Possibilities of “Nuclear Concepts Theory" on Educational Research, a Review

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Abstract

In 2002, Casas and Luengo created the “Nuclear Concepts Theory" (TCN in Spanish), which has served as theoretical framework for much research in the field of educational research. During 2005 it was created the research officer Group CIBERDIDACT of the University of Extremadura (Spain), which has been working in the cognitive structure knowledge of students, from the point of view of the TCN, constituting one of the main research lines of the Group. Almost a decade elapsed, have already obtained sufficient results to make a review of the point where we are and show the possibilities of TCN in education research. This communication aims to inform about the research on the TCN, from its origins, the context in which it developed, the theoretical framework in which it is based and its associated technique "Pathfinder Associative Networks". We also describe the software we use in our work (GOLUCA), which has been designed and implemented by our research group, and serves as a support on the analysis and representation of cognitive networks. The TCN has served as a theoretical framework in several theses and ten PhD research, which have been communicated at conferences and seminars, publications and book chapters. Its has been applied to fields as diverse as computers and education, evaluation of virtual environments, teaching in various areas (nursing, computer engineering, music education), but especially in research in Teaching of Mathematics (Geometry, Arithmetic, Trigonometry etc.). The TCN, since its inception, has had contributions and improvements both in terms of theoretical framework, itself and its technical partner, leaving many open questions, which are the subject of future research. At the present stage we can say that the investigation on TCN provides more questions than answers.

1 Introduction

In 2005 we created the official Research Group "CIBERDIDACT, belonging to the University of Extremadura (Spain) [1]. Among the research areas developed by the group, highlights a line of research that attempts to deepen the understanding of the cognitive structure of students, from the point of view of a theory also generated by the group: the " Nuclear Concepts Theory "(TCN in Spanish).

The origin of TCN, dating from 2002, during the investigation of the doctoral thesis of Dr Casas [2], studying the mathematical concept of angles, from the point of view of its conceptual network. The results can not be interpreted from the classical theoretical frameworks, pointing in the opposite direction than expected.This carried us to create a new theory that makes an integration proposal, based on established theories, but which aims to provide an innovative approach and that comes from the experiments: The Theory of Nuclear Concepts "(TCN) [3].

The theoretical framework of the TCN, arises from Cognitive Science, in the same line as Neisser [4], Piaget [5] and Ausubel [6] and more specifically, Shavelson [7] (Referred to the notion of cognitive structure) and many of the ideas of Rumelhart [8] (in organization of the Memoria, based on schemas or mental representations related to the Theory of Schemes ").

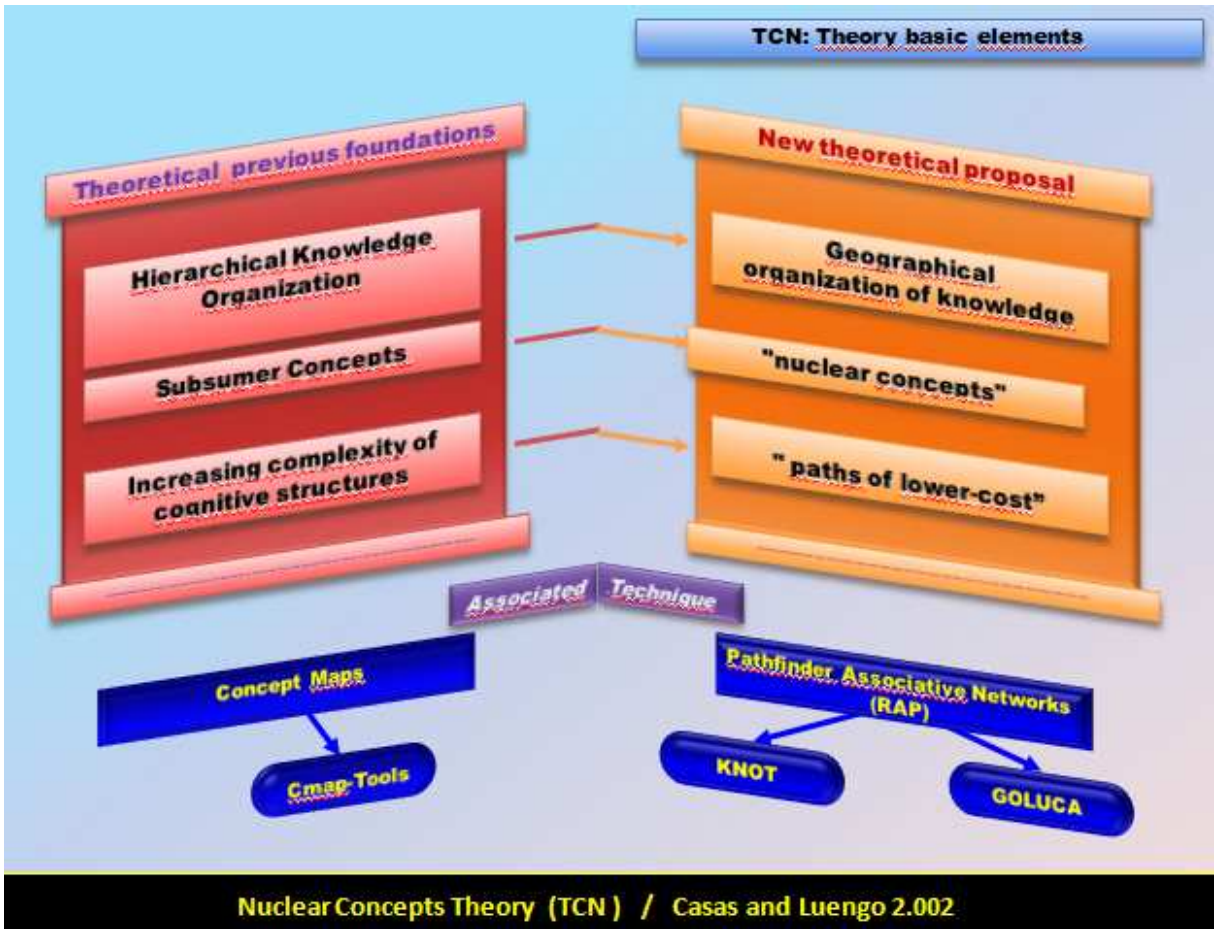
The TCN has also associated a technique that allows the representation of the knowledge structure in an analytical and graphic way, which gives us information about how learning occurs in response to changes in cognitive structure, using a procedure for obtaining noninvasive data.

The TCN and its associated thecnical, has been used in several research projects (three doctoral thesis that have been read, several licentiate thesis and many other Master's and PhD researches). At

the present, investigations are being made not only in our group, but by others researchers, especially in Iberoamerica.

2 “Nuclear concepts theory" (tcn). Basic ideas.

A reflection on the ways in which knowledge is acquired and stored in the student's cognitive structure and how it can be represented, has implications for teaching and educational research.
Cognitive structure is defined as a hypothetical construct that refers to the organization of relations between concepts in semantic memory or long-term memory. (Shavelson, 1972) [7].
The TCN (Casas, 2002 y 2003; Casas and Luengo 2003, 2004 and 2005) [3], offers a point of view to approach to the understanding of how to acquire and organize knowledge and how to characterize the cognitive structure. This is a new perspective to explain how learning processes occur in the human mind. Corresponds to the theoretical framework of Cognitive Science, taking as a reference those indicated in paragraph 1 (Introduction).
Research carried out by Casas and Luengo. (2004) [3] reflects on how it works the student's mind and how to internalize the basic mathematical concepts (and more specifically the concept of angle) and raises questions about how to represent the student's mindset concerning a topic,if we can use these representations for the research and if this cognitive point of view can have a didactic use. Casas worked with a population sample of 440 students of Extremadura, obtained in a multistage selection process with strata random cluster of courses and classes and found that strange results can not be explained on the basis of existing theories, so you need a new theory (TCN) that, based on earlier theories, explain these results.
The following scheme shows the basic elements of the TCN:



Accepting many of the ideas of Piaget, Ausubel and Novak as prior theoretical bases, TCN differs in some points but proposing new alternatives:

1. Disagree with the hierarchical organization of knowledge (not to explain the results) and then it propose an organization "geographical" of it (Casas and Luengo (2005) [3].
2. Facing the subsumer concepts it is presented the alternative of "nuclear concepts"(as concepts that anchor the cognitive structure)
3. Facing the increasing complexity of cognitive structures we propose a new concept called "paths of lower-cost ".

From this discrepancy come up many elements of the TCN theory, which are the "geographical organization of knowledge", the notion of "nuclear concepts" and the notion of "paths of lower-cost". (Casas, 2002 and 2003; Casas y Luengo 2003, 2004 and 2005) [3].
The "geographical organization of knowledge" is a metaphor to explain that the students' cognitive structure is not hierarchically organized around general concepts from wich emerge all the others, but concrete concepts that are not necessarily the most general concepts.
According to this theory there is no higher or lower level concepts, there is just concepts (nuclear concepts) that support the development of cognitive structure. In any case, the nuclear concepts are not necessarily the most general, are simply the most significant for the student, the most important in their cognitive structure. In practice, this theory is intended to emphasize that students organize their cognitive structure not only around the general or abstract concepts, but on concepts that in many cases may be just one example.
The paths of lower-cost" is the relationship of greater simplicity, but more importantly, which students use as they move gradually in the construction of knowledge though in their cognitive structure emerge increasingly related items each others. On this premise, the Theory of Nuclear Concepts proposes that, as learning progresses, the students' cognitive structure is gradually transformed, but paradoxically, in a simpler structure.
Within Cognitive Science there is great interest in techniques for knowledge representation and analysis. Most of these techniques use the spatial metaphor to describe the cognitive structure and are based on similarity data, which reflect the semantic proximity between the concepts on human memory.
Like other theories, TCN uses an own technique, Pathfinder Associative Networks (RAP) that provide cognitive networks face hierarchical trees that are represented in concept maps. There are programs, such as CmapTools, that represent these hierarchical networks. There are programs, such as CmapTools, that represent these hierarchical networks, and to represent the RAP, we use KNOT [9] and GOLUCA[10] programs (in different versions and developments).

3 Pathfinder associative networks (rap) and goluca programme.

Pathfinder Associative Networks (RAP) (Schvaneveldt,1990) [11], are representations of the relationships between concepts and provide information about a student's cognitive structure. These are graphical representations of cognitive structure in graphs form, in which concepts are represented as nodes or vertex and relations between them as segments line of variable length depending on the weight assigned and their semantic proximity.
RAP allow identify, in a simple, fast and efficient way, nuclear concepts around which students structure their knowledge. Teachers can then explore the conceptual knowledge of their students and know, through successive measurements, the evolution of knowledge networks of students and approach to the understanding of their cognitive structure.
RAP are obtained by selecting, first, the relevant concepts of a field of knowledge. The nearest concepts are most strongly related, and the more distant concepts will be less related. If we give numerical value to the force of these relations, we obtain a matrix of proximity data. KNOT and GOLUCA programs implement an algorithm that determines the strongest relationships and makes a network representation.
These programs allow us to obtain data, throught a very friendly interface that reflect the cognitive structure of students in a network. Using these networks we can get much information, not only graphically, but also network parameters calculated by the program. They have the advantage over the concept maps, that RAP are a "noninvasive method", and that it does not only represent the networks (as does CMap Tool) but also provide us data, and quantifies network characteristics such as coherence, complexity or similarity, among others. This allows comparison of the networks of different students and groups, networks of teachers etc, and to study the conceptual network evolution over time, what offers immense of possibilities for education research.

4 Applications And Research Results

Most of the TNC research has been generated by the Group CIBERDIDACT in the context of Master and PhD courses at the University of Extremadura: 4 doctoral theses, 11 Master Thesis and Final Master, and 20 publications (in books, journal articles and conference papers). Under the theoretical framework of TCN, it has been investigated on different topics related to TICs, mathematics and other topics, mostly in the field of education, but in others it has carried out work that aimed to improve the technique and to explore associated possibilities. In this review, in paragraph 5, we provide web links to access the list of work carried out by the group CIBERDIDACT since the release of TCN in 2002 until today.
As for the future of the research line and open questions that we asked, we can group them in four groups, suggesting the direction we need to take in the future in our research:

1.- Contributions to the TCN Framework (whose objectives are to test, complete and consolidate what we already know about TCN.
2.- To improve the technique Goluca for obtaining networks, provide the program Goluca of new features analyze, compare and triangulate the results with other techniques.
3.- Application of TCN to various areas of knowledge: Find new TNC strategies and applications in others areas of knowledge.
4.- Improving learning through hypertextual teaching units: the results founded under TCN influence in improving the learning process, through virtual teaching programs with hypertextual support.

To sum up, we believe that this line of research is already a solid base, we know many things, but now we have more questions than answers. Each investigation poses new questions that open and suggest new research, which encourages us to investigate further in TCN.

5. Ciberdidact research group in the theoretical framework of tcn and its technical associate:

- The complete list can be found at:
- Research lines: http://www.unex.es/investigacion/grupos/ciberdidact/estructura/lineas
- - Doctoral Thesis, Master Thesis and Final Master: http://www.unex.es/investigacion/grupos/ciberdidact/estructura/tesis
- Publications (books, journal articles and conference papers): http://www.unex.es/investigacion/grupos/ciberdidact/estructura/publicaciones
- Presentations at Conferences: http://www.unex.es/investigacion/grupos/ciberdidact/estructura/ponencias

References:

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[2] Doctor Thesis of Luis M. Casas, directed by Ricardo Luengo. Can be found in the "Aprengeom" of SEIEM in: http://www.uv.es/aprengeom/archivos2/Casas02a.pdf
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[9] Interlink Knot Program: http://interlinkinc.net/

[10] GOLUCA Program, designed and implemented by the Group CIBAERDIDACT. (http://www.unex.es/investigacion/grupos/ciberdidact)
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