Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 1 Issue 4, November - 2014

Creative Problems Solving In The Field Of Design:

A revision to research

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***Abstract*—**The article produces a general conceptual and theoretical outlook to problem solving concepts in order to establish elements of this cognitive ability and thus make a pedagogic and didactic pondering for the discipline of Design. The perspective of cognitive psychology which has characterized the cognitive styles constitutes a relevant standpoint to understand student heterogeneity; this counts on abundant results in different continents.

There has been a revision of the approach made by specialists in the pedagogy of technology and design and of important concepts for the development of the design capacity of problem solvers.

Solving problems of design, seen from the stance of cognitive styles, presents some important and interesting results that could serve in the pedagogical structures and educational programs as they promote both academic inclusion and an understanding of student dropouts.

Keywords— cognitive style; industrial design; formulating problems; solving-problems; creativity.

I. INTRODUCTION

This work completes one part of five stage larger project within the Design Program of the Jorge Tadeo Lozano University[d] (UJTL for its acronym in Spanish). Its aim is to establish the competencies that are required for the innovation, characterizing aspects of the design capacity, specifically in the development of industrial design projects centered around a line of design based on technology.

The first stage, already completed before, addressed the modality of information processing in the dimensions of Field Independence and Field Sensitivity[e] [5], [2] within the theory of cognitive styles (CS) extensively considered by Hederich and collaborators in Colombia [32].

Below, the results in the version of the Sawa, Gottschadt, Embedded Figures (SG-EFT), test (test of masked figures) are presented. The test has been widely used in Colombia in the version of Hederich & Camargo[f] [30]. This instrument has Cronbach alfa reliability (0.91 a 0.96)[g] and a corrected Spearman value – Brown of (0.9412)[h] Table 1 shows each of the descriptive statistics used in the characterization of the results obtained in a number of 125 valid tests.

TABLE 1. SG-EFT, general statistics

n	Valid	125
	Lost	1
Media		36,09
Median		37,00
Mode		37
Tip Dev.		6,750
Minimum		20
Maximum		48

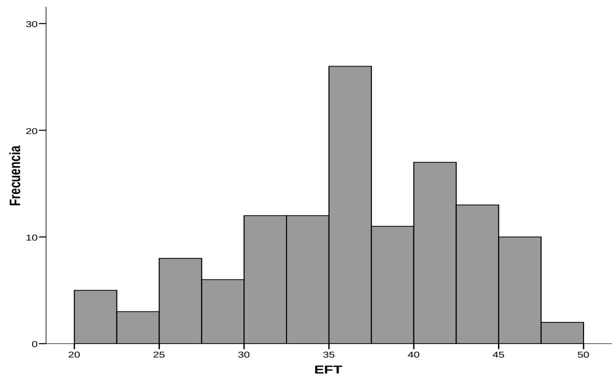

Fig. 1. Frequency Distribution of the SG-EFT.

[d] Origin of the document: Álvarez, F. y Martínez, E. (2010) "The Bridge is broken,… as get to the other side?" Characterization of the competence to framing and solving problems. Stage II-JTLU. Research report; Register No. 236-05-09 financed by the Research Division of the Jorge Tadeo Lozano University.

[e] Substituting the concept field dependence for field sensitivity has been approached from the positive meaning that being sensitive has, since the explanations given to students, object of study, the word dependence tends to be taken negatively by which does not correspond to the bipolarity that the dimension has; this has been also discussed Ramírez & Castañeda (1974) referred by Hederich, C., & Camargo, A. [34], p. 36.

[f] For example, Hederich y Camargo, [34], [35], [36]; Hederich, Camargo, Guzman y Pacheco, [40].

[g] Hederich, Camargo, & Reyes, Ritmos Cognitivos en la Escuela, [39], p. 48.

[h] The validity of the proof can be studied in detail in: Hederich, [33] pp. 259-262.

The results consistently indicate that the sample of students shows a tendency towards field independence which makes it evident the need to look into, with greater depth, the field of styles and their influence in the field of Design, since a balance was not observed, even in the SIC polarities.

A new study was carried out to review the existing research with respect to the framing and solving problem capacity within the development of projects in and for design; this appears to be interesting in order to come close to the competencies required for Industrial Designers. It will permit, in combination to other characteristics, to appreciate which features favor creative thinking and acting.

Initially it is wishful to identify the structure that leads to *the framing and solution of problems from a cognitive perspective*; there are contemporary studies found and important findings related to the field of creative problem solving (CPS[i] from now on), the technological development, the design capacity, among others. [25], [42], [43] [44], [8], [74], [75], [76] .

In the contemporary context, mismatches can be observed with respect to pedagogic, didactic and evaluative strategies which affect specification, development and concretion in learning processes. This is evident in educational settings of the particular teaching style of teachers in the classroom, whose tendency is towards redundancy of aphorism and isomorphism in the teaching and learning strategies in which the teacher is the only source of knowledge.[j]

It should be noted that the context of this experience is the Institutional Educational Project of the Jorge Tadeo Lozano University and specifically the Industrial Design Program [20], which hosts a variety of student profiles; its educational policy bets on an inclusive education. This commitment, without any doubt, needs understanding of the various possibilities that have been researched to frame and solve problems and so we can teach accordingly as part of the educational plan of industrial designers.

II. RESEARCH PROBLEM

The approach towards understanding the characteristics of the construction process, starting with the framing of the problem space and moving towards an incremental synthesis of alternatives of solution, is initially framed in a problem scenario that the construction of the structure of the problem goes through, as ill-structured by Andrade, [6].

The mental processes for solving the problem are embedded in prefiguring the solution, starting by using symbols and then revealing the navigation chart and the exploration of heuristics [10], [8], [14], [25], in words of Bachelard, imply the arrangement of concrete aspects as an alternative solution.

Initially, it should be remembered that structuring a problem progresses through a series of physical, emotional and above all mental activities which determine it. The perception, identification and framing of the problem [48], e.g., influence the likelihood of determining aspects of the problem. Similarly, moving from the abstract to a possibility of concretion or possible solution implies a correspondence between the design alternatives and the solution to the problem.

In this sense, when the system of the design situation is structured in a complex form, an internalization of the project, in the mind of the individual is evident; from then on is that it is possible to specialize and evaluate with arguments the different aspects.

Therefore, there are some elements to be considered that from the previous description of the architecture of a problem could influence the design responses. As such, the solutions in the design capability may present themselves as imitations, not as an original idea which has not been considered before [14]; these are improvements of an alternative due to cognitive orientations to delimit and dominate the determiners and fundamental requirements to the answer of a concrete design solution.

Based on what was previously presented, a question that could wrap up this complex process might be: How could these processes become key competencies for design focused in technological innovation?

III. OBJECTIVES AND METHODOLOGY OF THE STUDY

The overall purpose of the study consisted in portraying the *competency* to frame and solve problems centered on the structuring of the problem space as a cognitive ability. This falls within the development of industrial design projects based on technology and as part of a wider study of competencies for innovation. The methodological aspects are described in the following section.

A. *Methodology*

For the development of the proposal of the project, we used bibliometric and content analysis techniques by means of analysis and synthesis of creativity, cognitive and design theories to internet data bases.

Part of the development of the project implied reviewing some authors, specialized in the pedagogy of technology [8], [25], [45]. That allowed laying out the bases for the capacity to solve design problems of design based on a technological approach.

It is worth noting that, in going through the literature review, it became evident the existence of a great number of lines of work committed to innovation, among

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[i] English acronym Creative Problem Solving (CPS) which will be used from now on.
[j] Proposed by Hederich and colleagues, as an individualized frontal model [32], p. 8.

ISSN: 3159-0040
Vol. 1 Issue 4, November - 2014

which are psychology centers, universities, and wide-ranging industrial sectors working on understanding how the processes involved in CPS work, and on design and technology to develop methodologies and design products that respond to the ever increasing competitive markets.

This interest is due, partly, to the fact that there is a clear human potential to face problem situations which bring, without any doubt, quality of life to the human groups in their specific habitats. Equally, the creative solutions lead to such values as capital development, transactions that imply well-being and progress [7]. To reach these wishful levels, nations have focused their efforts in investing in technological development that implies research based on the training of specialized people in the field of innovation.

There is a notorious worldwide interest in understanding and improving the conditions to cultivate creative people. Therefore, it is a key issue to revise the findings related to CPS that have appeared during the last years. With the same purpose, the following section contains a review of the research results with respect to the intellectual production of the process that leads to framing and solving problems. Through a bibliometric exercise, the results are examined by consulting specific indexed literature in magazines and data bases.

IV. PROBLEM SOLVING IN RECENT RESEARCH

Key words related to the topic were established to make the inquiry of references that deal with the topic. Then, multidisciplinary data bases, such as ISI web of knowledge from the United States and Europe, REDALyC from Latin America and the Caribbean were reviewed; finally we looked at SCIELO and DIANET that cover Iberoamerica. In the same way, the work of authors of ample trajectory in the world of education, cognition and design were appraised.[k]

The texts analyzed in this blibliometric work were selected based on the research problem stated and its objectives. The search was made in English and Spanish. Next, you will find a series of tables that illustrate the inquiry.

A. Key words

The search terms used are shown in Table 1 and consist of a series of concepts that start by stating the framing or formulating process leading up to the incremental solving process of problems. The specific disciplinary and epistemic field was specified in the scope of inquiry.

TABLE 2. Key entries used in the search in data bases

Key Words
Formulating technology and design problems, cognitive approach
Solving problems in design
Loosely structured problems
Formulating problem spaces of design
Incremental synthesis in the solution of design problems.

Table 2 shows the results for the terms of inquiry that include combinations of the concepts in Table 3. In it, there are a total of 16 results, with which we can highlight that in spite of the multiple variations among the terms, the specialized production in that respect is not as abundant as one could imagine. Under the words 'formulating the problems for design from a cognitive approach' we found four articles, the majority of them in Spanish.

TABLE 3. Results obtained for key words in Spanish. These were translated for this paper.

Key Words with Results	
Formulating problems in design	2
Formulating problems for design, cognitive approach	4
Solving Problems in Design, cognitive approach	2
Solving Problems for Design	3
Solving Problems for Industrial Design, cognitive approach	2
Formulating problems in technology, cognitive approach	1
Solving Problems in technology, cognitive approach	1
Incremental Synthesis in solving problems of design	1
TOTAL	16

We began the search in terms of key words in English finding 14 results in the different data bases used as seen in Table 4. Of these results the majority were found under the concept of design problem solving. It is worth noting that the registered pieces most worked through were those that had the concept -of design- related to -problems- both in English and in Spanish. In total 30 registers were consolidated.

TABLE 4. Results obtained for keywords in English.

Key words in English	
Problem Solving	3
Solve design problems	5
Problem solving and cognitive styles	1
Design problem solving	5
TOTAL	14

Through this search system we obtained articles which have made significant contributions and as can be seen in Figure 2, it is possible to appreciate a type of rhythm of growth in the quantity of publications at a rate of one article every two years.

[k] Search done by the researchers with the collaboration of the Design student María F. Angel of the UJTL Industrial Design Program and Designer Carolina Parra.

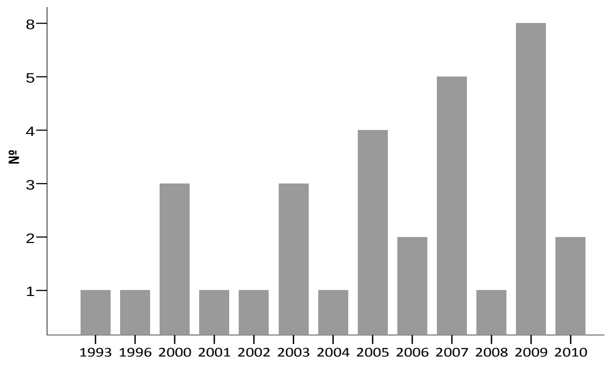

Fig. 2. Year of publications.

However, the number of texts produced is somewhat restricted for a period of 17 years. Therefore, beforehand it can be said that it is important to continue researching this sphere of technology, design and pedagogy from the perspective of the CPS.

B. Data bases consulted

Below are the results of the databases where indexed articles were found, and which were related to framing and solving problems in design and technology.

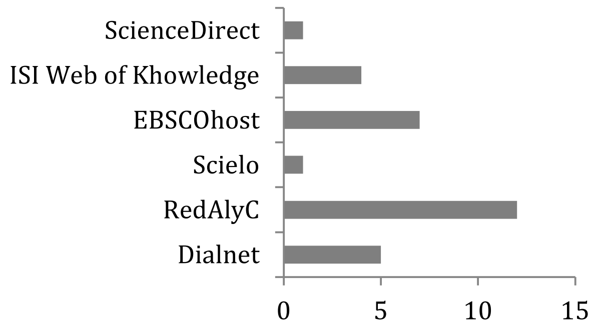

Fig.3. Results for each database consulted.

According to figure 3, the distribution of articles according to the databases consulted shows a greater concentration in the Latin American and Caribbean Web (REDALyC). Second came EBSCOhost with 7 results, then Dialnet with 5 articles, and in ISI, 4 were found. Last, simultaneously they appear in ScienceDirect and Dialnet with 1 result each. As will be seen in Figure 4, which includes the country of origin of each publication, those who make most use of these databases to let their research be known were the United States in the first place and second Colombia. Third in place, appear Australia, Mexico and Holland with three publications each. Then, England and Argentina follow with 2 articles each. Finally, Canada, Korea, Germany, Spain, Israel and Japan with 1 publication each.

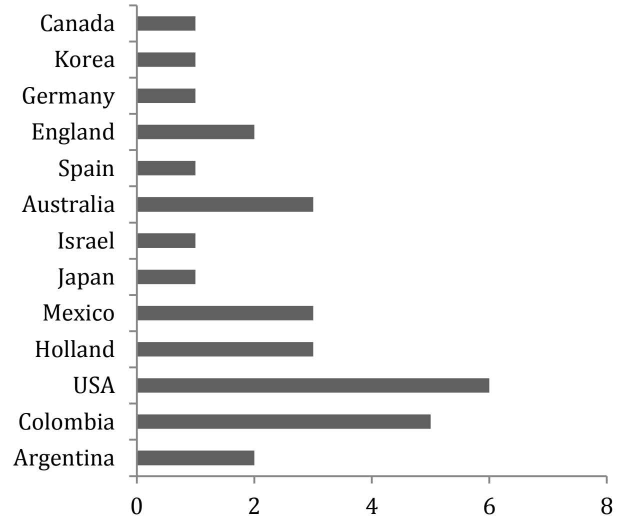

Fig.4. Results of the articles by country of origin

The specialized production presented around the key words highlights how important it is to continue exploring such concepts through stronger research efforts. Because of the great importance for understanding the design processes, better and more efficient training will be necessary to generate more creative and productive responses that promote the development of society and the environment.

1) Classification of the references according to the themes dealt with.

The results, as seen in Table 5, are presented organized according to the themes related to the formulation and solution of problems in design and technology. The greater contributions in this revision came from those interested in addressing the subject from a pedagogic and didactic perspective, then from the cognitive sciences, the competency approach and to a lesser extent from the TICs (Technologies of Information and communications), engineering, psychological reflections about CTS (science, technology and society) problems and the field of design.

TABLE 5. Main aspects dealt with in the articles.

Theme	Nº
Competencies	3
Didactic	7
Pedagogy	8
TICS	2
Engineering	2
Design	2
Cognition	4
CTS	2
TOTAL	30

Below are the results of the revision of the advances of research that show the different conceptual domains and their contributions to field of design.

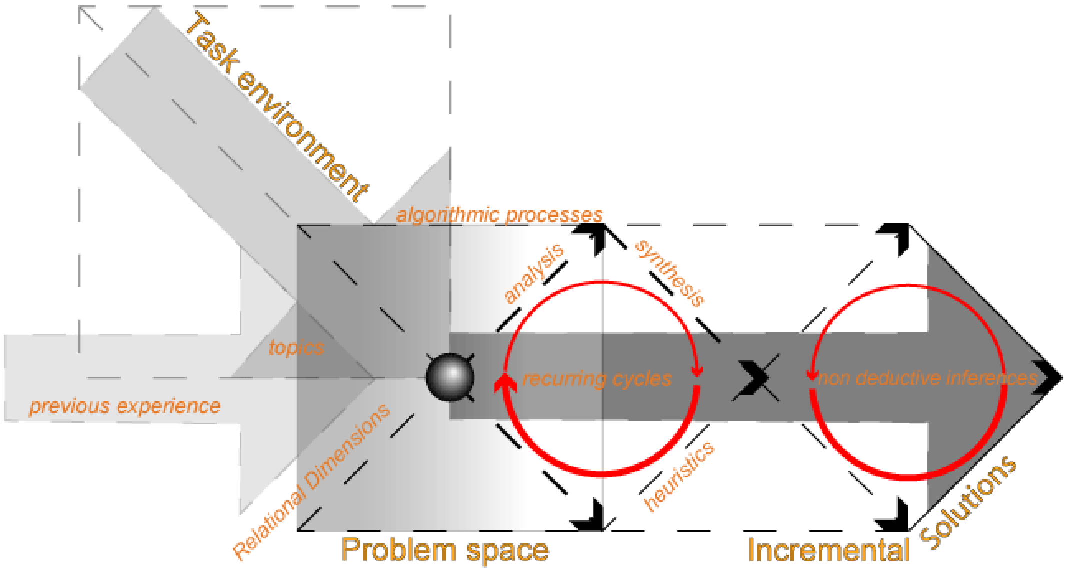

Fig.5. Structuring process which leads to the formulation and incremental solution of the problem.

V. DIFFERENT CONCEPTUAL DOMAINS RELATED TO FRAMING AND SOLVING PROBLEMS.

A. *Cognitive psychology and education in technology*

Framing and solving problems is defined as a cognitive and physical capacity of a person to present alternative solutions that present some degree of imbalance or disorder [62]. This capacity is closely linked to divergent thinking, the particular characteristics of weakly structured problems, [25], creativity, [14] perceptual restructuring [35], and the process of meaningful learning [9].

One of the fundamental theories that develop concepts related to solving problems from a cognitive approach perspective within the grounds of education in technology is the work of Andrade and colleagues [6], [7], [8]. They portray the attributes that outline patterns under which the technological environments of task, the structuring of the problem space of design and the incremental alternative solutions, are characterized.

Some of the structural elements characteristic of the process are briefly presented in the following segment. They start with the framing of the problems and lead up to the solutions of technology and design:

- *Task environment* as problem situations, defined in the design of expectations, needs or problematic situations, imbalance and disorder in specific contexts. They are considered from the sphere of the industrial design profession.
- *Negotiation process* in the construction and structuring of the problem space from a non-technical way among the designer and the actors involved; *Recurring cycles* in the process of structuring the framing of the problem and its solution.
- *Relational Dimensions* to the solution of the problem in the holistic dimension –distinct as modality of approximation to the solution by making decisions with arguments. Not related to design methodologies [8]. There are evidences that point out that students when following certain processes of design perform sequential tasks without continuity and end up constructinng a complex and systemic vision of the design process [58], [17].
- *The previous experience* of the designer is what permits to argument and elect the most probable routes for, the alternatives being explored, specialize and evaluate such election. This links the solution strategies of problems as heuristic - algorithmic processes- [14], [61], [18].
- The final solution as an *incremental synthesis* of the technological artifact, proved from the alternatives that are explored, specializes and evaluates that election. The presence of divergent thinking would operate with high levels of abstraction, [57], and in Boden's words would entail the command of the "rules and restrictions" (a type of game, for example: [60], p. 100. And, would go through mental processes as incubation, maturing, etc. [14].
- *Control strategy of limited commitment that* in general is developed and structured from an initial alternative [25].

The design solution is not just a logical answer but it presents some *non-deductive inferences* derived from *super* ordinate thinking [57]. Ausubel expressed that: "a fundamental principle for presenting solutions must have as a base the construction of previous structures from which to make inferences to reach a super ordinate level that permits him to be creative in the statement of the solution." [9].

One cannot leave aside the distinction of *technology* as a structure of the world of life that according to Vargas [77], refers to:

"a representation of the world, that has the design of social, economic, cultural, educational, relations as its base, with conditions for generating knowledge and products stemming from the resolution of problems in different spheres of daily life, both in the scientific and cultural dimension." (p. 136).

In this sense *technology* has clear implications in personal and social development; therefore, it requires an approach that includes pedagogy (education of the subject), education (reflection related to the type of society and quality of life) and epistemology as generator of knowledge stemming from design. As a consequence Vargas[77] refers to Antoni Colom, to indicate that: "this presupposes stating that an education for change implies studying in depth individualization since the adaptive solutions are found in the mental and intellectual resources of the subject." (p. 137).

B. A necessary characterization of industrial design

In the eyes of the philosopher Gastón Bachelard, design is an epistemological area where theory transforms into materiality [10], pp. 15-26. It takes the place of the operator that transforms abstraction into concretion. And according to Carlos Federici, design corresponds to an intelligible pre-figuration of the concrete originating in the written sign [22].

Thus, Design is a setting that problematizes in aspects related to epistemology: the complex systemic interrelations with respect to what is cultural. This covers anthropology, psychology and sociology. This is done so that the cognitive structure of the designer develops, with rules of:

- Logical-creative strategy
- Logical-creative experience,
- Discursive knowledge,
- Personal interactions,
- Personal disciplines
- Inter and transdiscipline [24]

This entails the mental modeling of a purpose in and for the qualitative transformation of a social, cultural and environmental context [8], [50].

This creative development requires, as stated by Norbert Wiener [81], four types of climate: an intellectual (Scientific- Technologic), a technical (productive-conformative), a social (human-cultural) and an economic (cost-benefit) climate. It is this new complex network of interactions, structured by the designer in the design process, where the cognitive hierarchy and consequently, his innovative, complex and systemic proposition in the socio-cultural context will become evident.

This new conceptual weaving achieved from a cognitive net, is what Novak [57] calls super ordinate knowledge -organized and hierarchical knowledge of higher levels of abstraction, combination and inclusiveness-. It's worth emphasizing that what was mentioned by Novak is not a foundation taken into account by multiple "methodolatries" [52], [8] used in design processes which is far-off from the approach of the complex and systemic praxis of design that is being structured in the project of competencies for innovation [4].

I. COGNITIVE ASPECTS IN THE FRAMING AND SOLVING PROCESS OF PROBLEMS IN DESIGN.

The approach in the process of design, starting from the structuring of an intervention scenario up to the final presentation of a product of design, is framed in the construction of a project. Epistemologically, the most pertinent is the psychogenetic and constructivist approach worked at length by Piaget [62], [63] and from another angle by Vigotsky [78], [79].

Fundamentally, with this onto and socio-genetic perspective, it is understood that the design goes through higher psychological processes, forms of mental organization [62], [63], and cultural internalization by the subject (Vigotsky), [78], [79]. This can be visualized in a dynamic and progressive way in the processes of design that professionals and students undertake.

Based on this perspective, it is necessary to admit that the restructuring that leads to the framing of a problem of design goes through a process of construction initiating in the grounds of daily life, of common knowledge, and passing by the genesis of an empirical structuring and consolidating in a systematic, generally logical and argumentative sphere (organizational forms).[10], [78], [77], [23].

García [23] explains that these organizational forms required in creation and design processes lead to building knowledge; he recalls that the development of knowledge consists of a double process. At the same time, Vargas Guillén [77] has no doubt when signaling this as a new space for generating new knowledge brought about by the design of solutions to concrete problems within the framework of the postmodern conditions. Following Garcia [23], in this process one can identify two essential elements:

- The Organization of the Activities of the Subject:

"That begins with the coordination of his actions, continues with the development of the constructive mechanism of knowledge and ends up with logic, that is, in the deductive and reinforcement forms." (p. 112).

- The Organization of the Empirical Material:

"That begins by assigning meaning, continues in making comparisons that lead to correspondences and elementary transformations, and ends in the interpretation of phenomena establishing causal relationships." (p. 112).

Garcia concludes mentioning that these developments lead to think of questions of epistemic nature. This reinforces the specific way of building knowledge of technology and design that goes through stages of intellectual approximations leading to more and more organized states of consciousness and highlighting its character as a discursive and disciplinary body.

In this sense, it is necessary to establish how the process that leads to becoming aware of the existence of a problem is; in the eyes of a layman it would never be such Piaget [62]. As Hanson points out as quoted by Garcia: "the child and the secular can see: they are not blind. But they cannot see what the physicist sees: they are blind with respect to what he sees." [24], (p. 41).

On his part Gallego [22], manifests that constructions in knowledge, that is, the construction of a problem that organizes the experiences into concepts (understanding the problems as intellectual constructs that imply solution through tasks of design), could not have been made haphazardly; this development requires reflection that separates intuition going beyond the 'how' question asking for the 'why' of the phenomena. Thus, when mentioning N.H. Coghlan to explain the achievements that consolidated the technical stage of civilizations, Gallego refers to "a series of conquests that are not explainable alleging accumulation by chance and discoveries at random." [22], (p. 73).

It seems clear that in assuming problems as constructions, these would be set within processes in which the phases or processes as such and the operations of support to those processes can be identified. With respect to this, Stoyanov & Kirschner from the Open University of Holland propose the following processes [74], (p. 50):

- Analysis of the setting of the problem
- Generation of ideas
- Selection of the most appropriate ideas
- Implementation and evaluation

With respect to the support processes to these stages in the solution of problems these authors pose questions to the following aspects:

- How to proceed in the stages of the solution to the problems?
- What to do when analyzing the setting of the problem?
- How to generate the ideas?
- How to select a solution and implement it in practice?

With that in mind, the authors underline that these would be a desired successes within a frame of learning competencies, for which it is worth considering its relation with Industrial Design as a profession.[4], [51].

These problems would be determined by the nature of the ill structured problems [25], and the cognitive processes involved in processes for presenting alternative solutions.[74], [43]..

Within this line of research that focuses on the formulation and solution of processes, Treffinger and colleagues [75], developed a model to represent the processes that require the CPS. It brings together, a variety of research with different groups and institutions among schools, universities, small and medium size companies and organizations done for more than five decades..

Treffinger's model suggests that the solving problem processes, far from being linear, constitute themselves in a nucleus of circular nature, i.e. they feedback each other continuously. Unfortunately though, no information regarding how Treffinger and colleagues make sense of the proposal of the nuclei of circular nature was found.

However, in the proposal of Andrade and colleagues [49], [8], this gap is solved through the concept of "recurring cycle" in the incremental synthesis process presented previously. Its structure consists of four basic elements which include, in turn, sub stages [75], (pp. 391-393):

1) **Understanding the challenge:** defining, constructing and focusing the efforts to solve the problem. This implies:
   a) Constructing opportunities
   b) Exploring data
   c) Framing the problem

2) **Generating ideas:** implies an approximation, based on a variety of options, to provide answers to the problem.

3) **Preparing themselves for action:** implies making decisions to commit to a promise of an alternative and planning its implementation.
   a) Development of solutions
   b) Building what is accepted

4) **Planning your approach:** Planning bringing everything together this is a management component that guides Designers (problem solvers) in the analysis and selection of procedural components and deliberate strategies. [43].

As we have tried to show, the structure described briefly has multiple coincidences with Andrade and colleagues' proposal, which reflects coherence, as seen from the different approximations, in the structures and processes that occur in the CPS.

Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 1 Issue 4, November - 2014

The process of structuring the setting of the task and the step towards defining the problem space of design corresponds to the tasks involved in –understanding the challenge- proposed by Treffinger and colleagues; likewise, the incremental synthesis of the artifact- would correspond to the steps of –preparing for action- and –generating ideas- of Treffinger and colleagues. Finally, the recurrent cycles of negotiation would be identified by valuing the tasks and what could be called management processes of design.

Schaagen [69] contributes another interesting perspective; he explains how expert designers solve problem and describes four types of knowledge required by those experts (pp. 287-289)[l].

- In the area of knowledge (disciplinary and discursive knowledge of design)
- Of heuristic strategies (tacit knowledge for doing) 21].
- Of control strategies (strategic logic).
- Of learning strategies (learning from solving problems experiences)

These four types of domain knowledge are directly related to multiple investigations from the perspective of - domain knowledge of design- [8], [10], [11], [17], 44], [53], [4], [19].

Consolidating the views with respect to the processes around the problem of design allows us to present in the following section, the relations within the process. This begins by structuring and formulating the problem up to its incremental solution related to the EC. It originates in the consistency with which the problem solvers prefer to approach this aptitude by carrying out both mentally and physically focused activities. [41], [44], [69], [25], [45], [61], [35].

A. The cognitive styles and the framing and solving problem process

In the results found up to the moment, in the first stage of development of the research on competencies for innovation, the concept of cognitive styles (CS) was explored, specially the dimension of Field Sensibility-Independence (FSI) as a polarity of the CS in which Witkin & Goodenough [83], state that "… as a product of the research that Witkin and his team did, it led them to organize it in a new structure that could no longer be understood from the tendency of a scheme of the 'global personality". The different findings were structured under the concept of 'diferentiation, that was understood as…"a useful construct to conceptualize the ample panorama of the individual consistencies." [83], (p. 41).

This FSI dimension was examined together with the design processes of everyday objects [1], [2], [3], [5], in which a series of interpretations related to the processes in design were considered; e. g.: Spotts & Mackler [72], have been concerned with the relation between CS and creativity; however, it was difficult to conclude that there is any evidence for polarity FSI preference in creative tasks, in the sense that both the Field Independent as well as the Field Sensitive are potentially creative individuals.

Within the same conclusion in the teaching of design, there was a need to implement inclusive didactics that promote the mobility of their polarity of CS, according to the diverse student profiles [13], [53], and support as well the learning styles and the thinking styles that students have developed [73]. It is also convenient to carry out more research with respect to the teaching styles of teachers[m] [44], [76], [42].

Another example of one of the possibilities and potentials of the CS in learning design capability is proposed by Loscos [47] when mentioning that "training or intervening perception adequately through language…" to modify the CS by means of a linguistic perceptive training program (LPTP) is possible to enrich certain polarity.

In spite of the latter, the problem solving topic really contains a full structuring, framing and incremental solution process of problems. In some connected research, one can observe an integral attempt towards these processes involved in what is known as creative problem solving (CPS), a theoretical approach that is based on an ample exploration of more than five decades of research [75].

With respect to the processes that take place when solving problems, it is important to note the work of Johnson (1972, p. 133) quoted by Treffinger, Selby, & Isaksen, [75] who focus in the problem as: a vacuum between, where *is it? Or*, *what does it have?* And an expected position or result.

Treffinger,and colleagues [75] put forward in detail that style influences how individuals perceive the information and the problems, process data, prepare and implement the solution, as well as how they constructively use the information to solve problems and manage change effectively.[n]

[l] "Domain knowledge, heuristic strategies; control strategies, learning strategies." [69], (p. 287).

[m] One of the conclusions of the II Pedagogical Forum on Learning Styles organized by La Salle University, Colombia, paper presented by Christian Hederich; November 4 to 5, 2009, La Salle University, Bogotá-Colombia.

[n] "Each dimension influences directly the ways people perceive problems and information, process data, generate possible solutions, make choices and decisions, and prepare to implement solutions. They also provide information that individuals can use constructively to solve problems and manage change more effectively". [75], (pp. 390-401).

TABLE 6. Principal polarities of the cognitive styles in the CPS devised by the authors.

Author	Style Dimension	Description
(Treffinger, Selby, & Isaksen)	Explorer vs. Developer Orientation to Change (OC)	The explorers tend to solve problems from the perspective of seeing unusual possibilities, explore new means and possibilities. Instead, developers facing the problems based on some initial basic elements, practical solutions and task reality.
	Internal vs. External or ***Introversion vs. extroversion*** (Meneely & Portillo, 2005) Manner of Processing (MP) (similar characteristics to the field independence-dependence (Álvarez R. & Martínez S., ; Hederich,)	The external respondents are persons that tend to solve problems based on the interactive interaction with other persons in discussing the ideas; in contrast, the internal respondents make use of their own resources to make decisions in solving problems.
	Person centered vs. task centered Ways of Deciding (WD)	Individuals centered in persons first consider the impact of their decisions in others. They prefer to get involved emotionally when establishing priorities.
Myers Briggs Type Indicators (MBTI) cited in: (Meneely & Portillo, p. 159; Pantoja O.) Kagan J. cited in: (Hedereich & Camargo, p. 32)	Intuition vs. Sensing	The intuitive individuals respond to situations based on unconsciousness since most of them cannot explain their decisions while sensing types tend to solve problems reacting to stimuli.
	Thinking vs. Feeling Or Reflexive vs. Impulsive[o]	People prefer to decide quickly (impulsive thinking) with little probability of certainty; or on the contrary, they consider the setting before responding and control the possible mistakes (reflexive thinking)
Kirton cited in: (Stoyanov & Kirschner, 2007; Pantoja O.)	Adaptor vs. innovator[p]	The adaptors tend to adhere elements to an established structure while innovators tend to solve problems with a particular structure more unusual but less feasible.
Bruner J., cited in: (Hederich & Camargo, p. 31)	Centered vs. Sweeping	Individuals who tend toward centeredness are focused in only one task and end it before beginning another while the sweeping tendency implies carrying out several tasks at the same time without caring for the ending.
(Hederich, M; Blanca Mena & Luna Blanco; Bloomberg; Iriarte, Cantillo, & Polo; Meneely & Portillo; Spotts & Mackler; Witkin, Moore, Goodenough, & Cox)	Independence vs. Dependence	This was developed initially in the first part of the project. [2]. Other polarities.

It is convenient to insist on the fact that a good approximation to the approach of CS in problem solving is provided by Treffinger and colleagues, who define problems as:

"…consistent individual differences in the ways people prefer to plan and carry out generating and focusing activities, in order to gain clarity, produce ideas, and prepare for action. An individual's natural disposition towards change management and problem solving is influenced in part by mindset, willingness to engage in and respond to a situation as presented, and the attitudinal dimensions of one's personality." [75], (p. 393).

Treffinger and colleagues concluded that, as other studies [53], [2], the dimensions of the styles in problem solving are potentially creative polarities and there can be no preference of one over the other; all the styles play an important role in the route towards problem solving.

With respect to the model of the process for formulating and solving problems, Treffinger and colleagues suggest that this process implies thinking and behaving to attain an objective [42]; for that, they rely on a model of the solving problem process based on the model of A. F. Osborn (1952, 1953). These authors propose that within an understanding of creativity, many researchers link the high level creative capacity to a creative style. Essentially the creative styles respond to a question,

How are you creative?

B. *Polarities of the CS relative to CPS*

We must insist on the importance of the role that CS has in creative problem solving since that dimension, that accounts for the global behavior of the individual

[o] Also reviewed by: Pantoja O., [59].

[p] Hederich & Camargo note the Holistic Dimension vs. the Analytic Dimension suggested by Riding R. as a synthesis of the Independence vs. Dependence dimensions, Reflexive vs. Impulsive; Sharpening vs. Leveling; and Adapting vs. Innovating [35], (pp. 29-32).

and that includes the other polarities, is the SIC dimension.

Both, Witkin and colleagues, and Hederich and colleagues, coincide in stating that the more holistic dimension, and that is a strong indicator of the CS, is the bipolarity Field Sensibility-Independence FSI. [83], [35].

It is worth mentioning what was stated by Witkin & Goodenough, when referring to this dimension, in order to establish aspects related to the CS with respect to de FSI dimension. It includes issues of perception and at the same time of personality of the individual based on the argument of differential psychology that transcends the CS, in general:

"The reasons why there is greater investment in research on the field dependence-independence issue in contrast to other cognitive styles, are numerous and varied. Among other reasons is the demonstrated extent of the dimension and its evident representation in daily life; as such, its manifestations is renowned…" [83], (p. 25).

Although the polarities are construed from a comprehensive wholeness perspective of the individual, there are some specific polarities of the styles closely linked to CPS that are shown in Table 5 according to the framing and problem solving stage.

We can distinguish problem solving creatively, in the sense of creating new ideas relative to creativity, from solving problems that comply with reaching a purpose in a not necessarily original or innovative form.

It is important to note what is stated by Treffinger and colleagues [q], in warning about the importance of these distinctions at the level of problem solving since there are prejudices around creativity, usually associating it to some professions such as artists and fail to recognize it in others as the creative tasks of engineers[83], (p. 396). The latter can lead educational programs to favor teaching strategies for some and exclude creative development strategies for others.

As Kirton says, cited by Stoyanov & Kirschner [74] the CS have a neutral value and each polarity of style dimension can produce creative solutions to problems as is confirmed by their findings. In the same way, Kirton's research suggests that people can operate with different style dimensions in each stage of the solving problem process.

In some studies one can find some criticism to the relation between the CS dimensions and their possibility to explain some of the CPS processes. However, this can be attributed to the experimental methodology as well as to the line or approach toward the CS[r]. For example, it is important to highlight that some research findings conceptualize the difference among CS of cognitive constructs such as knowledge and intelligence (Kirton, cited by Stoyanov & Kirschner [74], (p. 53).

C. *Awareness and its relation to framing and solving problems*

The hypothesis being analyzed through this research raises the idea that in both framing and solving problems, as a mental capacity and design competence based on technology, there is a set of cognitive elements and principles of interdependence that allow. On one hand, the modification of a task setting towards the shaping of the problem and on the other, pre-envisioning the development of possible alternatives towards the incremental synthesis.

The fundamental factor of the cognitive construction, which goes through the process of self-awareness studied and structured by Piaget [62] in his numerous experiences, could explain, in this project, the mechanisms that lead to guide a behavior headed towards solving problems (goal-aim).

Piaget concluded that awareness is a process that goes from "the periphery to the center"[s] which guides the behavior that begins by reaching a goal; this principle would be made up of two peripheral elements:

1. **Objectives:** "The awareness of the goal to reach or the intention as a global guide of the act."[t]
2. **Results:** Becoming aware of its ending (either success or failure)

With these peripheral principles, either consciously or unconsciously, the means to carry out results are triggered. (For example, small children can achieve their goal but cannot explain how they reached it [78]. In a similar form it looks as if designers would go through the same situation when they find the possibility to undertake a project or generate ideas to solve a problem but from an unconscious form.

On the other hand, Piaget describes the internal mechanisms that lead to awareness of actions, and knowing the objects; these are processes of turning actions into concepts.[u] Piaget also points out that the subject will carry out proofs if the goal is reached or not with which the means employed are reviewed, refining their actions or changing them.

Up to here, it seems clear that the diverse and specialized aspects to be considered in the processes involved in the design activity, specifically in the process

[q] "…, we focus on the behavioral preferences in solving problems or managing change rather than identifying a general personality type". [83], (p. 395).

[r] "The inconsistency of the data related to cognitive style can be attributed to the difference in definition of cognitive style: (a) either as a level-type construct (some styles are better that others), or (b) as a preference to approaching problems in a particular way". [74], (p. 53).

[s] Piaget [62], (p. 256).

[t] This calls the attention to the close relationship to the operational principles that define the technological process [26].

[u] How concepts are formed according to Piaget [62].

beginning with framing and leading to the solution of a problem, which has been explored in the literature up to date, present multiple edges or perspectives that require that educational, pedagogical and didactic proposals be adjusted to this diverse complexity of the CPS processes.

Finally it is relevant to refer to Pantoja [59] who quoting Cross N., well known researcher in the design field, expresses the close relationships within the design activity, especially in the framing, structuring and solving problem process in a creative way:

"how an individual addresses the situation, which becomes his object of knowledge and the way he brings up solutions to get better acquainted with it or to solve it, depends on his particular style or predominant styles." [59].

VI. FINAL COMMENTS

The need that leads to the development of this research implies contributing, from a cognitive perspective, approaching and suggesting some didactic strategies for the design discipline [18], [43], [42], that in some way benefit the educational processes of Industrial Designers.

The Institutional and Educational Policy Project (IEPP) of the JorgeTadeo Lozano University promotes an inclusive education and therefore it is necessary to adapt educational practices within the pedagogical and didactic spheres; these should be developed by constructing knowledge about contents, teaching and learning.

The conclusions that we expect to reach from these reflections, can also serve in some way, as a reference source for other academic programs in or external to the University or to those who might be interested in understanding the cognitive aspects involved in problem solving and their relationship with competencies for innovation.

Maldonado & Andrade [49] have defined some conditions for educating people so that they can solve problems with the purpose of developing what they call the -design capacity- . In this sense, this proposal gathers differential cognitive aspects and relates them to aspects of the discipline that create the object of study of design as a profession.

To put together a proposal in this field, it is important to review the conditions proposed by Maldonado and Andrade:

1. Development of certain motor, expression and experimenting abilities and skills.
2. A conceptual network as a minimum experience as a base for meaningful learning [18].
3. Capacity to express, in abstract terms (abstract thinking capacity) the concrete referents as a starting point for the design task.
4. Building functional prototypes that express, the structure and function of the partial or final solutions to the design problems.
5. Significant experience of the individual. "Building strong solving problem strategies, which are an aspect that distinguishes the work of specialists from that of beginners." (Gage, 1984). Cited by Maldonado & Andrade, [48]; also [69], [46].
6. Study of the historical development of objects. The systematic study of the practical solutions knowing about the technical experience of mankind.
7. Starting from the learning through guided discovery to end in learning by autonomous discovery.

It could end up being something paradoxical to teach designing if we consider this to be an innate capacity of an individual, which additionally implies divergent thinking while the academic processes generally are -frontal- and converge in sometimes homogenous results.

As seen, the complexities that are required for processing and the strategies involved in structuring the design project entail the starting point of an original and innovative idea, i.e. that lead to its manufacturing, or production for everyday use. It implies the work of more than one person since these processes of projects exceed information, tasks and require time management improvement, an outlook that will continue to be a challenge for educational programs of design that fail to recognize the group and collective elements of design and innovation.

However, design seen from a complex and systemic perspective allows us to understand that the findings of research, combined with the pedagogic and didactic efforts used in classrooms, permit many of these components of the equation -education for, and, in design- to be articulated synchronically and hierarchically.

On the other hand, in the academic world we find the challenge to think epistemologically and evaluate critically the education possibilities of more and more creative people placing in front the components for an inclusive education, that respect diversity both of the people and their potential.

VII. ACKNOWLEGMENT

Special acknowledgment to Fabiola Cabra Torres, PhD. In Educational Innovation, professor at the Javeriana University, for the revisions made to the main document.

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