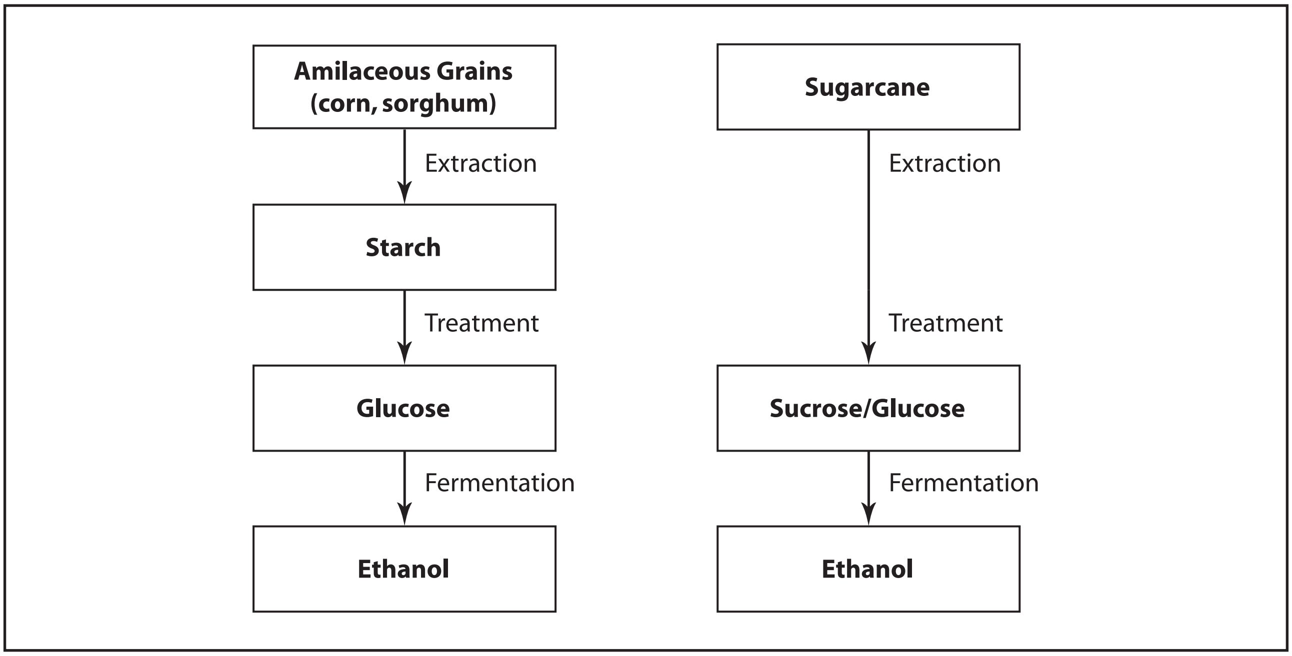
During the 1980s, ethanol, in addition to working in favor of reducing imports of crude oil and its derivatives, was also an important product on the agenda of Brazilian exports. However, starting in 1989, there was a period of net ethanol imports, as a result of the domestic supply crisis.

In recent years the trade balance was positive once again and there is a clear trend towards Brazil being a significant exporter of this product, due to the comparative advantages of producing in this country and the adoption of programs for the use of fuel alcohol in a variety of countries as a strategy for environmental improvement and emissions reductions.

Considering the fleet of vehicles powered by hydrated ethanol since 1980, and since 2003, with the inclusion of flex-fuel vehicles – those which can consume both gasoline with added anhydrous ethanol and hydrated ethanol directly – this fleet grew to 6,419,120 vehicles (ANFAVEA, 2009).

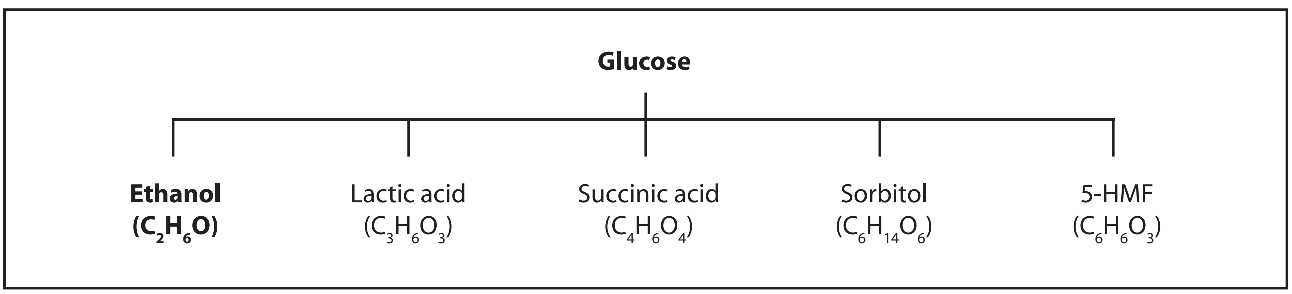
The sugar-alcohol production chain, which represents a significant alternative among Brazilian potentials, especially towards meeting the growing demand for fuel energy, is faced with the challenge to generate greater production of fuel alcohol as a substitute for gasoline, which comes from the petrochemical sector.

This ethanol production chain from biomass originates mainly from amylaceous grains (corn in the United States of America – the world's top ethanol producer) or from sucrose (sugarcane in Brazil – 2nd greatest ethanol producer), with the amylaceous grains being transformed first into starch and then into glucose, while from sugarcane sucrose is first extracted before being transformed into ethanol, as shown in Figure 2.



Source: BASTOS, 2007.

FIGURE 2 Main sources for obtaining 1st generation ethanol.



Source: BASTOS, 2007.

FIGURE 3 Sugar-Chemical Chain.

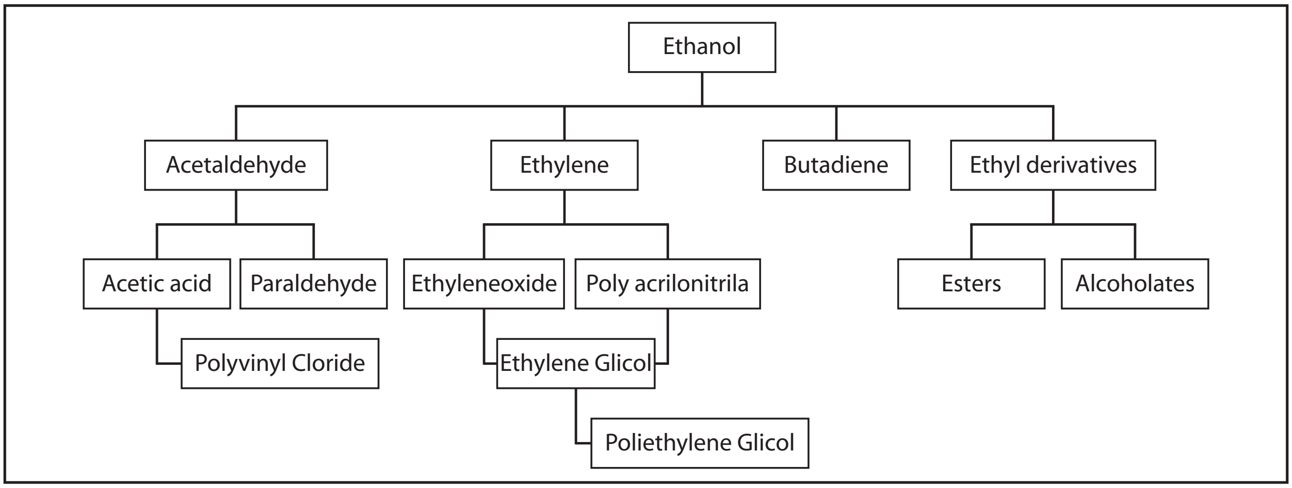
It is also possible to obtain many other products from the sugar-chemical chain starting from glucose as the feedstock and generating other products besides ethanol like lactic acid, succinic acid, sorbitol and 5-HMF (Figure 3).

In its turn, from the alcohol-chemical chain one can obtain the following products by using ethanol as the feedstock (Figure 4): acetaldehyde, acetic acid, polyvinyl chloride, paraldehyde, ethylene, ethylene oxide, polyacrylonitrile, ethylene glycol, polyethylene glycol, butadiene and ether derivatives (esters and alcoholates), among others.

The use of ethanol as a renewable source feedstock for the production of these different chemical products can serve as an alternative to naphtha, which comes from crude oil. This choice is the result of the production costs and price ratio for crude oil.

On the other hand, there is worldwide competition to obtain second generation ethanol (Figure 5) from cellulosic materials, which in this case would have production costs competitive with those obtained by the current processes and which would make it possible for other regions to enter the market as producers.

In addition to ethanol production, cellulosic materials or biomass would allow for the generation of energy by making use of the lignin, as well as the obtainment of oils, phenols and acetic acid, among others. From hemicellulose one can obtain furfural,



Source: Adapted from BASTOS, 2007.

FIGURE 4 Alcohol-chemical Chain.

maleic acid, xylose and mannose, among others. From cellulose, it is possible to obtain glucose and other fermentable sugars that can be transformed into ethanol or other products (YANG, 2006).

In this challenge to achieve the viability of these new processes, achieving new competitive levels, it becomes important to stimulate the development of innovative competencies in private and public organizations. And for this stimulus to take place, it is necessary to understand the process of technological and management evolution which has occurred in competitive sectors of Brazilian industry.

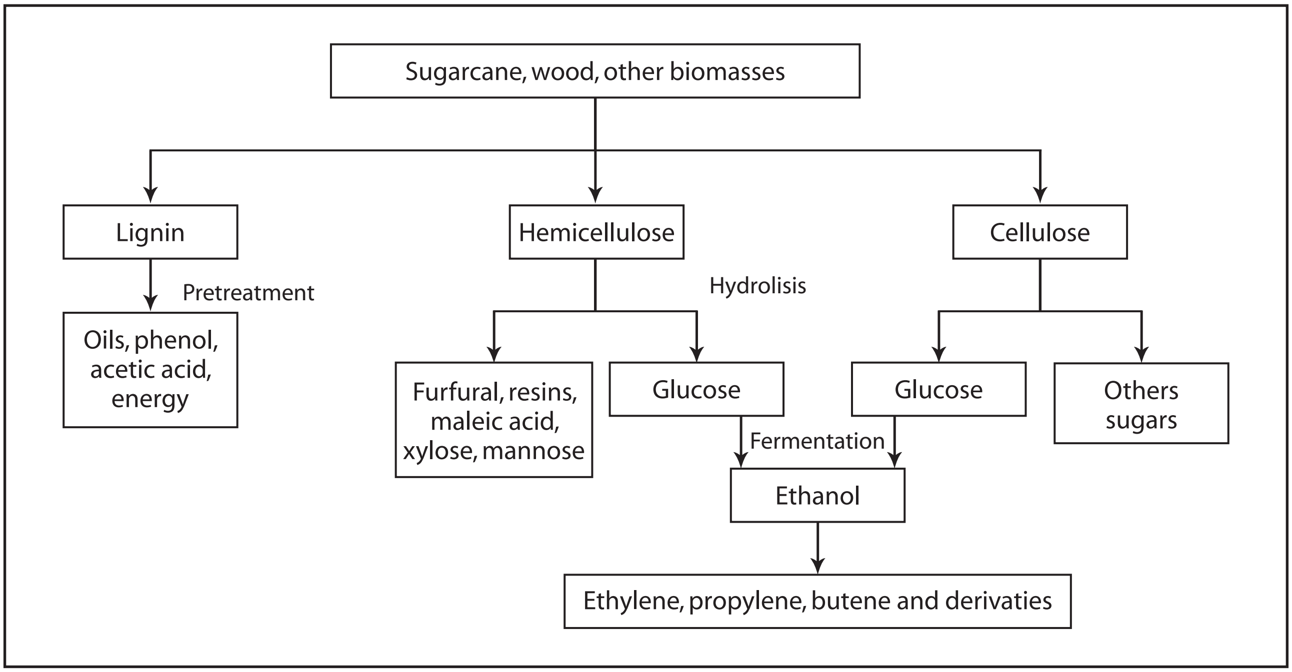
IDENTIFICATION OF ESSENTIAL INNOVATIVE COMPETENCE FOR THE SUGAR-ALCOHOL-CHEMICAL PRODUCTION CHAIN USING PROJECT-BASED LEARNING

After 30 years of constant technological development in the agricultural and industrial processes of the sugar-alcohol chain, it has become difficult to obtain further improvements in productivity and yield using the current production process. For this reason, it has become necessary to develop innovative competencies that will be able to break away from the conventional production processes, replacing them with alternative technological routes so as to achieve new levels of yield, efficiency, productivity and reduced production costs for all products (disruptive innovation).

In order to develop disruptive innovation (breakthroughs), it is possible to adopt the model of technological competencies that identifies different types and levels of innovative technological competencies according to the urgency and manner in which businesses accumulate these competencies and manage the process of learning over the course of time (FIGUEIREDO and TACLA, 2003).

The types of technological competencies are classified according to the stage of innovation and technological complexity, beginning at the basic level with technical, managerial and organizational competencies which are capable of operating existing technologies and passing to a higher level, with competencies in design, engineering, management and research and development towards the incremental innovation of products, processes and organizations. Next, on an even higher level, businesses have competencies for research, development and basic engineering and in project management to copy, implement and develop existing technologies and on the highest level, competency in research, development and engineering to develop and implement new technologies.

In this manner, we can map out these stages in traditional refineries that use crude oil as their feedstock source and compare them with biorefineries, which use biomass (sugarcane) as a feedstock source. As an example, we can cite, in the case of traditional refineries, that the naphtha, which will be used to produce ethylene, whereas in



Source: YANG, 2006.

FIGURE 5 Second generation ethanol production process.

biorefineries there is the obtainment of the ethanol which will be used to produce ethylene.

Alternative feedstock may make a new paradigm possible in the industry of conversion and crude oil derivatives, with these being replaced by ethanol derivatives. Figure 6 compares crude oil-based refineries with biomass biorefineries.

With this new concept of biorefinery, it becomes fundamental for chemistry and biotechnology to share competencies for the conversion processes and end products. In this sense, the use of a model capable of integrating competencies and providing synergy will be essential to make this viable.

In the most advanced stage of innovation, processes and projects are strongly integrated into the organization, emphasizing the acquirement of knowledge, creativity and the structuring of teams, which are supported through collaborative work, the use of information technology and innovation strategy.

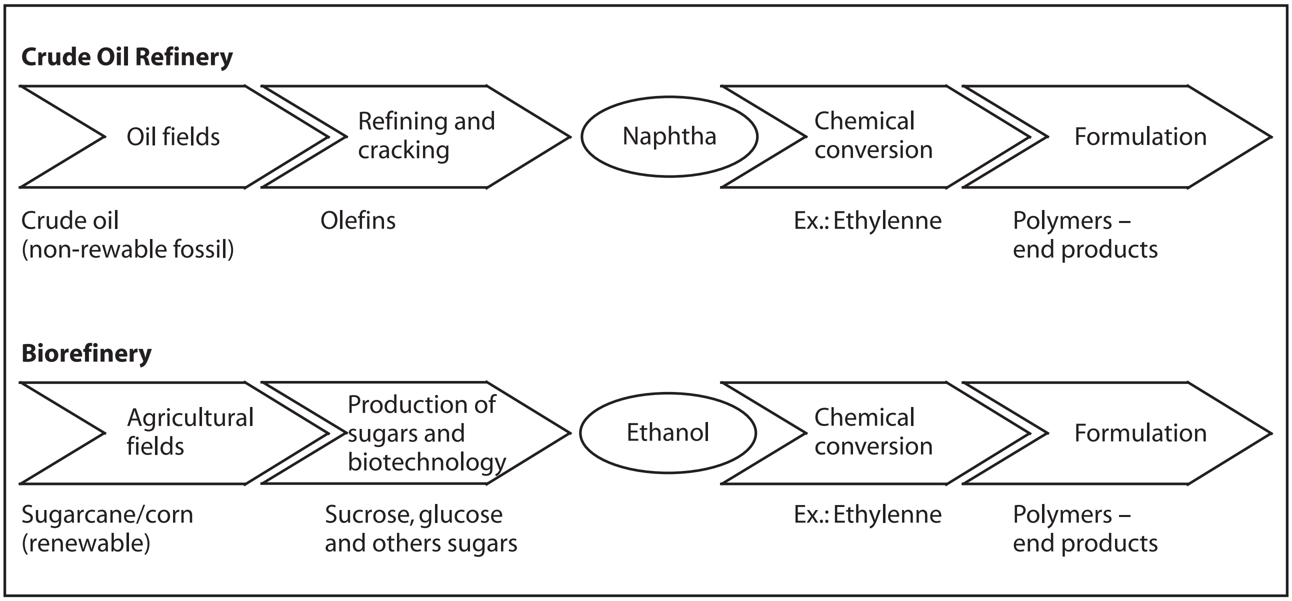
In this stage of development of essential innovative competencies, the proposal is to follow an innovation process model which consists of all the stages, from the creation of a new idea all the way to the commercialization of the product, as shown in Figure 7.

The dissemination of best practices identified in the essential processes can be facilitated through an environment of collaborative learning, which will allow for greater interaction between the different levels of activities and knowledge and can even facilitate the process of developing and acquiring essential innovative competencies.

To this end, the Project-based Learning – PBL method can be used, which aims to facilitate the learning process in a collaborative and multifunctional way, integrating different processes (TANNOUS, 2007). Each stage of the process will be sub-divided into sub-projects that are interconnected towards the reaching of the next stage, facilitating the development of competency management (Figure 8).

As an example, we can compare the competencies necessary for obtaining ethylene and develop a model to develop the essential competencies, especially the ones for innovation and engineering, starting from the stage of the creation of ideas, prototype development and feasibility plan, as shown in Table 3.

Next, the engineering competencies are shown, with their main production processes via the petrochemical route, using naphtha as the



Source: BASTOS, 2007.

FIGURE 6 Comparison of crude oil refineries and biorefineries.

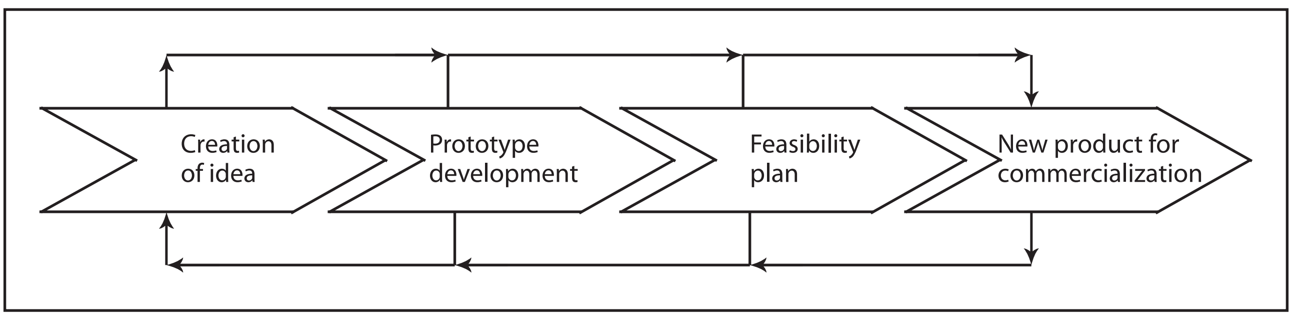


FIGURE 7 Stages of the innovation process.

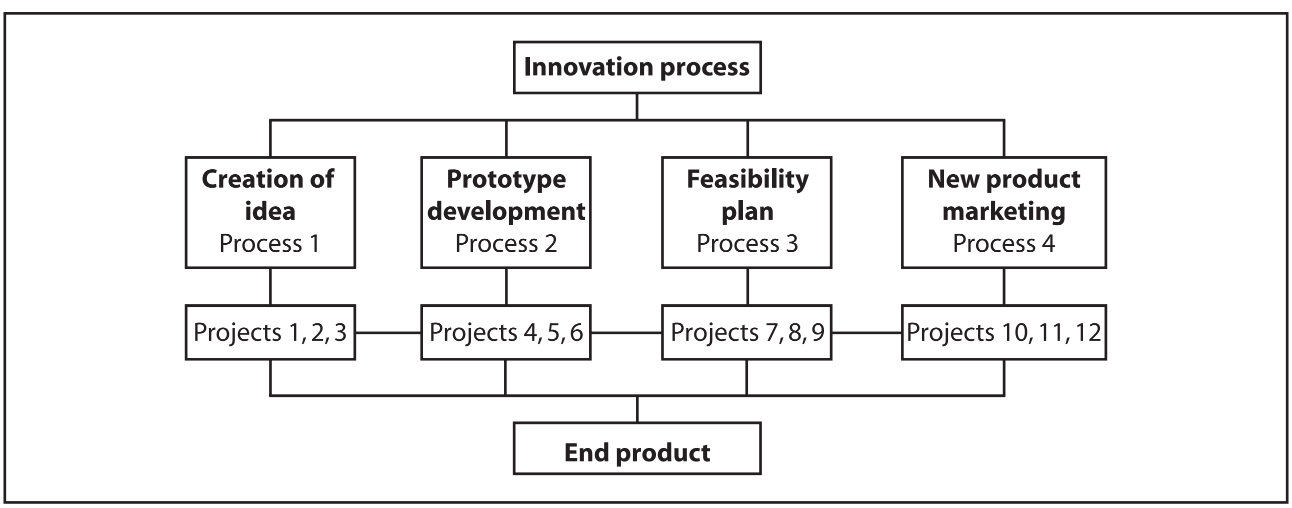


FIGURE 8 Project-based Learning for Innovation Process.

TABLE 3 Stages of the innovation process.

Stages	Innovation competencies
1 – Creation of idea	Capacity to prospect ideas internally and externally Knowledge and abilities in negotiation, persuasion and leadership techniques Capacity to identify and take advantage of opportunities
2 – Prototype development	Capacity for basic engineering, design engineering and product engineering
3 – Feasibility planning	Capacity for business planning Capacity for operational sizing Capacity for economic-financial analysis
4 – Product commercialization	Market research knowledge Capacity for market analysis Capacity and abilities for product commercialization

TABLE 4 Engineering competencies – crude oil refinery.

Stages (crude oil refining)	Engineering competencies
Exploration and extraction of crude oil (petrochemical refinery route)	Knowledge of prospection techniques Knowledge of extraction techniques
Crude oil refining and cracking (naphtha obtainment)	Knowledge of separation processes Knowledge of distillation techniques Knowledge of chemical catalysis

TABLE 5 Engineering competencies – biorefinery.

Stages (sugarcane biorefinery)	Engineering competencies
Sugarcane planting and harvesting (biochemical biorefinery route)	Knowledge of farming techniques Chemistry knowledge about soils and nutrients
Production of sugars, fermentation/distillation (ethanol obtainment)	Knowledge of separation techniques Knowledge of fermentation process Knowledge of distillation techniques

feedstock for the production of ethylene, as shown in Table 4.

In another way, we could describe the evolution of the main perspectives of innovation, from an initial stage in which innovation is individualized and has little interdependency, towards corporate innovation, with intermediate interdependency, all the way to distributed innovation, with strong interdependence and direct involvement of research and development integrated into strategic management (VEDOVELLO, 2006).

For comparison, we can also describe the engineering competencies in their main processes via the alcohol-chemical route, using ethanol as the feedstock in Tables 3, 4 and 5.

This being so, in order for technological capacity to succeed in provoking technological changes, it will be necessary to maintain funding, both towards using existing production processes and also obtaining funding to provoke these changes in the production processes and systems (VEDOVELLO, 2006).

These last competencies are the ones that are disseminated throughout the organization and production chain, including research centers, universities and external specialists.

FINAL CONSIDERATIONS

At the most advanced levels of innovative competencies, one must identify the development of new products and processes via engineering and P&D&I – Research, Development and Innovation with essential competencies for the management of world-class projects and the launching of innovative products.

Once the essential competencies are identified and adapted to the chosen production process, a plan for development and management of the innovative competence for the sugar-alcohol-chemical sector can be drawn up.

This competency development plan can be facilitated by means of a virtual learning environment, enabling, in addition to the development of competencies, that is, once the deficiencies and competitive advantages are known, management regarding the strong points that should be strengthened and the weak points that should be neutralized, it will become possible to strengthen and integrate other management methods, in the untiring search for competitive advantages.

With this model applied and the results being satisfactory, it can be replicated both for other processes and in-company departments and for other companies inserted into the chain, facilitating integrated management and contributing to the strengthening of the entire production chain of this new sugar-alcohol-chemical sector.

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