Chapter 10
Systemic Approach to Curriculum Design and Development

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10.1 Introduction

Engineering leaders and educators consider innovation to be an important topic in any program related to the training of engineers (Apelian 2007; National Academy of Engineering 2004). The development of traditional skills and knowledge are not the most important goals of an engineering curriculum nowadays, and due to the influence of technology and globalization, traditional engineering skills are now considered a commodity. Identifying this trend, Thomas Friedman (2005) described the modern world as "flat," trying to illustrate the great impact of technology and globalization on the economy of modern society. To make matters worse for new engineering graduates, today's computers are capable of doing almost everything engineers have done up until now. As a consequence, it is important to reorient engineering education in such a way that engineers are prepared to understand the societal context of their work from both a local and global perspective. Innovation and creativity also should be coupled with the engineer's ability to gather information, analyze it, make decisions, and take the right course of action.

Food engineering is a branch of engineering education that has inadvertently addressed the need for innovation in meeting the demands of technological and scientific advances in the new century. There are many challenges involved during processing in how to preserve the original quality of food and its active ingredients, which are considered good for humans. As a result, customization of food products is actually one of the strongest trends in the food industry today (Higgins 2007; Coulston et al. 2003). Thus, collaboration among food engineers, nutritionists, medical doctors, microbiologists and microelectronic engineers, together with other experts, has become an essential element in dealing with these challenges.

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J.M. Aguilera et al. (eds.), *Food Engineering Interfaces*, Food Engineering Series,
DOI 10.1007/978-1-4419-7475-4_10,

For one, it is necessary that engineers be capable of producing and offering customized products at fair prices to the market. This customization should not only attend to fair pricing and the consumers' tastes but to their health needs as well. Food engineers must be able to integrate new technologies into traditional processing lines in order to offer products nearer to consumer needs. They must also have an ample view of the food sector and be capable of relating people and procedures that affect the production and quality of food, by undertaking joint actions, making faster decisions, and sharing their knowledge and experience with conforming professional communities and peers located around the world.

To achieve this goal, engineering students should have flexible educational programs that encourage a systemic approach to the food industry, programs that allow them to travel the world and remain in permanent contact with their colleagues. These programs must also be developed according to international standards so students are allowed to travel without interrupting their studies. Nowadays the trend is to solve problems and make decisions from a broad perspective instead of concentrating on a specific discipline. Generally, however, this does not mean that the depth of understanding a specific scientific field is lost; rather it means that the engineering professional is able to decide which basic science principles are actually needed to solve a particular problem.

10.2 Systems Theory and Thinking

Systemic or systems theory has been taken into account by numerous scientific fields including the field of education (Cabrera and Colosi 2008; Kim and Senge 1994; Ison 2008; Senge 1990). Although there are many conflicting claims that need to be reconciled around this topic, such discussion is out of the scope of this chapter. Therefore the classical definition proposed by Ludwig von Bertalanffy in 1968 is being used as reference:

> Classical sciences tried to isolate the elements of the observed universe… Now we have learned that for an understanding of not only the elements, but their interrelations as well are required… It is necessary to study not only [the] parts and processes in isolation, but also to solve the problems [organization and order] resulting from dynamic interaction of parts, and making the behavior of the parts different when studied in isolation or within the whole… General system theory, therefore, is a general science of wholeness… The meaning of the somewhat mystical expression 'The whole is more than the sum of its parts' is simply that constitutive characteristics are not explainable from the characteristics of the isolated parts. The characteristics of the complex, therefore, appear as 'new' or 'emergent'….

Additionally, a system can be defined as a dynamic and complex whole interacting as a unit, located within an environment in which energy, material, and information flow between the different elements that compose the system and between the elements and their surrounding environments. If the set of courses, methods, people, and tools involved in a learning-teaching interaction are considered as a system, they will show certain characteristics as summarized in Table 10.1.

Table 10.1 Comparison between the characteristics of a basic system and those of the curriculum as a system

System	Curriculum
Dynamic and complex **whole** interacting as a unit	Dynamic and complex academic, social, technical, scientific and empiric **knowledge** interacting as a unit
Energy, material, and information **flowing** between the different elements that compose the system	Topics, issues, theories, information, people, feelings, perceptions, sciences, personal skills, and hidden things **flowing** between students, teachers, parents, industry, among others
Community located within an environment	Academic **community** immersed in a context
Energy, material, and information **flowing** from and to the surrounding environment	Knowledge and agents **interacting** within the academic community and national and international peer communities
Seeks **equilibrium** but can exhibit oscillating, chaotic or exponential behavior	Seeks **articulation** but has to be flexible. Loop planning and developing-assessing changes in every course

According to O'Connor and McDermott (1998), systems thinking (i.e., the practice of systems theory) comprises the whole and the parts as well as the links among parts. Furthermore, it studies the whole in order to understand the parts. It is a pattern of thinking that is not disciplinary in scope and can act as a bridge between the physical, natural, and social sciences. Four universal conceptual patterns have been observed in every system and can be used as tools to apply systems thinking in any situation, as proposed by Cabrera et al. (2008):

1. System definition
2. Distinction from others
3. Perspective or frame of reference
4. Relationships between systems and parts

10.2.1 Designing Curriculum Using Systems Thinking

If the four universal principles just described are followed in the design of a curriculum, the first step should be to define the framework and the system, its parts and its limits. Therefore, a definition of the curriculum from the point of view of the institution is needed. Additionally, the boundaries of this system should be identified to differentiate it from others. Finally, relationships should be identified.

Table 10.2 describes the different aspects that should be taken into account in defining the curriculum. Readers should note that even though Table 10.2 depicts a step by step methodology this is far from a real procedure. Many steps need to be carried out in parallel and many others will require revision after defining the whole curriculum. Figure 10.1 gives a closer visual description of the methodology used for systems thinking.

Table 10.2 Some steps taken into account during curriculum design

Activity	Systems thinking principles used
Define program (field and duration) and level (undergraduate or postgraduate)	Perspective, System definition, and distinction
Find similar programs (locally and abroad)	System distinction
Identify educational trends nationally and internationally	System distinction
Identify skills of student entering the program	Relationships (between system and environment)
Identify skills and competencies demanded by society	Relationships (between system and environment)
Identify institution's educational purposes	Perspective and system definition (parts)
Define problematic and nuclear topics to be taught	System definition (parts)
Define courses	System definition (parts) Relationships (between parts of system)
Define learning-teaching strategy	System definition (parts) Relationships (between parts of system)
Identify institutional capacities (teachers, buildings, equipment, software)	System definition (parts)
Define assessment strategy	System definition (parts) Relationships (between parts of system)

10.2.2 Designing Curriculum for Undergraduate Courses

Educational institutions are guided by educational goals, so the first step in designing a curriculum is to establish the goals. At the School of Engineering at Universidad de La Sabana, the main educational goal at the undergraduate level is to teach students how to design and manage their own projects when they become professionals.

To achieve this goal, an interdisciplinary curriculum is designed that takes into account the basic sciences, such as physics, chemistry, and biology, with mathematics as the common language, which allows the engineers to represent different phenomena. Study of the basic sciences should include the following objectives:

- Describe and study a phenomenon from the perspective of each basic science using mathematical language
- Identify the principles, laws, and theories that explain the natural phenomenon
- Understand the phenomenon as a whole from different points of view

Additionally, graduates are expected to have the following competencies as a result of their educational program. They should be able to:

- Adopt systems thinking as an attitude
- Identify food systems and their parts at different levels, such as tissues, processed products, and supply chains

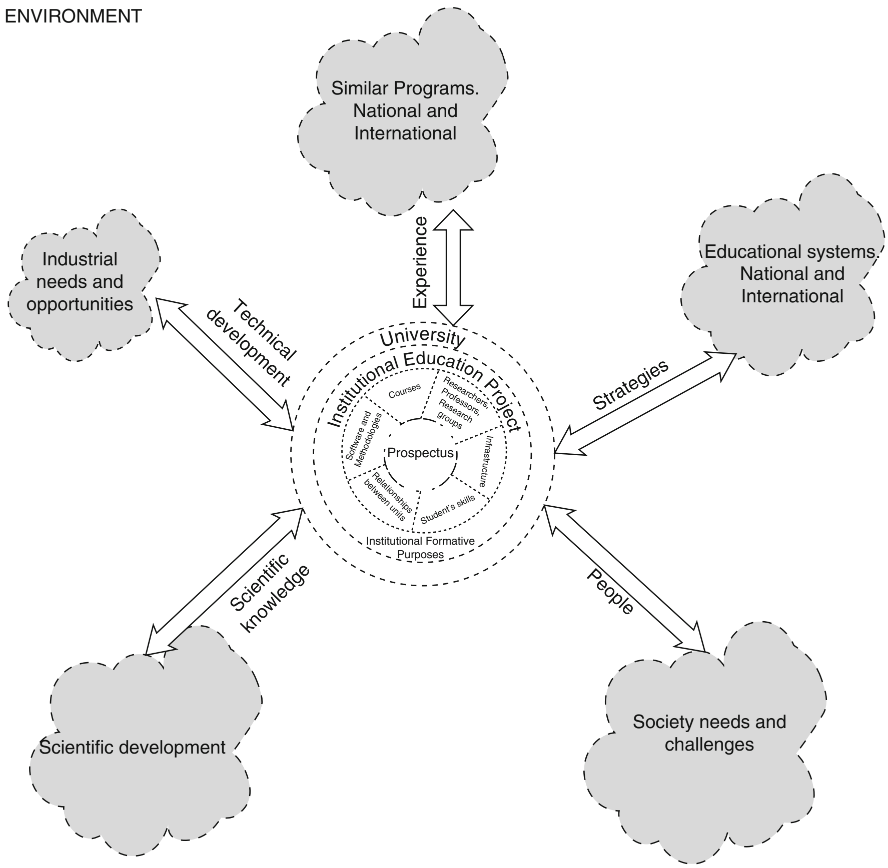

Fig. 10.1 Closer visual description used for curriculum design under systems thinking methodology

- Design processes taking into account the interactions between food materials and other components of the food chain
- Manage food handling and processing projects by considering all factors of the network

During this learning – teaching period, the educator should also assist students in finding the linkages between the concepts and reality.

10.2.3 Designing Curriculum for a Master's Degree Program

At this level the educational goal is to train students to be professionals, as capable of solving an industrial problem in an innovative way. To innovate means to perform a creative solution in order to obtain a new product. In the end, these

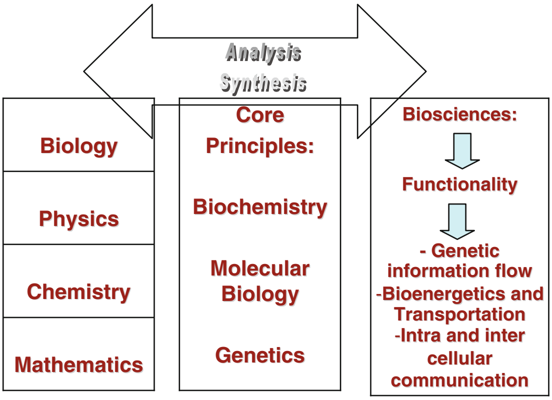

Fig. 10.2 Biosciences curriculum development

professionals who come from different disciplines should have in common their capacity to solve problems using systems thinking and integrating the different sciences. The training process has the following purposes:

- Develop the student's ability to solve problems using an integration of sciences approach.
- Develop the student's creativity and design capacity.
- Develop the student's ability in mathematical modeling.

In the case of the Master's program in Process Design and Management, the former training purposes are not only competencies to develop but are also specific courses wherein students can find practical situations to develop these skills.

10.2.4 Designing Curriculum for a Doctoral Program

At the doctoral level, the educational goal is to train researchers via different disciplines. For example, in the biosciences program, the goal is to guide students during the study of biological elements (molecules) and their vital functions, in such a way, that they are able to discover new and different uses for these molecules. To achieve this goal, the biosciences course uses a systems thinking approach to review different functions such as transport, signaling, and reproduction in cells. This systems thinking approach is supported by a permanent analysis-synthesis activity using concepts from molecular biology, biochemistry, and genetics (Fig. 10.2).

10.3 Conclusion

The four universal principles of systems thinking have been used at Universidad de la Sabana in curriculum design for both undergraduate and postgraduate levels. Additionally, systems thinking has been introduced as an educational goal in order to give engineers more skills in defining systems (their parts and interactions), which will serve as a tool in problem solving and decision taking.

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