New Methodological Approaches And Paradigms In The Pedagogy Of Systems Engineering

Nuevos enfoques metodológicos y paradigmas en la pedagogía de la ingeniería de sistemas

Novas abordagens metodológicas e paradigmas na pedagogia da Engenharia de sistemas

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Abstract

Introduction: The literature review article is a product of the research “New Methodological Approaches and Paradigms in the Pedagogy of Systems Engineering” developed at the Amazonia University during the year 2020.

Problem: The new challenges facing systems engineering require the development of an integrated approach to the content seen in academic training processes, as well as involving significant changes in teaching and learning methodologies and styles.

Objective: To analyze the methodological approaches and international paradigms in the pedagogy and teaching of engineering that have produced better results.

Methodology: The existing literature on New Approaches and Methodological Paradigms in the Pedagogy of Systems Engineering was analyzed in the local, national, and global context. The ScienceDirect, Scielo, Proquest, Web of Science Engineering, Scopus, Dialnet databases were extensively reviewed.

The results: A comparison is made between the international pedagogical approaches and those that have been developed in Colombia, to identify the key methods and principles that national universities need to integrate and promote the development of more creative and innovative professionals.

Conclusion: International pedagogical models choose to generate professionals with greater problem-solving capacity, amid a practical approach that allows them to influence and transform reality.

Originality: The understanding of alternative teaching approaches based on a particular reading of the current reality and the specific needs of the market in the digital age.

Limitations: The lack of primary sources, such as interviews, through which the perceptions of university managers or engineering professors are consulted.

Keywords: systems engineer, pedagogy, teaching, digital revolution.

Resumen

Introducción: el artículo de revisión de literatura es producto de la investigación “Nuevos Enfoques Metodológicos y Paradigmas en la Pedagogía de la Ingeniería de Sistemas” desarrollada en la Universidad de la Amazonia durante el año 2020.

Problema: los nuevos desafíos que enfrenta la ingeniería de sistemas requieren el desarrollo de un enfoque integrado en los contenidos que se ven en los procesos de formación académica, además de que implican cambios significativos en las metodologías y estilos de enseñanza y aprendizaje.

Objetivo: analizar los enfoques metodológicos y los paradigmas internacionales en la pedagogía y la enseñanza de la ingeniería que han producido mejores resultados.

Metodología: se analizó la literatura existente sobre Nuevos Enfoques y Paradigmas Metodológicos en la Pedagogía de la Ingeniería de Sistemas en un contexto local, nacional y global. Se revisaron intensamente las bases de datos ScienceDirect, Scielo, Proquest, Web of Science Engineering, Scopus, Dialnet.

Los resultados: Se establece una comparación entre los enfoques pedagógicos internacionales y los que se han desarrollado en Colombia, para identificar los métodos y principios clave que las universidades nacionales deben integrar para promover el desarrollo de profesionales más creativos y con mayor capacidad de innovación.

Conclusión: los modelos pedagógicos internacionales optan por generar profesionales con mayor capacidad de resolución de problemas, en medio de un enfoque práctico que les permita influir y transformar la realidad.

Originalidad: se basa en la comprensión de los nuevos enfoques de enseñanza a partir de una lectura particular de la realidad actual y de las necesidades específicas del mercado en la era digital.

Limitaciones: la falta de fuentes primarias como las entrevistas, a través de las cuales se consultan las percepciones de los directivos de las universidades o de los profesores de ingeniería.

Palabras clave: ingeniero de sistemas, pedagogía, enseñanza, revolución digital.

Resumo

Introdução: o artigo de revisão de literatura é o produto da pesquisa "Novas Abordagens Metodológicas e Paradigmas na Pedagogia da Engenharia de Sistemas" desenvolvida na Universidad de la Amazonia durante o ano de 2020.

Problema: Os novos desafios da engenharia de sistemas exigem o desenvolvimento de uma abordagem integrada dos conteúdos vistos nos processos de formação acadêmica, além de implicar mudanças significativas nas metodologias e estilos de ensino e aprendizagem.

Objetivo: analisar as abordagens metodológicas e paradigmas internacionais em pedagogia e ensino de engenharia que produziram os melhores resultados.

Metodologia: a literatura existente sobre Novas Abordagens e Paradigmas Metodológicos em Pedagogia de Engenharia de Sistemas foi analisada em um contexto local, nacional e global. As bases de dados ScienceDirect, Scielo, Proquest, Web of Science Engineering, Scopus, Dialnet foram intensamente revisadas.

Os resultados: Estabelece-se uma comparação entre as abordagens pedagógicas internacionais e as que foram desenvolvidas na Colômbia, para identificar os principais métodos e princípios que as universidades nacionais devem integrar para promover o desenvolvimento de profissionais mais criativos e com maior capacidade de inovação.

Conclusão: os modelos pedagógicos internacionais optam por gerar profissionais com maior capacidade resolutiva, em meio a uma abordagem prática que lhes permite influenciar e transformar a realidade.

Originalidade: baseia-se na compreensão de novas abordagens de ensino a partir de uma leitura particular da realidade atual e das necessidades específicas do mercado na era digital.

Limitações: a falta de fontes primárias como entrevistas, por meio das quais são consultadas as percepções de diretores universitários ou professores de engenharia.

Palavras-chave: engenheiro de sistemas, pedagogia, ensino, revolução digital.

INTRODUCTION

In the last thirty years, our civilization has experienced a development in the digital revolution with giant steps, transforming and generating changes in the social, educational, cultural, economic and political fields that have developed how people communicate, inform themselves and develop each of their daily activities; a situation that undoubtedly has generated new needs in professional training processes and, subsequently, academia, since the contents, teaching processes and methodological approaches must be aligned with the new needs and challenges of the context.

In Velez' and Benjumea's words [1] "the information society has established a new development and social structuration model based on I. C. T. which has produced relevant changes in education, in tools teachers count to teach with, the relation established between teachers and students and in adaptation processes through which students can develop different learning styles according to their necessities and capabilities".

Systems engineering is not indifferent to these processes of methodological transformation in academic matters and, with greater need, deserves special attention in the design and application of these new processes, maintaining a constant relationship between the digital revolution and learning styles as the profile of the systems engineer is key in the academic and professional world to merge, produce, transform and innovate the networks and data that structurally compose the technological development processes [2].

The systems engineer is a professional specialized in the design, programming, implementation and maintenance of computer systems, and their primary task is to manage networks and information systems so that the data handled within an organization are handled effectively and efficiently. Engineering has a research component aimed at the creation and implementation of software and hardware within organizations [3]; a situation that puts the profession of a systems engineer in a privileged place, for it could be said that in their hands is the progressivity of the digital revolution, depending indisputably on their ingenuity, dedication, inspiration, creativity and capacity for innovation.

In line with Imperiali's argumentation [4], the profile of the systems engineer must be comprehensive, taking into account that the principal capacities currently valued in the world's information society are the creativity, innovation and flexibility to be able to adapt to different exigency and risk types. Therefore, it is essential that systems engineering programs integrate the development of knowledge in different areas of training, so that engineers can perform with greater skill in different fields such as: web design, robotics, computer security, multimedia, technological infrastructure, software construction, telecommunications, and technology management, among others [5].

This means that, today, the systems engineer has an increasingly larger field of action and a fundamental position in a constantly developing society, as it has become one of the fundamental elements for the technological development of the world [6]. However, the central analysis topic is that of the new risks faced by systems engineering; not only a demand an integral focus development of the contents studied in the academic process but, moreover, the significative changes in teaching-learning methodologies and styles. They must be based on the possibility of generating effective capacities in problem resolution through different elements such as collaboration, significative learning and adaptative focus development, which permit the students to learn according to their learning rhythm and capacities.

In Imperiali's words [4], the binomial between technology and education, in the case of systems engineering, implies understanding the necessity to promote strategies which not only promote the access of the information, but improve the learning quality or enlarge the information access but also continually improve the learning efficiency. This efficiency; explain by Troiano, Breitman, and Gete-Alonso [2], is measured not only through students passing courses or subjects and getting good scores in tests, but in their capacity to reflect on problems presented in the information society and innovate through the design and application of concrete solutions.

According to Zapata and Flórez [7], these capabilities can only be generated: if flexible and versatile communication processes are established in the classroom, if different computer-based educational resources are used to facilitate the personalization of information and learning, if learning communities are generated within the courses, and if collaborative mechanisms help understand and process a large amount of information available in a faster and more versatile way.

Following Capote, Rizo and Bravo's appreciations [8], and taking into account the central role played by systems engineers in changing the paradigms in the world context, learning processes must look to form professionals who not only learn concepts and conceptual contents but know "how to do"; it means that they must be able to perform beyond the logic reality of the different structures, equipment and performances. Moreover, they must work through principles and attitudinal knowledge which promote values and a better disposition to face problems.

Additionally, it should take into account that there are different types of facts in a university career that guide, modify and transform learning- teaching styles. For example, as Zapata and Florez [7] mention, the type of career largely determines methodologies and approaches used to make students understand the contents and to promote joint processes for knowledge-building. On the other hand, Villamizar and Sanabria [9] explain that each academic trajectory promotes different learning styles as each specific moment in the formation process demands students' different types of capacities. Finally, Imperiali [4] explains how teachers' traditions, previous experiences and habits configure determined teaching styles, independently of the career and cycle.

Now, it is important to consider the appreciation of Marín, Cabas, Cabas, and Paredes [10] when they state that engineering training processes require the development of a set of specific competencies that are associated with the needs that exist in the market. It is, therefore, necessary for universities and all academic training centers to develop partnerships that help to identify market changes through implementing spaces in which engineers can discuss training programs.

Therefore, curricula and systems engineering programs should contain within their structure, subjects, or educational cycles that promote the development of competitive, enterprising individuals, and above all, with the ability to adapt to complex and unpredictable situations; the resilience capacity in professionals, today is an indispensable requirement to ensure their integrity. The argumentation that has been addressed and raised helps to recognize that teaching methodologies and styles vary according to a multiplicity of factors and that, in each case, teachers must consider how these factors can influence the development of changes in paradigms and work styles.

In the case of systems engineering, a series of active, sensorial, visual and sequential ways and forms to learn have been established, which implies the generation of different types of dynamics and strategies to call a student's attention to the need to maximize their capacities associated with creativity and innovation and to respond assertively to dilemmas imposed by the moment.

As already mentioned, it is necessary to provide quality to the profession of a systems engineer, to exalt the professionals from their training, because their role in society is of utmost importance if it is from these professionals that the evolution of new technologies is driven; new advances arise from comprehensive professionals, and from their competitiveness capacity, the evolution is generated; in our country, there is a wide academic offering among the different universities to train alternative systems engineers, but the questions are: Do they have academic curricula and methodologies to contribute to technological and digital evolution? Is our country providing new professionals with the academic tools to promote the creation of new technologies? Are we aware of the importance of the profession in the evolution of our species?

The above considers that the development of new technologies has transformed the different processes of our society, not only in labor matters, because it also plays an extremely important role in the processes of production, training, and education, but additionally, it has transformed the economic sector, providing technological and digital tools that facilitate and expand the field of action of individuals who make up our society.

The analysis posed opens the discussion about the currentness, pertinence and efficiency of systems engineering programs offered as a professional career in different Colombian universities. For this, it is essential to analyze and understand the most recent methodological approaches and paradigms in systems engineering pedagogy and those which have produced the best results in the world. Through this analysis it is possible to observe the approaches that Colombian universities have employed that lead to the development of the skills and capabilities required by systems engineers, so that they can respond to the demands of the local and international environment.

To fulfill this purpose, it is proposed to make an article through the literature review technique on methodologies and paradigms implemented in the teaching of engineering systems of recognized international universities. Also, we analyze the teaching approach that has been generated in the Colombian universities that offer the program in systems engineering, recognizing problems and limitations. In this way, with the development of this article, it is sought to establish a comparison and develop suggestions as a conclusion, which improve upon the profile of professional systems engineers.

The aim of the article is also to understand a particular problem; although it is true that through Law 30 of 1992, the Congress of the Republic of Colombia (1992) has assigned an important and fundamental role to comprehensive education for each of the higher education careers, to promote the full development of each of the student's abilities, in practice, there are significant inconsistencies with this utopian principle enshrined in the law.

According to Arias and Aristizábal [5], there are currently gaps between educative normative guidelines with what happens in the classrooms. It is because engineering students, although they finish their studies and graduate, rarely have the generic and specific skills and inherent competences for the profession.

This situation does not only imply updating and modernizing the norms from which education in Colombia is oriented, considering social, economic and political changes that have been generated due to technological development. It is also important to pay greater attention to the systems engineering career curriculum, observing how communication skills development is being strengthened within a self-learning context and collective knowledge construction.

In response to the above, the article analyzes the comprehensive training in engineering programs, in correspondence with Colombian educative quality policies. Likewise, the main conceptual, procedural and attitudinal competencies are recognized as distinctive features of the profile, and the most outstanding characteristics, which from the point of view must guide pedagogical practice and didactic mediation; elements that allow the elaboration of conclusions aimed at strengthening academic processes, changing the elaboration of the different curricula, and implementing adequate strategies that inspire and imprint, in the new professional's capacities and qualities, the generation of competitiveness, evolution, transformation, and technological development from the academic campus.

MATERIALS AND METHODS

A qualitative approach is used for the development of the article since it is understood that the analysis of each topic or situation involves a group of people and situations composed of distinct elements and relationships that must be understood and analyzed [11]. Through the review of literature and analysis, concepts and meanings are studied to propose concrete recommendations for improvement. According to the words of Rodriguez [3], qualitative research allows us to observe reality in its natural context, identifying the diverse realities, interactions, and relationships that are generated, always valuing the meanings that the people involved have in each process.

In this way, we seek to explore and get as much information as possible about systems engineering education programs in the world, in Latin America and Colombia; the collection of the aforementioned information will allow an analysis and comparison between each context. Finally, data involving opinions, perceptions and phenomena that guarantee the identification of methodologies and paradigms in systems engineering education are required.

The development of the three specific objectives will be carried out through a literature review of research documents, such as articles, books and official documents (governmental in terms of the government program regarding the development of the career in question); responding to the search for categories, such as: systems engineering curriculum, methodologies, and paradigms in systems engineering, innovation, competitiveness. The document selection criterion require that the documents have been published in academic journals within the last five years and that they are written in Spanish or English.

RESULTS

General considerations on engineering education

Sanz [12] believes that education must incorporate social, economic and cultural contexts, so that people can face the significant new world challenges that the information society has orchestrated. In this sense, education comprises many circumstances that seem external or that, at first glance, are not part of the classroom. Therefore, the challenge of engineers is to seek innovative and creative solutions that generate well-being and improve people's quality of life.

Hazen [13], on the other hand, postulates that the study of engineering should give importance to creativity and imagination that respond to the needs that are appearing in society, but, for the development of these skills, it is indispensable to doubt the

For this reason, pedagogy must undergo a transformation in which concepts and methods are rewritten and focused on the challenges that the traditional dynamic of Information and Communication Technology brings; within this search, ideas and research focused on the creation of methodologies arise, leaving traditional conceptions and opening the way to a more effective, lasting and critical learning process that allows the student to actively participate in their educational process [14].

The pedagogical transformation efforts have begun adopting methodologies with more focus on the student, so that the learning process, instead of being only receptive and repetitive, is constructive [15]. The intent of this type of "active" methodology is that the student not only obtains knowledge, but also learns how to be and how to do, which means that beyond theoretical aspects, pedagogy focuses in aspects that have to do with attitudes and procedures [16]. Within these methodologies, real everyday life situations are highlighted so that students detect problems, and propose strategies to solve them [17].

Information and Communication Technologies as an innovation tool in teaching

However, Information and Communication Technologies (ICTs) could be defined as those tools that are aimed to improve communication processes and that, also, allows learning processes to be more flexible and diverse in the sense that a subject can access the information and necessary dynamics to learn a topic anywhere with only the presence of an electronic device [18]. However, to make these ICTs learning processes viable, Colina and Bustamante [19], consider it necessary that educational institutions train their students in the efficient and adequate use of these tools so that, in the future, students can incorporate this knowledge into their personal and work life.

It is important to understand, therefore, that these technologies by themselves do not represent an immediate change in all pedagogical processes that comprise teaching and learning. The impact of ICTs on education depends entirely on how teachers incorporate and use them, their purpose and criteria when integrating them [20]. When a teacher incorporates them or an educational institution encourages their teachers to do so, transformations arise in educational structures and traditional teaching concepts; for this reason, schools should understand the impact their use has [21].

An example of this transformation, according to Zabala, Perez, and Rodriguez [22], was in the changes made at the University of Research and Development Colombia where they implemented a robotics competition every semester as a means of practical and competitive learning; seeking to generate knowledge, skills, and abilities in areas such as mathematics, programming, instrumentation, mechanics, and electronics; obtaining the interest of students and teachers to strengthen participation in the event by encouraging research skills.

Valerio and Paredes [23] consider that the incorporation of these tools has shown positive results, such as the creation of online courses; imparting the necessary knowledge in those subjects with higher failure rates and providing increased capacity via distance learning for those classes with high demand or; as González [24] points out, "web educational platforms such as E-status have been created to offer students a series of exercises which can be corrected during their development". It is worth highlighting the breakthrough that has been achieved through the intelligent cloud. Its sole purpose is to generate personalized learning experiences through digital books and adaptive learning, allowing teachers to have access to the content most used by each student and thus focus their teachings according to the demands of each student [25].

Rodríguez *et al.* [3] consider that the incursion of Information and Communication Technologies has made access to information necessary for all people in any activity they do, whether they are students or workers. Therefore, it is imperative that society evolves and adapts from all areas so that this evolution continues to be channelled correctly. ICT methodologies are an efficient alternative to fill those gaps that may be difficult for real-life professionals to face quickly and effectively regarding the requirements that the world demands.

In this sense, learning methodologies incorporating technological tools are indispensable because they allow students to have a much more active role in the pedagogical process, which leads them to more comprehensive and profitable training.

Likewise, Popov [26] considers that a positive change, in which engineering education has active, participatory and creative implications, is necessary. At the same time, the new forms of pedagogy focus on modifying the context in which learning takes place to improve the fields and also to transform traditional teaching [27]. Thus, through technology, there are spaces in which Artificial Intelligence (AI) is combined with technology to create learning environments which, besides improving teaching and learning processes, require students' interaction with electronic devices such as computers [28].

Among these developments in Artificial Intelligence, Intelligent Tutorial Systems – ITSs are found [29], which could be defined as cognitive tools that combine cognitive science discoveries, computational techniques and advances in Artificial Intelligence that seek to create systems that adapt to the needs of the students depending on the level of knowledge they possess, but that also work for teachers and their teaching styles [30]. In this sense, ITSs seek to personalize the teaching style, that is, that it works for the specific needs of each student and adapts to their learning pace [31].

For the design of an ITS in education, three main factors are usually taken into account. The first is the domain model, in which features are introduced that categorize the hierarchy of learning topics, the level of difficulty and the time that students must spend to develop the activities [32]. The second is the student model, in which a model is designed that incorporates the activities through which the students learn [33]. However, there is much controversy around this point because it is difficult to reach convergence on content about what the student considers appropriate; but the system must feed on this information. For this reason, basic overlay models have been used that are proposed by Carr and Goldstein [34] in which the levels of understanding that students are having on certain topics can be recorded and thus, determine if the student is effectively learning or if, on the contrary, the issue is not clear.

The third and final factor is the pedagogical model that seeks to consider the individual differences of students and, taking this into account, motivate them through different techniques to learn. In these models, we have considered the introduction of the pragmatic theory of Arruarte, Fernández, Ferrero, and Greer [35] on Cognitive Learning from Automatic Instruction, which considers the objectives that the institutions intend to achieve with the subjects that are taught, besides the characteristics of the students, identified by the teachers.

Teaching approaches to systems engineering in the international context

In the Anglo-Saxon scenario, Ventura, Palou and Zseliga [36] explain that, in systems engineering careers, the learning processes are oriented according to a previous analysis on the abilities and aptitudes of the students, to generate pedagogical models and approaches that adapt to the particular needs and that help to enhance the development of the strengths of each of the students. In this way, a basic input for the beginning of courses and careers in universities, is to fully understand the work and thinking styles, interests and variations in language.

Tallón [37, p. 1177] refers to the need to pay attention to the emergence of bilingual education in computer engineering, or that at least aims to cement the knowledge and applied use of the English language, conducting a specific study on operating systems based on the concrete experience of the operating systems courses taught entirely in English, which is based on the premise that English is the predominant language in the scientific and academic field, especially as far as computing and ICTs are concerned. The author argues that "This is more significant among Computer Engineering students who must be able to manage technological projects - for which a command of oral and written texts, typical of scientific literature in English, is required".

Thus, in the Anglo-Saxon model, the importance of promoting adaptive education is highlighted. In systems engineering careers of Spanish universities, the need to generate adaptive and flexible education models has also been understood. These models are transformed according to not only to the students' capabilities but also to the requirements of the competitive, professional and technological environment, to provide professional training to those who can face the new challenges imposed in a time where high technological dependence is characterized by processes associated with the digital revolution.

On the other hand, Crawley, Malmqvist, Östlund, Brodeur and Edström [38] point out that, in Europe, it has been key to promote the development of an adaptive approach to teaching systems engineering since it is based on the central assumption that good results in this career do not depend on the student's skills or the efficiency of the teaching methods, but rather on the development of a process through which the environment can adapt to the individual needs of each student.

However, it should be noted with Marín *et al.* [10] that the development of an adaptive and flexible approach requires complex commitments, and efforts for instructional spaces must be generated to promote education principles that focus on the individual as a basic construct to enhance the common development of the entire group.

These diagnostic dynamics generate cost overruns in the education system, which can be remedied in Europe due to the efficient development of the system and the need to continually advance the training of increasingly better-trained professionals, with better innovation and creativity capabilities to respond to the dilemmas that are constantly presented in the information age [1].

As seen, in the Anglo-Saxon environment and also in countries such as Spain, education based on learning styles has been oriented in the teaching of systems engineering as an indicator through which it is perceived that all students have different ways of conceiving reality, understanding the contents and processing information. This is why it is necessary to generate different teaching approaches, which are not rigid and to which students do not have to adapt to achieve academic success. According to the appreciations of Ventura, Palou, and Széliga [36, p. 81]: "Each student has a system of norms, notions, behaviors, and ideas that give meaning to practice". Therefore, to recognize how learning develops, it is key to consider how the student receives, processes, interprets, and transforms information.

Taking into account these original elements that have guided pedagogical approaches for teaching systems engineering in Europe, it is important to reference specific models. The pedagogical model of the University of Aalborg, located in Denmark, which since the 1970s has focused on the possibility that students have a fundamental role as actors involved in the construction of knowledge, starts from the premise that a pedagogical model has been based on the formulation and analysis of problems. In each class or activity, students must present a problem based on a specific topic or situation, which must be solved according to their specific abilities. In this way, adaptive and flexible learning is promoted along with collaborative learning, from which integral solution alternatives are projected.

According to Barge [39, p. 23], in the development of this pedagogical model, students have to study project courses within each semester. First, the project courses reinforce knowledge, to understand a set of concepts, themes, authors and references established as the basis for formulating and solving problems. Second, the project courses are specifically aimed at developing activities associated with problems, in which individual and group research processes are carried out, keeping results and records of the process. Thus: "With this educational model, students develop management skills, synthesis, and knowledge construction; while they can evaluate, integrate and apply knowledge which is not explicitly included in the academic curriculum".

Drupa also highlights the CDIO model (Conceive - Design - Implement - Operate). It was initially established in the Universities of Sweden but later spread to the rest of Europe and even America. According to Crawley *et al.* [38], this program is established through an analysis of engineering programs, which shows that students generally gained theoretical knowledge, but rarely knew how to apply them.

For their part, Garmpis and Gouvatsos [40, p. 155] designed and implemented a learning tool in Greece that emulates the Linux operating system, fundamentally generating an exact interface without the need to install such a system in the computers but rather deploying it in a web browser, through which the student can freely interact with the software in the meantime: "students can easily explore both graphical user interface (GUI) and command line of Ubuntu's environment. Additionally, students can ascertain the acquired knowledge through an automated examination process and learn from their mistakes as shown automatically".

For these reasons, the model was established through the formation of a group of experts in engineering and pedagogy, and company directors, who together determined the skills and abilities that engineers should have to perform adequately, considering the commercial and economic challenges that were generated at the industrial level. In this way, the construction of a strategy was oriented so that engineering students could be more prepared to solve everyday problems in companies so that they had a series of practical and effective skills. In this way, the development of a process that guides the construction of knowledge through four central axes, which are:

- Conceive: It implies understanding a market opportunity to develop the initial ideas that help to cover a need.
- Design: The operationalization of the idea is launched, using the necessary tools and equipment of engineering.
- Implementation: Tests, software and hardware processes, and implementation process management are performed.
- Operation: The idea is put into practice, designing improvement strategies and product life cycle, to verify if the business opportunity is taken advantage of.

As you can see, this model is undoubtedly aimed at solving the problems that arise in an industrial environment, to generate professionals who know how to do and who are trained to solve problems effectively, not only through the analysis of data and situations but also through concrete practice and direct impact on reality.

Now, to continue exploring international antecedents, it is important to review the case of the United States, where engineering education has been based on the Learning Factory model. The model had its beginnings in the 1990s when universities noticed that thanks to computational simulation, students depended to a large extent for their studies on a set of computational estimates, which had completely displaced the realization of physical prototypes.

It was evident, therefore, that engineering students spent more time doing calculations than doing engineering. This generated the need to develop pedagogical alternatives through which a greater balance could be generated between science, analysis and calculation with the concrete practice of engineering, that is, the physical manipulation of objects to transform them [41].

Based on these assumptions, the Learning Factory focuses on a collaborative work process, adaptable to students and based on problems. Its main objective is to promote active learning, through learning environments in which students can participate in simulations with real goals, processes and personnel [41].

In this model the simulation is established as a particular method of teaching, in which the student can experiment and participate in situations that mimic the industrial and organizational reality in one or several aspects. It is associated with the development of educational contexts and environments in which the student can put into practice their knowledge, understand the different circumstances, facts, and problems that may arise in practice as a professional, and also submit to the natural pressure that is generated in situations of the industrial type.

On the other hand, a Latin American experience was also found regarding Cloud Computing, since at the Universidad Técnica del Norte in Ecuador a methodology based on the generation of a Virtual Learning Environment (VLE) through Moodle platforms was implemented for the electronic engineering and communication networks degree, in conjunction with a pedagogical strategy called PACIE, designed within the same university and "which considers motivation, interaction and collaborative learning as fundamental parts in the process of academic formation" [42, p. 84].

Approaches to teaching systems engineering in Colombia

According to [43] the first groups and lines of research that concerned themselves with the issue of educational informatics were formed in Colombia in the 1980s. This initiative was driven by a group of professors who belonged to the faculties of systems engineering and sought new modalities to implement informatics in educational fields. Similarly, Parra [44] considers that these groups were the ones who supported and disseminated the first computer programs that aimed to train teachers to impart knowledge about systems. Therefore, spaces were built for the teaching of programming languages to assist teachers when creating programs that complement and help their teaching methods [45].

This type of pedagogical training was called "computer literacy" and the lack of knowledge about new computer technologies was not only an issue for students and adults but also with teachers and intellectuals in educational fields, who were encountering a new technological manifestation that they recognized as fundamental for pedagogical innovation [46].

Therefore, in the eighties, the Faculty of Engineering of the Universidad de Los Andes considered that it was prudent to initiate activities in which educational processes converged with information technology and, through the Latin American Center for Human Resources and Information Technology, two initial purposes were considered that concerned this project: The first was to support the educational programs that were being carried out remotely through electronic means. The second was to achieve a more widespread use of computers and, under this purpose, the creation of spaces in different parts of the country that were equipped with these electronic devices and that offered free access for anyone who needed it [47].

Likewise, schools began to be thought of as places where computer solutions were needed since, as Rueda [48] puts it, computational technology was fundamental for the questioning of systems and redefinition of their functions. Systems engineering supported its incursion in the educational field and legitimized its importance because it was understood that its application was not only advantageous in understanding how to operate computers or how to program them, but because it allowed relationships between public and private companies with different educational entities to be built, such as the Ministry of Education and the Ministry of National Education, alliances that allowed the development of the field called educational technology.

In the mid-1980s, some business sectors in Colombia began to get involved with the reconversion of the education system because of the inclusion of technology and the reduction of digital gaps. The IBM manager in Colombia considered that it was an obligation for both the educational system and the politicians to include information technology within the processes and take advantage of the tools that technology was providing [49].

However, even though the incorporation of technology was considered urgent and necessary for the innovation of education systems, new problems that had not been experienced before began to arise from its inclusion. The new ICTs required new teacher training that was already becoming obsolete for the demands of the new educational plans. This also led to a problem that prevented the articulation between the knowledge and skills taught by teachers and the needs that were increasing in the labor market at that time [50].

Similarly, contrary opinions began to emerge that did not consider technological implementation as profitable as it had been budgeted, that is, it was thought that the development of certain educational software (such as the Capital Test) would only replicate the teaching of Skinner and Suppes in a program instead of modifying these pedagogical precepts [51].

Also, Henao [52] saw the fact that some teachers were reluctant to accept change and innovation as problematic, basing their pedagogical methodologies on traditionalist views, attitudes that sought facilitation, and wrong intuitions. The obvious gap between tradition and innovation was becoming increasingly noticeable and, although it was recognized that technology was the next step in the processes around the world, teachers' training tended to continue exercising their profession without including these new tools [53].

IBM Colombia [54], one of the main precursors in the introduction of computer engineering in Colombia, recognized that the introduction of the computer in people's daily lives was very abrupt and that not even those who related from the beginning with this tool were able to glimpse the impact it would have. Understanding computer programming languages as fundamental forms of knowledge constituted a very abrupt change in all categories of life and, in the blink of an eye, the tools that had already begun to be implemented in schools quickly became obsolete [55].

Current situation of engineering in Colombia

Within five years, Colombian engineering careers have gained a greater volume of students in professional careers and, therefore, a greater supply of professionals ready to enter a competitive but demanded profession. In 2014, the Ministry of Information Technology and Communications warned that there was a shortage of engineers in the country when the Information Technology industry was experiencing a significant 12% annual growth [56].

At that time there was, as a consequence, intense demand for engineers, but the number of graduates in these careers was lower than needed [56]. Already in 2019, the report on the labor market of graduates of higher education of the Labor Observatory of the Ministry of Education (OLE), indicates that systems engineering is one of the 20 most demanded and highest paid careers in the country [57].

Activities such as programming, management, and computer systems development, software development, and specialization in network security are currently the most demanded, due to the level of advancement and use of technology and digital media to perform a range of tasks; from basic and daily activities to complex investigations that include cutting-edge technology. The systems engineer is a professional specialized in computer systems design, programming, application and maintenance. In this sense, the main task within this profession is to manage the networks and information systems so that the data managed within an organization is handled effectively and efficiently. Additionally, engineering has a research component aimed at the creation and implementation of software and hardware within organizations.

In accordance this, Uribe, Vera & Aldana [58, p. 3] collected the experience of the University of Quindio, a teaching-learning model was implemented based on accompaniment through the use of an information system that, through intelligent agents "allows the definition of tasks and functions necessary for the training of skills of the engineer in training. This system combines three types of agents (interface, information, and collaborative agents)", to follow up the educational processes and provide the accompaniment required by the electronic engineering student. The purpose of combining a hardware-software system for E-Learning is oriented to evaluate the knowledge and dominance, both individual and collective, of the course or subject of the established topics and also to allow, through practical activities, satisfactory leveling and performance.

In general, engineering such as electromechanics, mining, telecommunications, mechanics, electrical, computer science, production, systems, administrative and, especially, industrial, are engineering branches that occupy the top twenty in greatest demand and better salary in Colombia. In particular, systems engineering has a linkage rate of 84.8%. The estimated remuneration is currently at $ 1.979.749 according to the LOE [57]. Currently, systems engineers' professions and work are focused on providing hardware or infrastructure software solutions, research support in hard sciences, simulation processes development and process optimization.

In Colombia, it has been understood that engineering is, by nature, interdisciplinary, so it is oriented to the application of knowledge from mathematics, computer science, design, among others. As Julio Omar Ancízar, a professor at Antonio Nariño University and a graduate from the National University, systems engineering has powerful researching fields and actions such as "software engineering in modeling and developing solutions with the use of methodologies and IT tools" [59].

In line with this discussion, it is important to highlight that, while software industry has seen exponential growth in international markets, systems engineering programs have become one of the most fundamental elements for Colombia's technological development. Therefore, the systems engineer gathers knowledge in different fields, which allows them to perform with greater skill in different labor fields such as web design, robotics, computer security, multimedia, technological infrastructure, construction of software, telecommunications, technology management, among others. Hence, day by day, as highlighted in the Universia portal [59], systems engineers have greater influence in their functions development, which exceeds those of a technical nature or mere development.

However, the broad field of action of engineering professionals, especially those who focus on systems or software, must refine the skills that generate the most demand and that are required in different professional development contexts in the most basic tasks of the profession, namely the conceptual and practical handling of the functional and non-functional requirements of a software; because of this, Chanchí, Gómez and Campo [60, p. 2] reported on the implementation of digital teaching tools that allow these concepts to be consolidated in a teaching environment that places the student in a practical exercise, where they must discern whether the situations presented in the first stage of programming fit one type of requirement or another. This is done through a video game with emphasis on basic development subjects; "difficulties have been observed by students in these courses in terms of writing, recognition, and differentiation of functional and non-functional requirements".

However, it is possible to affirm, as López [61] points out, that systems engineering programs in Colombia are framed within computer science, software engineering or information systems. In contrast, in the United States and Europe, each of these approaches forms a particular curriculum. Therefore, a comprehensive approach that has been generated in Colombia, composed of different approaches in the basic knowledge imparted has resulted in a dilemma regarding the essence and objective of professional studies.

The main result of this situation is that, in Colombia, each university defines its own systems engineer's professional profile, according to its mission, vision and institutional educational project, without there being a context as such or a unified model that guides the criteria of teaching in universities.

This opens the discussion about how current and improved the different systems engineering curricula, offered as a professional career in the different universities of Colombia, truly are. In particular, fields such as engineering, which respond to the most specific needs for the development of the different industrial and communication sectors, make it necessary to have a balance between the generic competences of the professional profiles that correspond to them and the relationship between supply and demand in the labor markets. In this sense, academia and the business sector need to be allies in a strategic way so that they "help to identify and address common needs, where professionals can build spaces for participation based on the transfer and exchange of basic or applied knowledge in key areas of development" [10].

Complementing this aspect, the doctoral thesis of María Clara Gómez [62, p. 12], Professor at the National University of Colombia - Medellín campus, proposes the formulation of a general theory for the teaching of software engineering (SETMAT), understanding that, as in most branches of engineering in this field: "technical skills in computer science and social skills such as project management, communication, achievement orientation, and collaborative work, among others, are combined". In this sense, it is essential to establish an approach that integrates not only technical, theoretical and practical elements of software development into the training of students in this program, but also social skills that allow adaptability to the professional contexts to which these same students must adjust in their future work; motivations on which the SETMAT model bases its relevance in higher education institutions. In an article derived from the doctoral work, Gómez, Jaramillo, and Astudillo [63, p. 723] indicate that this methodology offers "a common conceptual framework to describe practices and strategies for teaching software engineering, identifying the minimum elements of a teaching strategy and offering teachers a mechanism to represent software engineering teaching practices".

Regarding the need to place the student in a teaching-learning environment that effectively prepares him/her to face the challenges of the working and professional world, the Universidad Nacional Abierta y a Distancia - UNAD, the main reference for virtual and distance education in the country, has proposed different methodologies focused on this aspect. Camelo-Quintero [64, p. 34] carried out a study on the experience of laboratories applied to electronic and telecommunications engineering programs, where a simulation modality was implemented, oriented to provide realistic situations in which a student can apply what they have learned in theory and combine it with simulated practice. This approach, the author stresses, is relevant to the extent that: "In engineering, practice becomes more relevant, compared to other areas of knowledge. In his daily work, the engineer is in permanent contact with reality and faces several situations that can be expressed in a classroom".

Implicitly, in the previous comment the need for training in skills and competencies of systems engineers is focused on having the ability to adapt, undertake and compete in highly uncertain and complex scenarios. With this enumeration of necessary skills, the fundamental role played by the engineer is understood and, in advance, the academic program for the development of public and private programs in the field of technological development in the country.

A first problematic element to address is that, despite the high demand for systems engineers in the country, which ranks second in "careers that offer most work in the country", with 3100 monthly offers, there is still a professionals' shortage in this branch; this fact, even considering that engineering is the area that occupies second place in several titles granted, at least in Bogotá city, as indicated by the LOE, with a participation of 19.9%. Significant difference keeps with the economy, administration, accounting and related careers that keep 42.6% of the titles in the city.

On the other hand, from Arias and Aristizabal's perspective [5], companies are modifying their search for systems engineers by delegating technicians or technologists who perform purely operational or programming functions. Faced with this, the authors identify that another problem presented in training programs is that the curricula do not reinforce the importance of having "innovative capacities", characterized by people developing the freedom to take opportunities according to their being and doing capacities.

In line with the above, the lack of motivation to complete a professional career in systems engineering - when a technical or technological study can be done - is evident. Lack of motivation that arises from elementary school, high school and reinforced when the horizon is perceived by those who would like to enter to pursue the career as systems engineers. Among the different reasons that dissuade students from pursuing a career in systems engineering is that the country does not produce its technology, that employees hired to perform specialized tasks in jobs that require complexity and experience are foreigners, and that the salary is low compared to the investment that must be made to economically pay for the career [65].

In addition to the economic and contracting issues faced by newly graduated systems engineers, it is clear that systems engineering teaching paradigms and methodologies development requires a thorough review. In this way, it is possible to improve the graduate's capacities so that they can compete in a demanding environment. It means that graduates can develop each of the qualities that have been mentioned throughout this approach (flexibility, adaptability, recursion, innovation capacity, etc.)

As Capote *et al.* [8] affirm, it is key that in Colombia the engineering teaching model focuses on knowledge acquisition and transmission development and on new ways of thinking development; which guide practice and action and help train students with continuous and meaningful learning.

CONCLUSIONS

The analysis of the information gathered and developed in this article shows that the models that guide the teaching of systems engineering throughout history and the evolution of new technologies have been forced to generate an aimed approach focused on promoting the development of practical students, who know how to decide and face the challenges imposed in the era of digital interconnection and globalization. Therefore, the development of teaching that motivates practice, problem-solving, and action as central elements from which a more proactive professional profile is established is promoted.

Taking into account the industrial development associated with computing, information technologies and digital communication systems, systems engineering has had to adapt to the demand for new needs by society, which are increasingly pressing and urgent. Therefore, the pedagogical practice of a traditional teaching model, through which students receive a series of knowledge and instruction cumulatively to respond to a set of achievements and tests, has had to be replaced by one in which participation mechanisms are established to help to promote the development of skills such as creativity, flexibility, adaptability, recursion and innovation capacity.

This significant change, which has been sought to be promoted in the world, though, for example, the Aalborg University pedagogical model, the CDIO model, and the Learning Factory, has also guided alternative approaches to teacher-student relationships. The student is no longer conceived as a receiver of information, whose main task is to learn and memorize it, but as an active agent in the learning process, where they must take the knowledge learned to transform and interpret it, generating new learning that enables it to function in the market and promote the development of innovation.

In this case, the teacher is also not the person who manages knowledge and applies a curriculum, but rather a guide to the learning process, which can establish and guide spaces for participation and can help to enhance students' capacities. For example, the CDIO model teaches the importance of promoting the systems engineers a set of integral capacities that allow them to: understand the business opportunities existing in the market, to put ideas into action through their engineering equipment, to carry out the necessary tests and put the ideas into operation, whilst also developing evaluation schemes. It can be seen with this example that education trends in systems engineering choose to promote the development of learning processes that result in action, in practice, and the consequent reality transformation through knowledge, equipment, instruments, and tools.

In this way, the learning models that guide the engineering teaching and learning in the world have understood the importance of enhancing interaction, participation and collaboration as key elements from which it is possible to promote better processes of problem understanding, identification and resolution. It is key to promote meaningful learning development to the extent that knowledge interpreted by the student must be linked to a specific reality, context characteristics and the particular market needs.

However, when analyzing the Colombian case, it is evident that in the country there is no such model that guides engineering education in all universities, and that the learning processes depend, in each case, on the mission of the institution, pedagogical approaches, curricular programs and class typologies implemented by teachers. There is therefore a lack of a common framework that establishes and defines the processes through which knowledge is built and capacities associated with creativity and innovation are promoted.

Another relevant problem that is recognized is the role played by the market, since companies are opting for engineers who are capable of performing basic, operative, and repetitive engineering tasks, to ensure the development of a series of business processes, but in reality, they are not concerned about looking for the profile of a creative engineer who is capable of questioning processes, proposing improvements and adaptations that favorably affect organizational development. Thus, considering that professional profiles are formed according to the needs and requirements of the market, in Colombia there should be strategic alliances between universities and companies, to guide and jointly design a new profile of systems engineers, more active, enterprising, critical, creative and innovative.

This is key given that, today, one of the fundamental principles guiding the competitive and social development of a country is precisely innovation, understood as a fundamental capacity in the processes of economic internationalization and global positioning. Today, competitiveness has shaped new geography, as countries confront each other, seeking to position their goods and products not only locally but globally, in fear of the demands of globalization and neoliberalism, for which the development of innovation and entrepreneurship strategies in training careers is key and vital; especially those that have a strong relationship with technology and software development, such as systems engineering [66].

Regarding this need of the professional field to adapt its epistemological and pragmatic bases, Mendoza, et. al. [67, p. 97] place these concerns from another branch of engineering, the industrial one, which has been positioned as one of the most booming, both because of the demand it has generated in the academic and labor markets, inherently, becoming a wider field than what the traditional conceptions of engineering established at the beginning as the branch in charge of managing, planning and implementing industrial models. In this sense, the authors state that "The programs of Industrial engineering, have to integrate the content of engineering with humanities, science, and technology; knowing the involving environment it manages and comparing it with the external environment from their own experiences".

In this way, in Colombian universities, it is key that innovation concepts linked to competitiveness, understood from an interdisciplinary point of view, will be recognized as a holistic practice that envelops a large number of variables related to systems engineering students or professional's capabilities, such as creativity and innovation. From there, industry offers the possibilities to develop and promote ideas, and the plethora of element characteristics linked to productivity, such as market needs, quality standards of services and products, the situation of competitors and possibilities that exist to positively impact a particular market.

Therefore, innovation, tackled from a competitiveness concept, is understood as a practical, comprehensive and complex phenomenon, which involves an act of innovation and constant improvement. Its foundations rely on adequate knowledge of every one of the factors related to academic development and professional training processes, as a means to guarantee competitiveness.

In summary, the importance of promoting meaningful learning that generates a deep knowledge about the context surrounding the development of operational and discursive skills in systems engineering is recognized, thus forming professionals who know how to recognize social and cultural market peculiarities and which can influence reality through their practice. The international teaching models that have been analyzed allow us to recognize that, in effect, the main value that guides engineering education is precisely it's practical and transforming power.

The above is key to establish effective articulation processes between what is taught in universities and a systems engineering career and what it is understood, contemplated and experienced. In this way, meaningful learning is understood as a perspective through which the student has greater autonomy, and the possibility of relating content to problems arising in a specific environment, with the previous knowledge acquired during the training process [68].

Without a doubt, meaningful learning promotes the development of different skills and abilities, relating contents with different market important aspects. In this sense, knowledge appropriation is vital for students to integrate both knowledge analyzed in class and the configuration of new discourses and practices that allow them to favorably influence economic, productive transforming processes and productive reality.

Finally, international models also recognize the important role and social responsibility of the systems engineer, as one of their tasks is to ensure that computational development helps to improve human processes and activities, without harming them. Therefore, an important approach to the career of systems engineering, in the current environment characterized by globalization, technological diffusion, and interconnection, is to promote the development of ethical principles and standards that help protect society and shape ever better uses and applications for computing and programming.

The analysis of the experiences of each country and each source addressed in this research, allow us to conclude that one of the indispensable elements for the evolution and adequate development of the profession of systems engineer, is practice; an element that allows both students and teachers, and therefore future professionals, to constantly develop, innovate and create personalized, individual and joint learning strategies, aimed at implementing a comprehensive approach.

Regardless of the approach or profile that each institution gives and sets in its academic curriculum, the standard of quality is derived from practice, because only practice leads to the integration of the concepts learned from the classroom and testing of the same; not forgetting that practice indirectly impresses the desire to exceed standards. These are very successful strategies, as are the projects developed in the different institutions, filled with motivation and consequently the intellectual competence, allowing for an adequate evolution of the methodologies for the correct teaching of systems engineering; understanding that we are currently facing a globalized world with increasingly demanding needs in terms of technologies and communication, a situation that makes it increasingly necessary to provide adequate training for professionals in systems engineering.

References

[1] J. y. B. P. Vélez, *Estrategia de Innovación en Educación en Ingeniería*, Medellín, Colombia.: Universidad Nacional de Colombia. Facultad de Minas, 2017. doi: https://doi.org/10.13140/RG.2.2.34361.39520.

[2] H. Troiano, M. Breitman y C. Gete-Alonso, «Estilos de aprendizaje que predominan entre los estudiantes universitarios,» *Enseñanza Universitaria,,* vol. 23, pp. 63-82, 2004. [En línea]. Disponible en: https://idus.us.es/handle/11441/59368.

[3] F. M. D. y. J. U. Rodríguez, «Educación en Ingenierías: de las clases magistrales a la pedagogía del aprendizaje activo,» *Ingeniería y Desarrollo,,* vol. 20, no 2, pp. 44-88, 2012. [En línea]. Disponible en: http://www.scielo.org.co/pdf/inde/v30n1/v30n1a08.pdf.

[4] I. Imperiali, «Enseñanza de la Ingeniería. Hacia un modelo pedagógico transformador,» *Buenos Iares: DIIT.,* 2017. [En línea]. Disponible en: https://reddi.unlam.edu.ar/index.php/ReDDi/article/view/44/75.

[5] C. Arias y M. Aristizábal, «Capacidades innovadoras y tendencias tecnológicas en los curriculos de los programas de ingeniería de sistemas,» *RITI Journal,* vol. 6, no 11, pp. 25-33, 2018. [En línea]. Disponible en: https://dialnet.unirioja.es/servlet/articulo?codigo=7107377.

[6] J. Sánchez, «Ingeniería pedagógica, nuevo desafío para los objetos de aprendizaje.,» *Ciencia e Ingeniería,* vol. 32, no 1, pp. 105-114, 2011. [En línea]. Disponible en: https://www.redalyc.org/pdf/5075/507550790015.pdf.

[7] M. Zapata y L. Flores, «Identificación de los estilos de aprendizaje en estudiantes universitarios,» *Revista Estilos de Aprendizaje,* vol. 2, pp. 130-152, 2008. doi: https://doi.org/10.55777/rea.v1i2.854.

[8] G. Capote, N. Rizo y G. Bravo, «La formación de ingenieros en la actualidad. Una explicación necesaria,» *Revista Universidad y Sociedad,* vol. 8, no 1, pp. 21-28, 2016. [En línea]. Disponible en: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2218-36202016000100004.

[9] G. Villamizar y N. Sanabria, «Relación entre estilos de aprendizaje y rendimiento académico en estudiantes universitarios,» *Universidad pontificia bolivariana,* vol. 1, pp. 114-123, 2009. [En línea]. Disponible en: https://repository.upb.edu.co/handle/20.500.11912/465.

[10] F. Marín, L. Cabas, L. Cabas y A. Paredes, «Formación Integral en Profesionales de la ingeniería. Análisis en el Plano de la Calidad,» *Formación Universitaria,* vol. 11, no 1, pp. 13-24, 2018. [En línea]. doi: http://dx.doi.org/10.4067/S0718-50062018000100013.

[11] A. C. Salgado Lévano, «INVESTIGACIÓN CUALITATIVA: DISEÑOS, EVALUACIÓN DEL RIGOR METODOLÓGICO Y RETOS,» *Liberabit,* vol. 13, no 13, pp. 71-78, 2007 [En linea]. Disponible en: http://www.scielo.org.pe/pdf/liber/v13n13/a09v13n13.pdf.

[12] P. Sanz, «Metodología activa y aprendizaje autónomo con las TIC.,» *Departamento Didáctico de las lenguas y las Ciencias Humanas y Sociales,* vol. 24, no 1, pp. 1-20, 2003. [En línea]. Disponible en: https://www.researchgate.net/profile/Pedro_Dominguez_Sanz/publication/255663977_Metodologia_activa_y_aprendizaje_autonomo_con_las_TIC/links/54afa8b30cf29661a3d5c8f6/Metodologia-activa-y-aprendizaje-autonomo-con-las-TIC.pdf.

[13] D. Hazen, «¿Está en crisis la enseñanza de la ingeniería?,» *Dyna,* vol. 52, no 2, pp. 47-52, 1977. [En línea]. Disponible en: https://dialnet.unirioja.es/servlet/articulo?codigo=4606911.

[14] B. Martínez, J. García y P. Robledo, «Valoración docente de las metodologías activas: Un aspecto clave en el proceso de Convergencia Europea.,» *Aula abierta,* no 35, pp. 49-62, 2007. [En línea]. Disponible en: https://redined.mecd.gob.es/xmlui/handle/11162/4848.

[15] C. Monereo y J. Pozo, «La cultura educativa en la universidad,» de *La universidad ante la nueva cultura educativa: Enseñar y aprender para la autonomía*, Madrid, España, Síntesis, 2003. [En línea]. doi: https://doi.org/10.13140/2.1.5069.2168, pp. 15-32.

[16] A. Fernández, «Nuevas metodologías docentes,» *Valencia, España: Universidad Politécnica de Valencia,* 2005. [En línea]. Disponible en: http://roble.pntic.mec.es/jprp0006/tesis/metodologia/nuevas_metodologias_docentes_de%20fernandez_march.pdf.

[17] A. Durand, «. El método del caso, una opción didáctica. Aplicación a la enseñanza de la Ingeniería Química.,» *Ingeniería Química,* no 426, pp. 135-141, 2005. [En línea]. Disponible en: https://dialnet.unirioja.es/servlet/articulo?codigo=1263106.

[18] L. Castillo, «Una mirada a la academia y a la investigación en ambientes virtuales: sus características basadas en el uso de las tecnologías de la información y la comunicación (TIC),» *Revista de la comunidad académica UDES,* vol. 23, no 2, pp. 40-47, 2004.

[19] L. Colina y S. Bustamante, «Educación a distancia y TIC: Transformación para la innovación en educación superior,» *Redalyc,,* vol. 8, no 1, pp. 100-122, 2009. [En línea]. Disponible en: https://www.redalyc.org/articulo.oa?id=78411785007.

[20] A. Solari y G. Monge, «Un desafío hacia el futuro: Educación a distancia, nuevas tecnologías y docencia universitaria.,» *Recuperado el,* vol. 28, 2004. [En línea]. Disponible en: http://www.geocities.ws/alievies/hwct/t4/birriroberto.pdf.

[21] M. Sepúlveda y I. Calderón, «Las TIC y los procesos de enseñanza-aprendizaje: la supremacía de las programaciones, los modelos de enseñanza y las calificaciones ante las demandas de la sociedad del conocimiento.,» *RIE,* vol. 44, no 5, pp. 1-13, 2007. [En línea]. doi: https://doi.org/10.35362/rie4452217.

[22] S. A. Zabala Vargas, J. A. Pérez López y H. F. Rodríguez Hernández, «Estrategia para el desarrollo de aprendizajes en ingeniería basado en robótica educativa y competitiva: caso Universitaria de Investigación y Desarrollo, UDI,» *Ingenieria Solidaria,* vol. 9, no 16 , pp. 153-159, 2014. [En línea]. doi: https://doi.org/10.16925/in.v9i16.539.

[23] C. Valerio y J. Paredes, «Evaluación del uso y manejo de las tecnologías de la información y la comunicación en los docentes universitarios. Un caso mexicano,» *RELATEC,* vol. 7, no 1, pp. 13-32, 2008. [En línea]. Disponible en: https://relatec.unex.es/article/view/391.

[24] J. González, Plataformas digitales para aprender activa y cooperativamente., Barcelona: Observatorio Universidad y Discapacidad, 2007. [En línea]. Disponible en: https://upcommons.upc.edu/bitstream/handle/2117/22165/UNI2.0%20_versi%C3%B3n%20definitiva.pdf.

[25] J. I. Rodríguez Molano, L. D. Forero Zea y Y. F. Piñeros Reina, «Propuesta de arquitectura y construcción de aprendizaje automático (AA) como estrategia para la reducción de los niveles de deserción universitaria debido a factores académicos,» *Ingenieria Solidaria,* vol. 15, no 3 [En línea]. doi: https://doi.org/10.16925/2357-6014.2019.03.06, pp. 1-23, 2019.

[26] A. Popov, «Final undergraduate project in engineering: towards more efficient and effective tutorials,» *European Journal of Engineering Education,* vol. 28, no 1, pp. 17-26, 2003. [Online]. doi: https://doi.org/10.1080/0304379021000055722.

[27] M. T. Chi, S. A. Siler, H. Jeong, T. Yamauchi y R. G. Hausmann, «Learning from human tutoring,» *Cognitive Science,* vol. 25, no 4, pp. 471-533, 2001. [Online]. doi: https://doi.org/10.1207/s15516709cog2504_1.

[28] C. R. Huapaya, G. M. Arona y F. A. Lizarralde, «Enseñanza de la ingeniería con sistemas tutoriales inteligentes,» *Información tecnológica,* vol. 16, no 5, pp. 75-78, 2005. [En línea]. doi: http://dx.doi.org/10.4067/S0718-07642005000500012.

[29] T. Murray, «Authoring knowledge-based tutors: Tools for content, instructional strategy, student model, and interface design.,» *The journal of the learning sciences,* vol. 7, no 1, pp. 5-64, 1998. [Online]. doi: https://doi.org/10.1207/s15327809jls0701_2.

[30] T. Murray, «Authoring Intelligent Tutoring Systems: An analysis of the state of the art,» *International Journal of Artificial Intelligence in Education,* vol. 19, pp. 98- 129, 1999. [Online]. Available at: https://telearn.archives-ouvertes.fr/hal-00197339/.

[31] R. M. Felder y J. Spurlin, «Applications, reliability and validity of the index of learning styles,» *International journal of engineering education,* vol. 21, no 1, pp. 103-112., 2005. . [Online]. Available at: https://www.engr.ncsu.edu/wp-content/uploads/drive/1ZbL_vMB7JmHGABSgr-xCCP2z-xiS_bBp/2005-ILS_Validation(IJEE).pdf .

[32] D. H. Jonassen, T. C. Reeves, N. Hong, D. Harvey y K. Peters, «Concept mapping as cognitive learning and assessment tools.,» *Journal of interactive learning research,* vol. 8, no 3, p. 289, 1997. [Online]. Available at: https://dl.acm.org/doi/abs/10.5555/313722.313725.

[33] R. Sison y M. Shimura, «Student modeling and Machine Learning,» *Journal of Artificial Intelligence in Education,* vol. 9, pp. 128-158, 1998. [Online]. Available at: https://telearn.archives-ouvertes.fr/hal-00197339/.

[34] B. Carr y I. P. Goldstein, «Overlays: A theory of modelling for computer aided instruction,» *Massachusetts Institute of Tech Cambridge Artificial Intelligence Lab.,* p. 24, 1977. [Online]. Available at: https://apps.dtic.mil/dtic/tr/fulltext/u2/a052210.pdf.

[35] A. Arruarte, I. Fernández-Castro y J. Greer, «The CLAI model: a cognitive theory of instruction to guide ITS development,» *Journal of Interactive Learning Research,* vol. 7, no 3, p. 277, 1996. [online]. Available at: https://search.proquest.com/openview/1fb6bab7a4f8f4a7c76c9a8f3ed1ad54/1?pq-origsite=gscholar&cbl=2031153.

[36] A. Ventura, I. Palou y C. Zseliga, «Estilos de aprendizaje y enseñanza en ingeniería: una propuesta de educación adaptativa para primer año.,» *Revista Educación en Ingeniería,* vol. 12, no 8, pp. 22-54, 2014. [En línea]. doi: https://doi.org/10.26507/rei.v9n18.461.

[37] A. J. Tallón Ballesteros, «Enseñanza de ingeniería informática en inglés: sistemas operativos como caso de estudio,» *opción,* vol. 31, no 1, pp. 1175-1189, 2015. [En línea]. Disponible en: https://idus.us.es/handle/11441/49127.

[38] E. Crawley, E. Malmqvist, S. Östlund, D. Brodeur y K. Edström, «Historical accounts of engineering education.,» *Rethinking engineering education,,* vol. 2, pp. 231-255., 2014. [Online]. doi: https://doi.org/10.1007/978-3-319-05561-9_10.

[39] S. Barge, «Principles of Problem and Project Based Learning The Aalborg PBL Model,» *Aalborg University.,* 2010. [Online]. Available at: https://www.aau.dk/digitalAssets/62/62747_pbl_aalborg_modellen.pdf.

[40] A. Garmpis y N. Gouvatsos, «Innovative teaching methods in Operating Systems: The Linux case,» *Innovative approaches in Education.,* vol. 1, 2012. [Online]. doi: https://doi.org/10.13140/2.1.1611.4888.

[41] J. Z. A. S. L. y. J. J. Lamancusa, «Bernard M. Gordon Prize Lecture: The Learning Factory: Industry-Partnered Active Learning.,» *Journal of engineering education,* vol. 97, no 1, pp. 5-11, 2008. [Online]. doi: https://doi.org/10.1002/j.2168-9830.2008.tb00949.x.

[42] A. C. Ramírez Recalde, A. C. Umaquinga Criollo, E. A. Maya Olalla y C. A. A. Vásquez , «Metodología de enseñanza y aprendizaje en tecnologías de Cloud Computing: Un estudio de caso en la Carrera de Ingeniería Electrónica y Redes de Comunicación de la Universidad Técnica del Norte,» *Revista Ibérica de Sistemas e Tecnologias de Informação,* no E25, pp. 72-86, 2020. [En línea]. Disponible en: https://search.proquest.com/openview/6134a93593c6b2f1ecbd8da095e3d5ef/1?pq-origsite=gscholar&cbl=1006393.

[43] F. Rueda, «Investigación sobre informática educativa: experiencias del grupo de informática educativa Uniandes.,» *Boletín de Informática Educativa,* vol. 1, no 1, pp. 59-63, 1998. [En línea]. Disponible en: https://studylib.es/doc/6213521/investigacion-sobre-informatica-educativa.

[44] C. A. Parra, «Intersecciones entre las TIC, la educación y la pedagogía en Colombia: hacia una reconstrucción de múltiples miradas.,» *Nómadas (Col),* no 33, pp. 215-22, 2010. [En línea]. Disponible en: http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0121-75502010000200015.

[45] G. Cortés, «Formación de docentes en informática.,» *Boletín de Informática Educativa,* vol. 4, no 1, p. 4, 1991. [En línea]. Disponible en: https://centrodeconocimiento.ccb.org.co/buscador/Record/ir-1992-6288.

[46] A. Martínez, C. Noguera y J. Castro, Currículo y Modernización. Cuatro décadas de educación en Colombia., Bogotá: Magisterio, 2003. [En línea]. Disponible en: http://www.albertomartinezboom.com/escritos/libros/2003_Curriculo_y_Modernizacion.pdf.

[47] A. Hernández, «Revolución informática: Colombia buscar ser actor. Asociación Colombiana de Ingenieros de Sistemas.,» *Revista Sistemas,* vol. 14, pp. 9-22, 1983. [En línea]. Disponible en: https://www.dropbox.com/s/1887c2vewi7k3qb/Revista%20Sistemas%2014.PDF?dl=0.

[48] F. Rueda, «Computación en la nube: ¿Una realidad o una estrategía comercial?,» *Revista Sistemas,* vol. 16, pp. 5-6, 2010. [En línea]. Disponible en: https://acis.org.co/portal/Revista/112/Revista%20Sistemas%20Edición%20112.pdf.

[49] P. Zapata, «El computador y su impacto social.,» *Revista Sistemas,* no 27, pp. 49-54., 1986. [En línea]. Disponible en: https://www.dropbox.com/s/hrkb5kmmiulfz8a/Revista%20Sistemas%2027.pdf?dl=0.

[50] M. Ochoa, «Los docentes y las nuevas tecnologías de la información,» de *Educadores e Internet*, Bogotá, Colombia, Promesas, dilemas y realidades, 1988, pp. 189-214. [En línea]. Disponible en: http://repositorio.colciencias.gov.co/handle/11146/1689.

[51] A. Mockus, «Pedagogías, escritura e informática,» de *Promesas, dilemas y realidades.*, Bogotá, Colombia, Educadores e Internet, 1988, pp. 103-154.

[52] O. Henao, Valor diagnóstico de algunos factores lingüísticos frente al aprendizaje de la lectoescritura., Medellín: Universidad de Antioquia., 1987. [En línea]. Disponible en http://www.worldcat.org/oclc/23152749.

[53] L. Maldonado, «Procesos de interacción en un aula computarizada.,» *Boletín de Informática Educativa,* vol. 5, no 3, pp. 47-60, 1992. [En línea]. Disponible en: http://hdl.handle.net/1992/6264.

[54] IBM Colombia, Historia de la computación, Bogotá: Museo Colombiano de Informática: Asociación Colombiana de Ingenieros de Sistemas, 1990. [En línea]. Disponible en: http://acistente.acis.org.co/typo43/fileadmin/Revista_100/ED_100_INVESTIGACION.pdf.

[55] C. Vasco, «La informática en los programas de matemáticas de la educación básica. En: V. Gómez.,» de *Educadores e Internet. Promesas, dilemas y realidades*, Bogotá, Colombia, Colciencias, 1988. [En línea]. Disponible en: http://handbook.usfx.bo/nueva/vicerrectorado/citas/TECNOLOGICAS_20/Informatica/35.pdf, pp. 77-102.

[56] Revista Dinero, «Industria de las TIC necesita más ingenieros,» 8 junio 2014. [En línea]. Available: https://www.dinero.com/pais/articulo/mercado-laboral-ingenieros-sistemas-colombia/199380.

[57] Observatorio laboral para la educación, «Mercado laboral de graduados de educación superior: análisis para la ciudad de Bogotá D.C.,» julio de 2019. [En línea]. Available: https://ole.mineducacion.gov.co/1769/articles-387151_recurso_1.pdf.

[58] J. A. Uribe Martinez, A. Vera , J. Marin y J. A. Aldana Gutierrez, «Plataforma Hardware-Software para la asistencia de los espacios de trabajo en la enseñanza de Ingeniería Electrónica (A hardware-software platform to assist learning workspaces in electronic engineering),» de *Innovation in Education and Inclusion : Proceedings of the 16th LACCEI International Multi-Conference for Engineering, Education and Technology*, Lima, Perú, July 18-20, 2018. [En línea]. doi: https://doi.org/10.18687/LACCEI2018.1.1.508.

[59] Universia Colombia, «Por qué estudiar Ingeniería de Sistemas,» 4 enero 2019. [En línea]. Available: https://noticias.universia.net.co/educacion/noticia/2016/09/19/1143711/estudiar-ingenieria-sistemas.html.

[60] G. . E. Chanchí, G., M. C. Gómez y W. Y. Campo, «Proposal of an educational video game for the teaching-learning of the requirements classification in software engineering,» *Revista Iberica de Sistemas e Tecnologias de Informacao,* vol. 2019, no E22, pp. 1-14, 2019. [online] Available at: https://www.scopus.com/record/display.uri?eid=2-s2.0-85075286427&origin=inward&txGid=1b00917d416c76de1676fb766a2c508b.

[61] S. López, *El papel del ingeniero de sistemas en Colombia en la transformación hacia una racionalidad democrática, según la Teoría Crítica de la Tecnología,* Medellín: Universidad EAFIT. [En linea]. Disponible en: https://repository.eafit.edu.co/bitstream/handle/10784/12108/Sofía_LópezGonzález_2017.pdf?sequence=2&isAllowed=y, 2017.

[62] M. . C. Gomez Álvarez, «Formulación de una teoría general para la enseñanza de ingeniería de software. Doctorado thesis, Universidad Nacional de Colombia - Sede Medellín.,» *Escuela de Sistemas.,* 2018. [En línea]. Disponible en: https://repositorio.unal.edu.co/handle/unal/63303.

[63] M. C. Gómez Álvarez, C. M. Zapata Jaramillo, y H. Astudillo, «SETMAT (Software Engineering Teaching Method and Theory): Una teoría para la enseñanza de Ingeniería de Software,» *Revista Ibérica de Sistemas e Tecnologias de Informação,* vol. 2019, no 19, pp. 721-734, 2019. [En linea]. Disponible en: http://www.scopus.com/inward/record.url?scp=85069155861&partnerID=8YFLogxK.

[64] E. F. Camelo-Quintero, «Implementación de prácticas de laboratorio en la educación virtual de los programas de ingeniería electrónica y telecomunicaciones,» *Virtu@lmente,* vol. 7, no 1, 2019. [En línea]. doi: https://doi.org/10.21158/2357514x.v7.n1.2019.2319.

[65] M. Serna y A. Serna, «La formación en Ingeniería en Colombia: Una situación que preocupa,» *Universidad.com.co.,* 2013. [En línea]. Disponible en: http://www.universidad.edu.co/images/cmlopera/descargables/formacioningenieria.pdf.

[66] . G. A. Flórez Osorio, P. M. Metaute Paniagua, P. . A. Rúgeles Contreras y . D. A. Castaño, «La dinamización de las estrategias pedagógicas actuales: una necesidad aplicable a los procesos de enseñanza y aprendizaje de los estudiantes de ingeniería del siglo XXI,» *Revista Lasallista de Investigación,* vol. 15, no 1, pp. 46-56, 2018. [En línea]. doi: https://doi.org/10.22507/rli.v15n1a4.

[67] J. Mendoza Chacón, J. F. Ramírez-Bolaños, H. S. Floréz-Obceno y J. D. Diáz-Castro, «Desarrollo y evolución de la ingeniería industrial y su papel en la educación,» *Revista Ingeniería y Competitividad,* vol. 18, no 2, 2016 .[en linea]. doi: https://doi.org/10.25100/iyc.v18i2.2156.

[68] D. González , S. Castañeda Figueiras y M. . d. l. Á. Maytorena, Estrategias Referidas al Aprendizaje, la Instruccion y la Evaluacion, México: Universidad de Sonora, 2006 . [En línea]. Disponible en: https://dialnet.unirioja.es/servlet/articulo?codigo=2576161.