https://doi.org/10.25100/iyc.v18i2.2156 INDUSTRIAL ENGINEERING

Developing and evolution of industrial engineering and its paper in education

INGENIERÍA INDUSTRIAL

Desarrollo y evolución de la ingeniería industrial y su papel en la educación

Jaime H. Mendoza-Chacón*, John F. Ramírez-Bolaños*, Hemilé S. Floréz-Obceno*, Jesús D. Diáz-Castro*

**Facultad de Ingeniería Industrial, Fundación Universitaria de Popayán. Popayán, Colombia. jaime.mendoza@docente.fup.edu.co, john.ramirez@docente.fup.edu.co, ind41112003@mail.fup.edu.co, ind42112044@mail.fup.edu.co*

(Recibido: Octubre 09 de 2015 – Aceptado: Marzo 18 de 2016)

Abstract

Professionals with knowledge of industrial processes to ensure the best performance of the companies arisen in order to response to the needs of a society that constantly adapts and changes facing nature. This paper intended to show a vision of engineering through a literature review from its birth to what could be in its future; particularly the role of industrial engineering in education, based on articles from authors who have already researched and written on this subject, whose main conclusion is that the Industrial Engineering must be more participative regarding the institutionalism represented by universities, the company with its determining factor in society and the welfare of the population.

Keywords: *Education, engineering, industrial engineering.*

Resumen

Los profesionales con conocimiento de los procesos industriales que garanticen el mejor funcionamiento de las empresas, surgieron como respuesta a las necesidades de una sociedad que constantemente se adapta y enfrenta a los cambios que la naturaleza y esta les imponen. El presente trabajo pretendió mostrar una visión de la ingeniería por medio de una revisión bibliográfica desde su nacimiento hasta lo que se cree sería su futuro y en particular el papel que desempeña la ingeniería industrial en la educación, tomando como base artículos de autores que ya han investigado y escrito sobre el tema, cuya principal deducción fue que la Ingeniería Industrial debe ser más participativa respecto a la institucionalidad representada por las universidades, la empresa con su factor determinante en la sociedad y el bienestar de la población.

Palabras clave: *Educación, ingeniería, ingeniería industrial.*

1. Introduction

The changes that the world has experienced make necessary to prepare itself to face them; one of the ways to accomplish succeed and achieve the objectives is to improve people's education. For that reason, the processes occurring in Europe and the United States as the industrial revolution, impacted in a directly or indirectly way in the changes that society needs all over the world. The growth in scientific and technological knowledge, entrepreneurship, the establishment of new economic policies, administrative and financial technology, demanded greater efficiency and effectiveness in education systems, it is necessary to train people in order to respond to these new approaches and give solutions to the problems.

Then comes professional people with knowledge of industrial processes, trained to plan, implement and execute programs that guarantee the best operation in companies. These are industrial engineers, who combine social knowledge, natural sciences, mathematics, technology, administration and economy. This is how the birth of industrial engineering in Colombia is dated with the beginning of industrialization process in the twentieth century. However, it is unclear the role of industrial engineers in society even from teaching school, thus, it is essential the role that education plays in it (Jeffers et al. 2004; Pawley, 2009). Industrial engineers must be prepared for an industrialized society with constant changes in scientific, economic, social, environmental and technological levels in order to achieve competitive excellence (Peña, 2009).

The purpose of this work is to present how has been the trend in industrial engineering from its birth, its process of change, its near future and role in education, directing by a literature review of the subject. Whose main conclusion was that the Industrial Engineering must be more participative regarding the institutionalism represented by universities, the company with its decisive factor in society and people's welfare.

2. Birth of the engineering in the world

The engineering concept was born with the man's ability; with the invention of the first tools for his subsistence. Civilizations like the Egyptian used wooden trunks like a system to drag material in a more efficient way and with less use of energy. Then, it appeared in the world great developments, such as: concepts of columns, arches and different forms in the construction becoming in a big expression of civil engineering. Then appeared the principles of mechanical engineering with the invention of some mechanisms that used screws, gears and pulleys; after, appears Leonardo da Vinci designing flying machines; Galileo Galilei created the telescope; and with the new world the maritime trips and the development of naval engineering started (Grech, 2001). The term "engineer" was used for the first time in the 14th century to reference to the one who operated an *engine* (Rae et al., 2001; Lienhard, 2006). With the industrial revolution the field of action to the engineering was opened, in 1781, then, James Watt attained to patent the first steam machine , the ancient sources of energy were incorporated to its systems but this did not attain to avoid his extinction years later (Grech, 2001). After these big advances in the steam machines with Franklin and Faraday's work, transform the mechanical energy to electrical energy is achieved, thanks to this it could be used like a source of power in industry (Grech, 2001). Thomas Alba Edison invented the incandescent light bulb and contributed to big advances designing batteries for the energy storage (Grech, 2001). England, France and Germany were the first countries in recognizing the profession of engineer, being a work executed by the most notable soldiers (Corchuelo, 2004). The technical advances of 19th century greatly broadened the field of the engineering and they introduced a big number of specializations. The United States made substantive technological developments with the Massachusetts Institute of Technology -MIT- opened in 1865 by contributions of the geologist William Barton Rogers; at the beginning only industrial sciences were thought, and then emerged several branches: aerospace, chemical, shipbuilding, roads, canals and ports, telecommunications, electrical, electronics, industrial engineering, geology, materials and information technology. The fast development of semiconductors for the electronics industry in the 1960s, gave a boost to the materials science. In the late 1980s, fields of knowledge that were previously outside as genetic engineering and nuclear research appeared (Corchuelo, 2004). In America, the history

of the engineering traces started from to the Pre-Columbian period: into the Incas, Mayas, Aztecas constructions. In Colombia, in a lower degree, the constructions Chibcha and Tayrons culture were discovered; in all them were developed the numbering and mathematics systems more or less elaborated. In the colony period, the civil defense works, walls, castles and big religious monuments are associated to the engineering, also it was used to mines engineering, by obvious reasons (Rincon et al., 2010). Engineering then, answers to the world-wide needs and were opening fields in different disciplines.

3. The industrial engineering in the world

The industrial engineering attained a development in the textile industry with the invention of the mechanical spinning wheel in 1775 by Sir Richard Arkwrigth in England. Besides, he also created the first model of operative control system in factories to regulate employees' production (Jimenez, 2008). Babbaje (1792-1891) formed the analytical systems to improve the increasing operations and productivity in factories; but it was the need to change the way as those industries worked when the United States and Europe started the transformation. F. Taylor improved the methods of materials handling, he is called the "father of the scientific administration". Harrintong Emerson defended the efficient operations and the payment of prizes by increasing the production. (Universidad de la Guajira, 2003). With the birth of the industrial engineering Federico Winslow Taylor's findings were recognized and he is considered the father of the industrial engineering (1856-1915). He studied the human factor, the mechanics and the materials inside the production process; he developed a system based in the concept of task, reducing the dead times and the displacements in the United States of America; to this author is attributed in 1903 the costs disposal and material fixing to improve the work; proposing the study of times to optimize the processes. In 1912 Henry Fayol considered as the father of the modern operational theory implanted two concepts: the principles of the direction and manage duties. Frank Gilberth, who was a bricklayer, devised a system to reduce times: hiring personal to low cost; he also identified 17 basic movements from human body which made the work planning an easier task. On the other hand, Barnes' studies collaborated to decrease materials costs and employees' fatigue, this method was used to improve the performance (Jimenez, 2008). Also Henry Gantt changed the system to a method of economic incentives to the workers and foremen that showed to be more efficient that the others in the factory. In 1917 he implemented a method by planning aims previously fixed, which is known like the diagram of Gantt (Grech, 2001). In the thirties, Allan Mogensen developed methods for working simplification just establishing the term of "engineering of methods" used by H.B. Later, Maynar In1932 with the second world-war he promoted the term operations research (UNAM, 2001). The industrial revolution did that they recognized the concept of industrial process, contributing to big changes in the work handle in the companies, and with the implementation of methodologies close to the introduction of times and movements, establishing work standards to make the products, the planning of the processes and its systematization. Industrial engineering has evolved in different fields making important contributions in social, environmental and technological levels; providing sustainable development conceived like equity, competitiveness and sustainability process, based in ethical, cultural, socioeconomic, ecological, institutional, politicians, technicians and productive principles (Londoño, 2011; Vega, 2013).

4. Birth of engineering in Colombia

Ortiz & Giraldo (2003) do a brief review about the beginning of the engineering in Colombia, it started in the Independence war, when Juan del Corral inaugurated in Medellín, in August of 1814, the Academy of Military Engineers. This was the first Colombian School of Engineering.

The Franciscan school, nowadays Los Andes University, was the school base: young men initiated in letters, they received a military course that had six treaties; in addition, they learnt arithmetic, classical and analytical geometry,

trigonometry and algebra; they would study military architecture, hydraulic and civil, artillery, geography, cartography, principles of the tactics and other subjects. According to the engineer Álvarez (2008) at the end of 19th century Colombia had hardly two hundred engineers, many of them formed in foreign universities. From 1881 to 1884 the School of Engineering worked as a dependency of the Ministry of War. In 1902, when the war of the One thousand Days finished, the faculty worked without interruption in the National University. In 1910-1935 period the Engineering and Mathematical Faculty of the National University of Colombia constitutes one of the most brilliant institution of its development until then (Hernandez, 2011). In 1935 there were some favorable commercial scales that detour the attention to the coffee growing; this situation articulated Colombia with the world-wide market. The school of Mines in Medellin provided a skilled degree in engineering of oils, and the Bucaramanga and Cali universities initiated special courses of mechanical engineering and industrial engineering. In 1940, it was the Industrial University of Santander the one who formed professionals in industrial Engineering; for that reason, in 1958 Industrial University of Santander created the first faculty of Industrial Engineering. The Second World War in 1945 interrupted the arrival of raw material to Colombia; it was the University of Antioquia, the one who prepared engineers devoted to the production of these raw materials. In that way, in 1961 in the national University was created the Departments of Electrical Engineering and Mechanical Engineering, and in 1965 they incorporated the Department of Chemical Engineering, as the culmination of the process of academic and administrative integration made in the university. In 1969 the Department of Agricultural Engineering and in 1978 the Department of Engineering of Systems were created (Hernandez, 2011).

In 1966 the University of Antioquia promoted the diversification of the careers. They created Industrial Engineering in 1966, Metallurgist in 1967. At the beginning of the decade of 1990 in the University of Antioquia only existed the master degree in Environmental Engineering; afterwards they created specializations in Industrial Engineering and in Electronics, and the university supported the creation of the mastery and the doctorate in Chemical Sciences. Later, all the Colombian universities saw the need to prepare professional in this area and created the engineering careers: in 1961 The Andes University with a humanist profile, in 1968, the University of Antioquia. In 1972 the Distrital University Francisco José de Caldas, in 1974 the Pontificia university and technological of Colombia UPTC , in 1975 the Libre University, in 1977 the Valle University establish the training of this profession, in 1996 in Medellín a earthquake of the National University established the Faculty of Industrial Engineering, in 2003 the program of Industrial Engineering obtained the Register qualified by 7 years, authorized by the Ministry of National Education by the resolution 3249 of 15 December of the 2003. In the university foundation of Popayán, the academic program of industrial engineering was born according to agreement 004 of 11 October 1993 whose first promotion was in 1999 (Gaviria, 2003; Hernandez, 2011).

The need of industrial engineering and its professionals, was linked to the birth of the industry in Colombia with everything and the problems of create companies in our country, Valero (1998) mentions that in the nineteenth century in the center of Colombia the industrial development was little; between 1881-1893 some advances of the industrial revolution on railway were made; period known as regeneration because of support measures of state. In 1858 the first exploitations of iron were made and it was installed an oven in the farm “ la pradera”; however efforts to create company were unsuccessful. Segovia & Navarro (1967) explain that between 1900 and 1930 it was created the company "Rayando papel" by Mr. José Vicente Mogollon who played an important role in the country's development because even in times of crisis as it was the war of the thousand days were founded 321 publications from newspapers to magazines purchasing paper and ink to Mr. Mogollon; Lorenzo Codazzi worked with hydraulic

energy acquiring equipment in the United States; the company "El Zancudo" was organized in Antioquia demonstrating the role of occupational health, efficiency and training of workers and mining technician; in 1875 was create the mining company of Antioquia; in Cartagena in 1891 the first energy plant is born; in 1878 the first company of matches is created. It can be said that the formation of business in Colombia has played a decisive role in the development of the country and therefore in education forming professionals to cover this necesity. Raymond (1987) wrote that between 1907 to 1980 were performed in the region of Santander department agro-industrial projects, industry pioneer in yarn, manufacture of sugar, exports of coffee, rubber, leather cattle and leather goat , wheat harvest, production of chocolate and alcohol, but these attempts failed because of the bad roads, low productivity and high costs. Jaime Salazar Montoya spoke of the creation of the transport company; "Transport Salazar" a family business between 1918 and 2000.

In Colombia's economic growth began during the first two decades of the twentieth century. The development of the coffee economy, access to the economy of international credit, changes in economic policy, expanding infrastructure, rapid urbanization, demographic changes, the proliferation of a contingent of peasant masses and the beginning the industrialization process mark the mutations suffered by the Colombian nation on its way to modernization. The economic heritage of the nineteenth century and the geographical conformation of the country printed a regional character to the industralization, as recorded the experiences of Antioquia with the gold trade, Barranquilla with the development of the port, Bogota with trade and business and Valle del Cauca with the opening of the port of Buenaventura and the Pacific railway construction; expanding commercial networks (Dávila, 2003).

5. Industrial engineering and education

The education role is fundamental according the approach that students should receive specially in engineering. Nowadays, it is a profession which applies the knowledge of the basic sciences for the efficient use of the materials and nature strengths in order to satisfy the increasing needs of the humanity (Palm et al., 2012).

The education in engineering has suffered important transformation processes: In 1088 and 1167 education in arithmetic, astronomy, geometry, logical, music and rhetorical has a special emphasis; in the middle age the emphasis was the cartography and the development of areas related with bridges construction, tunnels and roads;. In the renaissance navigation was the knowledge which prevailed (Lockard, 2010). Later, the industrial revolution started with the development of the steam machines in 1780, but even if the education was given in basic areas, the profession of engineer was not determined. This appeared in 1818 where the schools of civil engineering were created, then, because of the needs of construction buildings, railroad tracks, bridges, machinery, etc., the mechanical engineering has its origins. Then, England, France and Italy concentrated on military requirements and some universities focused their education on these branches. The modern university arises in Berlin in 1809 where they joined the needs to teach the basic areas of the engineering and the investigation. Later in the United States of America under the concept of the British Empire in 1802 the military academy of west initiated the education based on engineering of the construction, where it involved the students in partial works to know the existent reality. In the Statement of the Sorbonne in 1998 it was expressed the will to create an European space devoted to the superior education. Later, through the Statement of 19th June 1999, it was defined measures for this ambitious process of convergence. Following, in Prague life was defined as an essential element to improve European competitiveness, social progress, the creation of equality of opportunities and life quality. It defines the active role of the universities, institutions of higher education and the students in the development of convergence process, as well as the creation of the quality insurance systems and the institutions for certification and accreditation. In 2005 the Conference of Bergen evidenced three big changes that must to exist: 1.The creation of

closer relationships between university education and investigation incorporating doctoral studies as a connection between them; 2. the development of social dimension improving equality conditions to access to higher education 3.to facilitate to the students financial resources and international mobility. The paper of the industrial engineers is to establish a balanced combination of a solid scientific and technical training; different technologies and disciplines applied inside the economic -business and social-humanistic areas, the understanding that comes from the reality of the industrial state (from a wide and global perspective) and the capacity to interrelate different disciplines that take part in complex systems (create, develop and manage), they do professional reasons to be. (Canos et al., 2009).

With the evolution of the university in Europe, and the increasing need of organizational engineering, a professional with a solid mathematical training and statistical was born, people who knows what the subjects are, what are they use, and how put them in practice in a company through the operation of management tools, with the purpose to allow to offer products and services in lower time with more productivity, quality, reliability and possible efficiency. Also people able to diagnose problems, and analyze them (Marín et al., 2009). In Europe the Engineering of manufacture is associated with the industrial engineering in the training programs in a lot of universities. However, the introductions of subjects such as statistics, probability and investigation of operations have given place to the courses reduction or elimination especially when the Japanese products began to control the market. For this situation the government and the universities of the USA answered by the promotion of the engineering of manufacture. Courses related with the processes of manufacture, systems of manufacture engineering, design of systems, and production have been added to the studies plan of engineering (Elsayed, 1999). The industrial Engineering arose in Peru with the aim to increase the quality and the productivity of companies. The current industrial engineer is multidisciplinary, professionals are able to face challenges because of its scientific training and management, and this career is very versed with information technologies. These capacities give to professionals versatility, flexibility on their decisions. In the last years the design, the creativity, the investigation, the development, and the innovation have been the aim to keep improving the career (Palm et al., 2012).

Eliot et al. (2011). In the current vision of higher education and the future aims are: the learning centered in the active paper of the students, the mobility and the relevance of postgraduate and doctorate, accreditation, professional associations, and professional contextualization. For this, is necessary to accomplish an education change based in the school and learning, Lyou educational systems considers students' integral learning is more than information transfer. Then, with the purposes to achieve and optimal educational process it will be guaranteed that students will work in suitable academic environment, it will consolidate technical skills, merits, attitudes and abilities (Zambrano et al., 2009) and in the future, students must be prepared for an engineer career that will be more related with the services than manufactured goods (Wei, 2005).

Strategies for infuse global perspectives in practices and programs of industrial engineering have to be included; the next engineers generation must to be prepared to confront the challenges of the future. (Jackson et al., 2010) In other words, the programs based in the traditional studies plan that requires the assistance in the school are less attractive for the possible students. The potential impact on traditional campuses that do not meet the challenge is not pleasant to contemplate it (Felder et al., 2000) it is recommended strengthen the engineering, by the construction of the concept of sustainability that involve concepts of processes design and products for the future (molecular transformation), thoughts of systems, including complex systems, uncertainty, analysis of the life cycle of products, identification of systems limits for balances of energy and matter, thermodynamic and its relation with the sustainability, renewable energy, creativity, team work, communication, work in moral and ethical

leadership, and stand out the engineer like an social agent (Mihelcic et al., 2008; Marín et al., 2009; Byrne, 2010; The Royal Academy of Engineering, 2007; Moloney, 2010; Mulder et al., 2010; Newberry, 2004; Drake et al., 2005; Rydhagen et al., 2011; Hsu, 2004; Cordoba, 2007).

Dávila. (2016). talked about of the systemic approach of organizations "the interacting groups and the organization as a whole can be viewed as systems or subsystems "; implemented in engineering schools, especially in industrial engineering programs. Systems analysis, provides a framework in which operational research techniques and their applications are used; linear programming courses and other operations research techniques were offered for the first time in the program of Industrial Engineering at the University of the Andes in 1966; operational research was included in the Magister program in industrial engineering in 1968 and was discontinued ten years later. Since then "systems" (systems approaches) to "systematize" (electronic data management) were confused.

In 1972 in the course "Organizational Dynamics" the book of Katz & Kahn clarified the differences in it. He talked about too of the link with Taylorism, whose central purpose is to optimize operational productivity .The research does not reduce maximizing productivity maximizing the productivity of human labor; seeks to optimize operations (not exclusively human or human-machine) of the conceived precisely as a system organization. The pioneers of operational research, Churchman, Ackoff and Annoff, expressed since 1957 as follows: Operational research is the application of methods, techniques and scientific instruments to problems involving the operations of a system to provide optimal solutions for the problem. The connection of operational research with systems theory is that this used basic assumptions of systemic approach. The application of operations research techniques must be used as a reference in systems analysis thus: 1. Formulation of the problem: 2. Construction of a mathematical model to represent the system in question; 3. Derive a solution from the model; 4. Test the model and the solution derived from that; 5. Being useful to deal with engineering problems.

The new information and communication technologies (ICTs) are basic tools that should be incorporated into education as a support for the students training. Activities such as discussions on-line, by which students continue to develop new knowledge and skills with the help of computers, internet, email, chats, text messages, where there are no space and time limitations between teacher and student, This learning is known as e-learning (Contreras et al., 2011). Now, learning that combines education through traditional classroom activities with the non-contact technology, is known as b-learning, it is a result of traditional education and the need to improve forms of learning in order to student appropriate the knowledge more easily (Ramirez, 2010; Coaten, 2003).One of the responsibilities of universities is to train students with quality, specifically industrial engineers must use technological tools in order to link theory with practice, solving needs of today's industry, this is theory of constructivism (Janjai et al., 2012; Miller et al., 2015) raised a virtual factory model that can be modified to students facing real situations that they can change, making the student closer to the actual experience. This tells us that there is a basic need to combine traditional teaching methods and teacher’s role, with changes in teaching strategies with the help of new technologies.

6. Profile of the industrial engineer

The industrial engineer must to have an interdisciplinary and integral training, where the knowledges of administration, economy, operations research, production, social and human factor, environmental and computer knowledge are combined allowing professionals to have a wide vision of the society which they manage; The engineer may direct his perspective to the strategic processes planning, observe his performance and take decisions; use the new technologies for the companies, for the investigation and the education,

having as basic values like: honesty, ethical and professionalism performance. The engineering is a creative process; it is a profession in which the knowledge of the natural sciences, the mathematics and the industrial technician, acquired by the experience and the practice, applies to transform the matter and the sources of energy in the nature, with the purpose to design, implement, keep or operate systems, teams, products or processes that answer a definite need. Also they add that the engineer is an economic agent that works in profit of the humanity, under restrictions given by the technological context, economic, social and ethical (ABET, 1988; National Academy of Engineering, 2004; The Royal Academy of Engineering, 2007). The 21st century has characteristics that differentiate it of the previous. In effect, it is affirmed that the competitions and knowledges that schools of engineering develop are not sufficient to perform in today's world (Natarajan, 2009; King, 2009; National Academy of Engineering, 2005).

7. The industrial engineer in the future

In the current society the future of the industrial engineers is knowing and applying the acquired knowledge and adapt it to a society that is in continuous process of change, where the vision to advance to these challenges is the priority, recovering the professional ethics that gives the freedom to fight against corruption processes that do not allow a society progress.

The apparition of new technologies due to the competition continues the development of new processes and products. New practices must be presented like management and work, new organizational structures new complementary form and new methods of decision (Gonzáles, 2004).

According to Biles, the industrial engineering can group its roots in three big interacting groups: the engineering of production, the administrative engineering and the engineering of human and ergonomic factors (Rojas, 2010). The business functions as we know them today: research and development, engineering of design, manufacture, marketing, and customer service, will be so highly integrated that combine integral and virtual way to respond into the market(Hernandez et al., 2011). If the students do not learn to appreciate elements about the science such as its history, its relations with the culture, with the religion, with different visions of the world, the trade, its philosophical suppositions (epistemological, ontological and methodological ideas) then, the opportunity for the science and the engineering to enrich the culture and the human lives is wasted (Matthews, 1994; Byrne, 2010).

It is important that the engineers have an integral education that allow them involve the solutions impact of engineering in a social and global context. The engineers require knowing the nature of the engineering, optimizing a big variety of requests and technical, practical and political restrictions in the design of solutions (ABET, 1988). In this same road, a new definition of engineering that includes a new concept has opened a big step: the sustainability. *The Engineering Council,* of the United Kingdom, has identified six principles of sustainability: 1) contribute to build a sustainable society in the present and the future; 2) apply professional and responsibly to perform a leadership role ; 3) do much more that fulfill with codes and the valid legislation; 4) use resources in a efficient and effective way; 5) look for multiple visions to resolve challenges of sustainability; and 6) handle the risk, so it minimizes adverse impacts in the population and in the environment (Bogle et al., 2010).

Industrial Engineering must be more participative regarding the institutions represented by universities, the companies with their determining factor in society and the welfare of the population, in order to achieve a common goal; quality and social responsibility within the productive framework.

8. Conclusions

The engineering processes started from the birth of the humanity proving solutions to different

situations that confronted humans. The industrial engineering has played a basic paper in the development of the society in the measure that it satisfies the needs in different fields like the social. Economic, official, financial, environmental and computer.

The engineer of the future confronts a society in constant change with new disciplines, that have to be integrated with technological processes and has to fight in a competitive society recovering the ethics and professionalism, elements that give freedom to combat the corruption that do not allow the progress in our society. The future industrial engineer has to interacting in three big fields to know: the engineering of production, the administrative engineering and the engineering of human and ergonomic factors supported by the new technologies.

The Industrial Engineering has to be more participatory with the institutions represented by the universities, the company with its determinant factor in the society and the welfare of the population, with the purpose to achieve a common aim: quality and social responsibility inside the productive frame. The programs of Industrial engineering in the prospect have to integrate the content of the engineering with the humanities, science and technology. Knowing the involving environment it manages and comparing it with the external environment with his own experiences.

9. References

ABET (Engineering Accreditation Commission). (1988). *Criteria for accrediting engineering programs. Effective for evaluations during the 2009-2010 Accreditation Cycle*. http://www.ordemengenheiros.pt/fotos/editor2/eurace/abet.pdf

Álvarez, J. (2008). *La nueva ingeniería industrial en Colombia*. http://www.uis.edu.co/webUIS/es/mediosComunicacion/revistaSantander/revista3/60NuevaIngInd.pdf

Bogle, D. & Seanab, M. (2010). *The six principles of sustainability*. http://www.engab.org.uk/engcdocuments/internet/Website/tce%20article%20on%20sustainability%20March%202010.pdf

Byrne, E. (2010). *Educating the chemical engineer of the future.* http://www.engc.org.uk/engcdocuments/internet/Website/tce%20article%20on%20sustainability%20March%202010.pdf

Canos, L., García, J., García, J. & Marín, J. (2009). *Competencias Profesionales y Perfil Del Ingeniero De Organización Ante El Espacio Europeo De Educación Superior.* http://www.cibersociedad.net/congres2009/es/coms/competencias-profesionales-y-perfil-del-ingeniero-de-organizacion-ante-el-espacio-europeo-de-educacion-superior/907/

Coaten, N. (2003). *Blended e-learning.* http://www.educaweb.com/esp/servicios/monografico/formacionvirtual/1181076.asp

Contreras, L., González, K., & Fuentes, H. (2011). Uso de las Tics y especialmente del Blended Learning en la enseñanza universitaria. *Revista Educación y Desarrollo Social* 5 (1), 151-160.

Corchuelo, M. (2004). Una aproximación a los procesos de formación de ingenieros. *Revista Electrónica de la Red de Investigación Educativa* 1 (1), 1-10.

Dávila, C. (2003). *Empresas y empresarios en la historia de Colombia: Siglos XIX – XX. Una colección de estudios recientes*. 1ra ed. Bogotá: Norma.

Dávila, C. (2016). *Evolución Histórica de la administración los pioneros y la evolución de la teoría sistémica de las organizaciones*. http://empresarialnet.com/A5UCC/LAORGSISTEMICAuno.htm

Dávila, C. (2016). *Una nota sobre el enfoque sistémico de las organizaciones en Colombia*. http://www.elguiadelviajero.com/A5UCC/LAORGSISTEMICAcol.htm

Drake, M., Griffin, P., Kirkman, R. & Swann, J. (2005). Engineering ethical curricula: Assessment and comparison of two approaches. *Journal of Engineering Education* 94 (2), 223-231.

Eliot, M. & Turns, J. (2012). Constructing professional portafolios: Sense-Making and Professional Identity Development for Engineering undergraduates. *Journal of Engineering Education* 100 (4), 630-654.

Elsayed, E. (2007). Industrial Engineering Education: A Prospective. *European Journal of Engineering Education* 24 (4), 415-421.

Felder, R., Woods, D., Stice, J. & Rugarsia, A. (2000). The future of education engineering II. Teaching methods that work. *Chemical Engineering Education* 34 (1), 29-39.

Gallego, R., Pérez, R., Gallego, A. & Pascuas, J. (2004). *Didáctica constructivista aportes y perspectivas.* http://www.saber.ula.ve/bitstream/123456789/19856/2/articulo14.pdf.

Garzón, C. & Moreno, C. (2011). La facultad de ingeniería 2030. *Special Issue - 150 Years UN Engineering Faculty* 31 (1), 91-99.

Gaviria, A. & Valencia, A. (2003). *Evolución histórica de la facultad de ingeniería de la universidad de Antioquia.* http://ingenieria.udea.edu.co/historia.html

Grech, P. (2013). *Introducción a la Ingeniería, un enfoque a través del diseño.* Bogotá: Prentice Hall, Inc.

Hernández, D. (2012). 150 años construyendo nación con ingenio propio. *Revista Universidad Nacional de Colombia* 31 (1), 51-55.

Hsu, C. (2004). *Dilbert's Dilemma*. In US News and World Report, Washington, DC, United States, p. 54-59.

Jackson, H., Tharini, K., Zapalska, A. & Zelmanowitz, S. (2010). *Strategies to Infuse Global Perspectives and Industrial Collaboration in Engineering Education.* 40th ASEE/IEEE. Frontiers in Education Conference (FIE), Washington, DC, United States, p. S1J1-S1J5.

Janjai, S. (2012). Improvement of the ability of the students in an education program to design the lesson plans by using an instruction model based on the theories of constructivism and metacognition. *Procedia Engineering*, 32, 1163-1168.

Jeffers, A., Safferman, A. & Safferman, S. (2004). Understanding K–12 Engineering Outreach Programs. *Journal of Professional Issues in Engineering Education & Practice* 130 (2), 95-108.

Jimenez, S. (2008). *Blog Introducción a la Ingeniería Industrial.* http://ingenieriaindustrialupbbga.blogspot.com/2008/08/ingenieria-industrial.html

King, J. (2009). Educating engineers for the 21st century. *International Engineering Education* 1 (2), 3-28.

Lienhard, J. (2006). *How Invention Begins: Echoes of Old voices in the Rise of New Machines*. New York: Oxford University Press, Inc.

Lockard, C. (2010). "The Sea Common to All": Maritime Frontiers, Port Cities, and Chinese Traders in the Southeast Asian Age of Commerce, ca. 1400- 1750. *Journal of World History* 21 (2), 219-247.

Londoño, R. (2011). Aportes y perspectivas de la ingeniería en el desarrollo humano en Colombia, en el devenir de los últimos 200 años. *Revista Épsilon* (16), 11-30.

Marín, J., García, J., Perello, M. & Canos, L. (2009). Proposal of skills for the bachelor degree of Industrial Engineering in the context of the new curriculum. *Journal Intangible Capital* 5 (4), 387-406.

Matthews, M. (1994). *Science Teaching: The Role of History and Philosophy of Science.* New York: Psychology Press.

Mihelcic, J., Paterson, K., Phillips, L., Zhang, Q., Watkins, D., Barkdoll, B., Fuchs, V., Fry, L. & Hokanson, D. (2008). Educating engineers in the sustainable futures model with a global perspective. *Civil Engineering & Environmental Systems* 25 (4), 255-263.

Miller, A. & Bures, M. (2015). New approach to industrial engineering education with the help of interactive tools. *Procedia Social and Behavioral Sciences* 174, 3413-3419.

Moloney, C. (2010). *Understanding across the disciplines: Towards strategies for sustainable engineering education for the 21st century.* Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, IEEE, Newfoundland and Labrador, Canada, p. 1-31.

Mulder, K., Segalas, J. & Ferrer, D. (2010). Educating engineers for/in sustainable development? What we knew, what we learned, and what we should learn. *Thermal Science* 14 (3), 625-639.

Natarajan, R. (2009). *International Engineering Education: Proceedings of the INAE-CAETS-IITM*. In Conference World Scientific, London, England, p. 155.

National Academy of Engineering. (2004). *The Engineer of 2020. Visions of engineering in the new century.* Washington, DC: The National Academies Press.

National Academy of Engineering. (2005). *Educating the Engineer of 2020: Adapting Engineering Education to the New Century.* Washington, DC: The National Academies Press.

Newberry, B. (2004). The Dilemma of Ethics in Engineering Education. *Science & Engineering Ethics* 10 (2), 343-351.

Palma, M., De los Rios, I. & Guerrero, D. (2012). Higher education in industrial engineering in Peru: towards a new model based on skills. *Journal of Engineering Education, Procedia - Social and Behavioral Sciences* 46, 1570-1580.

Pawley, A. (2009). Universalized Narratives: Patterns in How Faculty Members Define "Engineering". *Journal of Engineering Education* 98 (4), 309-319.