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Approaches and models of professional competence: Definition of competence in the training of engineers in Latin America

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Abstract- The article discusses the review of the state of professional competence art, presenting a compilation of indexed research in the two most comprehensive multidisciplinary databases: "Scopus" and "Web of Science" from 1950 to 2012. By analyzing scientific domain of research literature the existence of eight approaches of professional competence is shown, some related to the corresponding international system of competence certification which are supported by different philosophies with a common base. These theoretical and visually positions presented are compared with each other and serve to approach the competence analysis for higher education in engineering. From the presented approaches, it is emphasized that the holistic approach is the most appropriate for coding competence for higher education in engineering. In the analysis of competence in engineering the Tuning Project in Latin America is described and two competence encodings are presented: CDIO and IPMA, both are compared to the Tuning Project for Latin America in order to answer the question of what would be the most useful to cover professional competence needs in Engineering in Latin America.

Key words- professional competence, competence in engineering, analysis of scientific domain.

I. INTRODUCTION

In today's academia, there are a variety of definitions and different approaches of professional competence used in the various disciplines of science. Initiatives and strategic processes of change have led to the term "professional competence" to be part of a discourse and innovative training proposals more "professional" such as: the rapprochement between the labor world and education/training; the adaptation of workers to technology changes and social organization of production and work; the renovation of education/ training institutions, of professors /instructors, of the educational/training offer itself; and of the methods of acquisition and recognition of occupational qualifications [1], [2], [3], [4].

This renewal of approaches has led us to revise the two most comprehensive multidisciplinary databases: "Scopus" and "Web of Science", and the research literature of professional competence from 1950 to 2012, in order to define the models in which they are based and to be able to have a visual outline of the state of the professional competence art. Through scientific maps generated by specialized software the display of information is achieved: Citespace II and VosViewer.

Eight models were found which are algorithmically classified based on the characteristics, research themes in common and the relationships established by the authors in formulating hypotheses and in developing their research. For every model a description of their characteristics, findings and principal representatives were presented. This was done in order to establish which features are the most important for training in higher education in engineering and thereby find professional competence coding which are useful for the training of engineers.

The results lead the researchers to consider, as suitable, three encodings competence: CDIO (from the Massachusetts Institute of Technology MIT) based on the life cycle of a process: Conceive, Design, Implement and Operate. The second from the Project Management of International Project Management Association (IPMA), and the Tuning Project for Latin America. The comparison of encodings reveals which one that will have better results in the training of engineers in Latin America.

II. METHODOLOGY

The methodology for reviewing the state of the art of professional competence through the analysis of scientific domains is based on the methodologies proposed by Börner, Chen and Boyack [5] Marsden [6] and McCain [7] including: a) Previous bibliographic analysis, b) Selection of sources and data extraction, c) Quality of data, d) Analysis level and software selection, and e) information display and interpretation. The work review of Sergio Tobon [7], of Weinert [9] and of Guerrero, De los Rios & Diaz-Puente [10] are highlighted in the literature review. In the data extraction 3641 documents of Scopus and 1279 documents of Web of Knowledge were collected.

The level of analysis of this study involves a mixed co-citation of documents [11], [12], [13] and co-occurrence of words [14], [15]. By using the software Citespace II, considered the most appropriate for our level of analysis, 2 graphs (see Figure 1 and 2) that are interpreted in the results section were made.

For this analysis, it is important to take into account the following [16]: a) The scientific papers are represented by nodes, b) nodes with high relevance are highlighted in the chart with a purple outer ring b) the radius of the nodes represents the level of citation thereof, c) the node citation history is represented by colored rings around the node, d) The color of the relations between two nodes represent the year that both nodes were cited by other nodes. e) The color scale used is shown at the bottom of each graph.

III. RESULTS

In Figure 1 and 2, 8 groups of scientific papers are identified. 5 of these groups related to professional competence approaches described by Guerrero, De Los Rios and Diaz Puente [10]: # 1 individual behavioral competence, # 2 competence in the workplace, # 3 cognitive and motivational competence, # 4 integration of competence and #5 core of competence in organizations.

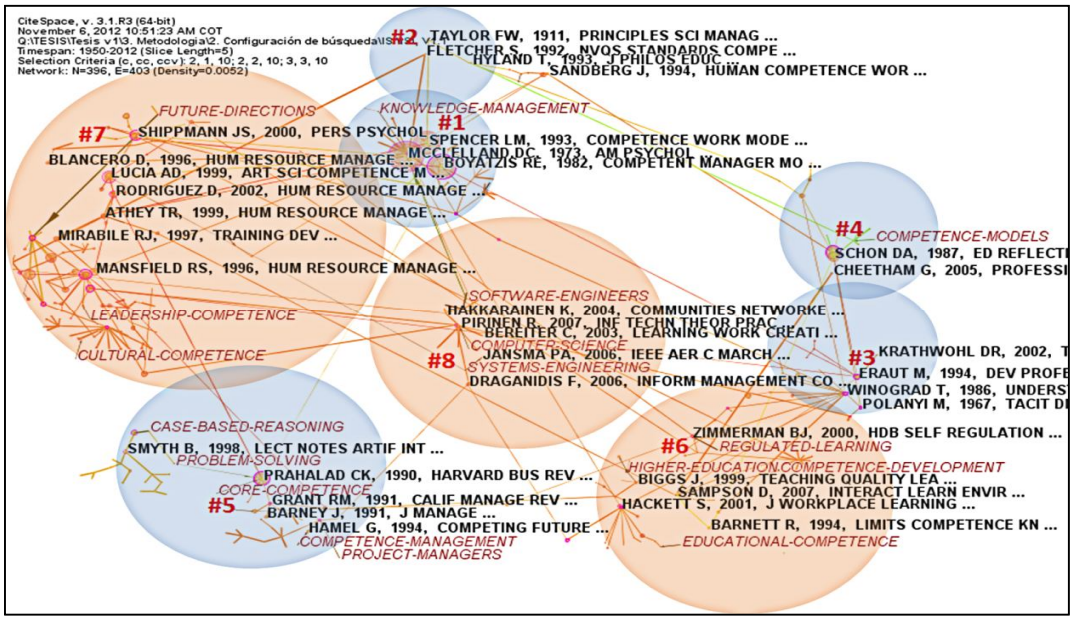

Figure 1. Mixed analysis of co-citation of documents and co-occurrence of words - Web of Science

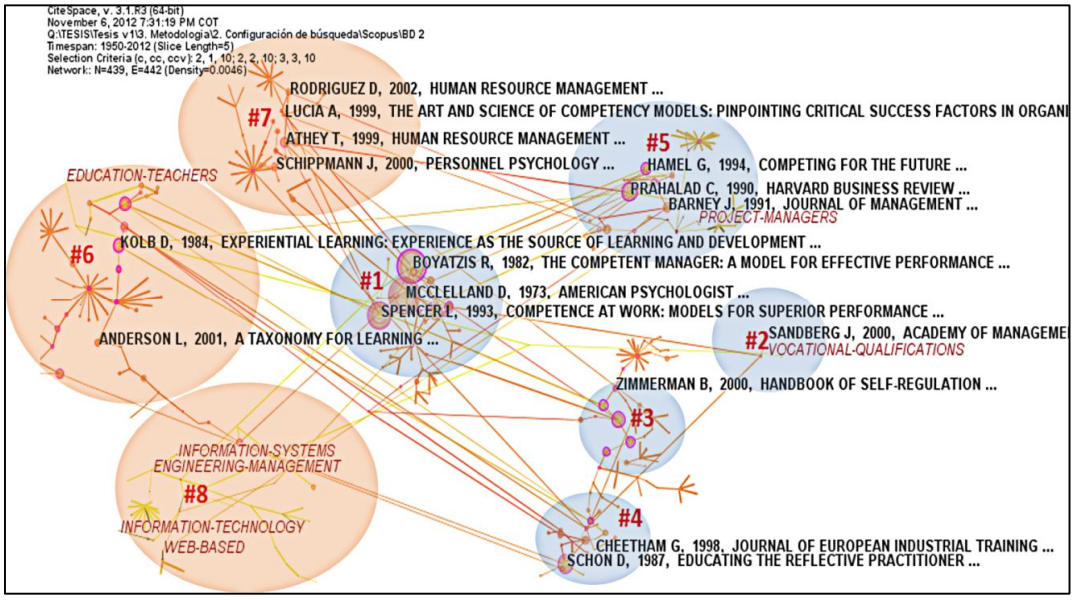

Figure 2. Mixed analysis of co-citation of documents and co-occurrence of words - Scopus

In Group # 1 McClelland [17], Boyatzis [18] Spencer [19] are referred and have a high degree of centrality and maintain relationships of co-citation with at least one member of the other groups, i.e. in research related to professional competence the behavioral approach is considered. As Guerrero [10] refers the research of these authors reflect on the individual's behavior as a major factor in the performance of tasks that helps obtain specific results in certain contexts.

In Group # 2 Taylor [20] is identified as lead author and the NVQs documented by Fletcher [21] who presents the overview and key issues of NVQ movement to create, implement and maintain a standard competence-based program. In this approach competence is established from the essential functions of the individual which contribute significantly to the desired results. Hyland's work [22]; he exposes the limitations of the work approach and Sandberg's work [23], who through his results shows that the particular way of conceiving work, defines certain essential attributes and organizes them in a distinctive structure of competence at work.

In Group # 3 Bloom's work is identified and described through Krathwohl's reflection [24]: Bloom's taxonomy. This small group is closely related to the group # 6 due to the contribution of Bloom's taxonomy to examine the importance, curriculum alignment and educational opportunities in order to improve the planning of the curriculum. In this group Michael Eraut's work [25] is framed; he analyzes the different types of knowledge and know-how used by professionals in their work; Winograt's work [26] who described the person's cognitive processes; and Polanyi's work [27] with his "tacit knowledge".

In Group # 4 the contributions of Schon [28] and Cheetham [29] are mainly identified; they consider the competence as the result of a mixture of underlying personal issues. This group is related to group # 2, # 3, # 6 and # 1 as it integrates different approaches in a complex set which is called meta-competence, which determine the existence of functional cognitive competence, of behavior and ethical values.

In Group # 5 the work of Prahalad and Hamel [30], [31] are identified; they focus on the core organization competence which seek to generate competitive advantages, promote learning and developing of new skills. In this group Wernerfelt's work [32] is highlighted with his company resource-based theory; Grant's [33] and Barney's work [34] with the approach of the business strategy formulation by effective use of resources and capabilities; and the contributions of Vidal-Gomez [35] to provide a framework for identifying competence in organizations.

Group # 6 is related to the competence formation in higher education, where Biggs [36] is identified as the main author with his most influential contribution referred to "constructive alignment" to achieve the development of students' skills. Here Barnett's work [37] is also framed; he suggested that the notions of competence were totally inadequate for higher education; Hackett's work [38] which describes two training approaches in higher education: training based on competence and reflective practice; Zimmerman's contributions [39] in the reflection of self-regulation to redirect the thoughts, feelings and actions of students towards the achievement of the objectives from a cognitive, motivational and behavioral view; Sampson's contribution [40] with its standard metadata model for the description of skills in formal education.

Group # 7 is related to the competence from the perspective of industrial and organizational psychology, where Shippmann's work [41] is mainly highlighted with his analysis of competence models through 10 scale levels which are being used in the work evaluation, in new models of competence and in the development of standards for practice. The contributions of authors like Athey [42], Blancero [43] Lucia [44], Mansfield [45], Mirabile [46] and Rodriguez [47] are also found. They described the competence models to promote professional development and the need of a consistent and systematic strategy of application.

In Group #8 competence architecture is studied from the perspective of Engineering and Technology. The main authors in this group are: Hakkarainen [48] who introduced the concept of innovative communities, generators of competence. Draganidis [49] who concluded that technology plays an important role in the evolution of management systems for competence; and Jansma [50], who develops a competence list of systems engineers.

TABLE 1
COMPARISON OF APPROACHES OF COMPETENCE

Models of Competence based on	Characteristics	Area	Approach	Related institutions	Information Systems	Restrictions	Beginning
Place of work	It is established from the essential functions of the individual contributing significantly to the desired results. The role of the worker must be understood in relation to the environment and other functions.	Labor	Empiricist	QCAD, Ofqual	NVQ – GCSE	It analyzes business functions and not human competence. The objectives and functions of the company are formulated in terms of their relationship with the environment.	The United Kingdom
Behavioral theory	This approach prevails behavior of individuals in the task performance and will see specific results in a given context. Results-oriented standards. Superior performance specifications defined by educational research.	Labor / Educational	Behaviorist	NCEE – NCCA - ICE	SCANS - PMI	It preponderates the observation of the people's behavior in confronting the task from the description of what he/she can do and no what he/she actually does, regardless of other personal dimensions.	The United States
Business strategy	The competition is a reality that helps direct the company efforts on a given route, and therefore requires certain skills of its participants. It introduces the Core Competence concept.	Labor	Behaviorist	-	-	The approach is proposed as a method for achieving competitiveness. Managers can lose opportunities to achieve a higher performance by focusing its efforts on some competence.	Japan, USA
Cognitive - motivational	The competence are attributed to the cognitive activity and motivational components of the individual. Furthermore, by identifying competence and indicators it is based on N. Bloom's taxonomy, the work of Piaget and Vygotsky.	Educational	Constructivist, Rationalist, Empiricist	-	-	This thorough approach is associated with a highly comprehensive and meaningful learning; but this need not necessarily lead to good professional performance	USA and Europe.
Holistic Approach	The education of a critical and reflective individual, meaningful learning and innovative in terms of collaboration, co-leadership of the learner and trainer. Development of basic, transferable and transferable competence are essential aspects of this approach.	Labor / Educational	Gestalt, Systemic, Existentialist	IPMA	4-L-C system	It is more complex, looking at all dimensions of the individual, and subsumes the previous levels within all of that representation.	Europe and USA

TABLE 1
COMPARISON OF APPROACHES OF COMPETENCE
(Continue)

		Characteristics	Area	Approach	Related institutions	Information Systems	Restrictions	Beginning
Models of Competence based on		Competence is greater than a skill; it includes knowledge, attitudes which are connected with work performance and can be improved and even achieve excellent professional performance when these constitute an integrated whole. Human Resources Management requires competency models for effective consistency, continuity and performance.	Labor	Systemic / Interpretative	ETED	"bilan de compétences"	Although it goes beyond the reductionist vision of the working approach, there is a strong contextual dependence of attributes, obtained through the worker's experience (access through the subject). There is difficulty in generalizing the results.	France, Austria.
	Place of work	Here competence are seen as complex processes that people put into action-action-creation, to solve problems and do activities (of everyday life and in the labor-professional context), contributing to the construction and transformation of reality. The competence involve people as agents of social wellness capable of performing in an unknown future.	Educational / Social	Socio-constructive	Cedefop, HBO	KMK, WEB	There is the question of how to determine if the person has reached competition or not. Competence development is time consuming, and some skills are only acquired after the Higher Education, which makes it difficult the evaluation of continuous learning.	Netherlands, Germany
	Behavioral theory	Here the role of technology and engineering is highlighted; apart from being an innovative component, it is a component associated with the knowledge, training and aptitude of people. It promotes the concept of creativity that includes ongoing development, the relationship with the environment, and use of existing resources. Technology plays an important role in the evolution of management systems for skills and lifelong learning.	Labor	Constructivist / Behavioral	-	-	It always has in mind a trio in perfect communion elements: people, technology and processes, ignoring social and innermost issues of the person.	Europe

The Table 1 above presents a comparative table of eight approaches of professional competence described as a summary: the characteristics, the area in which they operate, the philosophical approach to which they belong, certification systems related to the model, the limitations and the country where they originate.

From the comparative approaches it is emphasized that the holistic approach is the most appropriate for competence coding for higher education in engineering. Here professionals are increasingly required and bring into action a complex mixture of knowledge, skills, attitudes and values which, depending on the needs of a particular context, specific attributes are involved for an intelligent performance, helping to place ethics and values as part of the competent performing elements and the need for reflective practice. On the other hand, they have to be prepared for lifelong learning and must also have good communication and teamwork, where technical skills are not enough in today's world [51], [52], [53], [54] [55], [56].

However to achieve this demand, higher education institutions required learning methodologies different from today's, where actors and responsible of institutions carry out a set of activities to achieve the best training of future professionals [56] [54].
In this context, Education in engineering should be more holistic; it must have a body of knowledge and skills which are based on a set of coded competence, such as competence in the area of subject matter as well as general competence on business and social contexts and activity, and understanding of the characteristics of future professional [57 [58], [59].

In the holistic approach IPMA world certification system [60] is emphasized. This proposes its model in 4 levels (4-LC system): IPMA Levels A, B, C and D, which through the "Eye of the competition" show the three dimensions of professional competence: contextual and behavioral techniques. Within these three dimensions there are 46 elements of competence (See Table 2) considered suitable for engineering students as previously mentioned.

TABLE 3

CODE OF IPMA COMPETENCE [60]

1. TECHNICAL COMPETENCE	2. BEHAVIOURAL COMPETENCE	3. CONTEXTUAL COMPETENCE
1.01 Success in Project Management	2.01 Leadership	3.01 Guidance to projects
1.02 Parties involved	2.02 Commitment and motivation	3.02 Guidance to programs
1.03 Project requirements and objectives	2.03 Self-control	3.03 Guidance to portfolios
1.04 Risk and opportunity	2.04 Self-confidence	3.04 Implantation of projects, programs and portfolios
1.05 Quality	2.05 Relaxation	3.05 Permanent organization
1.06 Project organización	2.06 Open attitude	3.06 Business
1.07 Teamwork	2.07 Creativity	3.07 Systems, products and technologies
1.08 Problem solving	2.08 Guiding to results	3.08 Personnel management
1.09 Project structures	2.09 Efficiency	3.09 Health, safety and environment
1.10 Scope and deliverables	2.10 Consultation	3.10 Finances
1.11 Time and project phases	2.11 Negociation	3.11 Legal
1.12 Resources	2.12 Conflicts and crisis	
1.13 Costs and financing	2.13 Reliability	
1.14 Procurement and Contracts	2.14 Appraisal of values	
1.15 Changes	2.15 Ethics	
1.16 Control and reports		
1.17 Documentation and Information		
1.18 Communication		
1.19 Launching		
1.20 Closing		

Furthermore, within engineering, necessary skills have been detected in modern engineers. Those competence have been defined in one of the most serious work: the proposal CDIO (Conceive, Design, Implement and Operate) of the Massachusetts Institute of Technology (MIT). This proposal has three general objectives: master a thorough knowledge of basic techniques, leadership in the creation and operation of new products, processes and systems and understand the importance and strategic impact of research and technological development in society, which are proposed through the development of standards and the CDIO syllabus. This syllabus defines the competence that students must have when finishing their training as engineers, being the result of the conjunction of interests of all those involved in engineering activity. In the definition of competence, participation is used as a key tool through surveys: faculty, industry, alumni, and among others.

In Table 3, the first and second level competence are shown defined by CDIO and organized into four areas of training: technical knowledge and critical thinking, professional and personal skills, interpersonal skills and CDIO (Conceive-Design-Implement-Operate) [60] [61].

TABLE 4
OBJETIVES OF FIRST AND SECOND LEVEL OF CDIO SYLLABUS

1	TECHNICAL KNOWLEDGE AND REASONING	3	INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
1.1	Necessary basic knowledge of underlying sciences	3.1	Teamwork
1.2	A body of knowledge of the Basic Engineering	3.2	Communication
1.3	Knowledge of the fundamentals of Advanced Engineering	3.3	Mastery of a foreign language
2	**SKILLS AND PERSONAL AND PROFESSIONAL ATTRIBUTES**	**4**	**CONCEIVE, DESIGN, IMPLEMENT AND OPERATE SYSTEMS IN THE COMPANY AND SOCIAL CONTEXT**
2.1	Engineering Reasoning and Problem Solving	4.1	Social and external context
2.2	Experimentation and knowledge discovery	4.2	The contexts of businesses and companies
2.3	Systemic thinking	4.3	Conceive
2.4	Personal skills and attitudes	4.4	Design
2.5	Professional skills and attitudes	4.5	Implement
		4.6	Operate

With the revision of the context of competence approaches made here and the presentation of two competence encodings defined above, the authors proceed to make comparisons between IPMA and CDIO proposals to try to determine the best competence coding for engineering education in Latin America, that is why a common denominator is used : The Tuning America Latina project.

The Tuning America Latina project is one of the most serious work undertaken in the definition of competence for the training of professionals. This project is intended to "tune" educational structures of Latin America initiating a debate whose aim is to identify, exchange information and improve cooperation between institutions of higher education for the development of quality, effectiveness and transparency [51]. The Tuning America Latina looks for common points of reference focused on competence, presenting a final list of 27 generic competencies (see Table 4), which are important in a changing society where demands tend to be in constant reformulation [63].

TABLE 4
COMPETENCE TUNING-AMERICA LATINA

1) Capacity for abstraction, analysis and synthesis	14) Capacity for creativity.
2) Ability to apply knowledge in practice	15) Ability to identify, propose and solve problems
3) Ability to organize and plan time.	16) Ability to make decisions.
4) Knowledge the study field and the profession	17) Teamwork skills
5) Social responsibility and civic engagement	18) Interpersonal skills.
6) Oral and written communication skills.	19) Capacity to motivate and lead to common goals
7) Communication skills in a second language.	20) Commitment to environmental protection.
8) Information and communication technology skills.	21) Commitment to their sociocultural environment.
9) Research capacity.	22) Value and respect for diversity and multiculturalism.
10) Ability to learn and update knowledge continually.	23) Ability to work in international contexts.
11) Skills for searching, processing and analyzing information from various sources.	24) Ability to work autonomously.
12) Critical capacity and self-criticism.	25) Ability to formulate and manage projects
13) Ability to act in new situations.	26) Ethical commitment
	27) Commitment to quality.

Table 5 shows how the CDIO competence are reflected in the competence Tuning AL. It is also noted that there are two Tuning competence which are not clearly addressed by CDIO: 24. "Ability to work autonomously". It could be attributed to element 2.4. "Interpersonal skills and attitudes" of CDIO but it is not expressed clearly and it is more widespread. It is noted that Item 3. "Ability to organize and plan the time", from Tuning generic competences, it is not treated exactly in the competent elements in first and second level of CDIO. But if we look at the elements of the third and fourth level, one could say that this 3 competence is developed from Tuning 3. However Tuning better defines and clearly such an important generic competence and not as a detail of that competence.

With regard to the comparison with IPMA, the competence defined by Tuning undoubtedly are incorporated in all the competence elements defined by IPMA for Project Management. Competence 7 of Tuning, to master a second language, it is not expressly stated in IPMA and the competence element 1.18 will have to be emphasized. Thus, Tuning competence are more complete in that area.

IV. CONCLUSIONS

By going beyond traditional methods of study bibliographies, a more refined answer is provided to analyze large sets of data. Also there is convergence work around professional competence, finding 8 groups formed from common characteristics and research topics. These are: a) The behavioral competence, b) Competence in the workplace, c) Cognitive and motivational competence, d) Holistic approach of competence, e) Competence Core as business strategy, f) Competence in higher education g) Competence in industrial psychology, h) Competence in the context of engineering and technology.

The holistic approach is the least reductionist of the models studied and analyzed and contains essential aspects which facilitate direct application to the professional competence in higher education of engineering in which the graduate profile should contain key elements of knowledge, skills and professionals abilities, and especially attitudes and values, within a holistic approach of professional competence.

The authors state that Tuning-AL competence coding can be used for the holistic training of engineering students from Latin America to take on the challenge of developing of competence required in the professional training process. Therefore, it is necessary to design and complement an educational model whose curriculum is based on these competence leading to the development of skills, knowledge and attitudes of undergraduates that society needs.

TABLE 5
COMPARISON OF TUNING LATIN AMERICA COMPETENCE AND IPMA AND CDIO COMPETENCE ELEMENTS

Tuning América Latina	IPMA – Competencias Técnicas																					IPMA – Competencias Comportamiento														
	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.17	1.18	1.19	1.20	2.01	2.02	2.03	2.04	2.05	2.06	2.07	2.08	2.09	2.10	2.11	2.12	2.13	2.14	2.15
1										X																			X							
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25	X				X				X				X																							
26																																				X
27					X																															

Tuning América Latina	IPMA – Competencias Contextuales											CDIO – Conocimiento técnico y razonamiento			CDIO – Habilidades y atributos personales y profesionales					CDIO – Habilidades interpersonales: trabajar en equipo y comunicación			CDIO – Concebir, diseñar, implentar y operar sistemas en la empresa y sistema social					
	3.01	3.02	3.03	3.04	3.05	3.06	3.07	3.08	3.09	3.10	3.11	1.01	1.02	1.03	2.01	2.02	2.03	2.04	2.05	3.01	3.02	3.03	4.01	4.02	4.03	4.04	4.05	4.06
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24										X	X							X										
25	X	X	X	X																X					X			
26																			X					X				
27																											X	X

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