Curriculum Design in GIS&Sc within ISEGI-UNL

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Abstract

This paper will address the main issues that led to the proposal of a new curriculum for postgraduate studies in Geographic Information Systems and Science (GIS&Sc) within the Institute for Statistics and Information Management of the New University of Lisbon (ISEGI-UNL). The curriculum design was subjected to different theories and curriculum conceptions, under the assumption that the emergence of varied teaching/learning frameworks, coupled with technological developments such as the Internet, may assist in the translation of the fundamentals of the discipline into pedagogical concepts and relevant experiences. The conceptual framework of the project has been established around three major analysis domains: (1) evaluation of the implications stemming from the implementation of the Bologna Process, (2) development of comprehensive appraisal tools for the identification of the fundamental and specific topics within GIS&Sc education and training, and (3) exploration of open learning environments to advance the learner-centered design approach.

1. Overview of the Project - Scope and Objectives

Developed in collaboration with UNIGIS International, the ISEGI-UNL Postgraduate and Master Degree Program in Geographical Information Systems and Science, currently in its fifth edition, is designed to give students a comprehensive education in both the theoretical and practical aspects of the analysis of geographic information. The program of studies is designed to meet the requirements of a wide range of public and private organizations, to give the necessary background to understand the technical, scientific and organizational aspects of GIS, to provide hands-on experience, with special emphasis on acquiring knowledge of the design and implementation of GIS projects, and to ensure a scientific qualification for a career as an applied GIS&Sc researcher. With its focus on working professionals, the program provides opportunities for professionals to acquire knowledge and skills in the field of GIS&Sc, while also giving the students recognized international qualifications.

This is the first masters program given by a Portuguese university institution fully available through the internet using technologies of distance teaching (e-learning). It is organized in four semesters comprehending a total of 120 ECTS, distributed through five learning areas (Geographic Representation and Visualization; Geospatial Data Acquisition and Manipulation; Databases and Data Modeling; Geospatial Data Analysis and GeoComputation, and Geographical Information Systems, Society and Organizations).

The innovative nature of the course, both in methods and curricular structure, has determined the implementation of an internal quality assessment in order to follow the quality of the teaching being offered and a general idea of the accomplished results which could be made [1, 2]. In that sense, in 2002, a self evaluation process was started, based on an inquiry made to the students who participated in the first edition of the course. The inquiry contemplated a number of questions concerning teachers and staff quality, relevance of subject matters, technical support efficiency and technological support performance. Although the results of

this study led to a first evaluation of the program of studies and an improvement of some less satisfying aspects, in particular those concerned with the technological problems of the platform, to this day the program of study has not been yet the object of a systematic process of assessment or innovation. For this reason, the project now being presented was based on the assumption that new and important challenges forced the establishment of an encompassing and in-depth approach for curriculum innovation and renewal. Not considered a proposal for curriculum revision or assessment, the project focused on a methodology for curricula design that allows for the framing of the processes considered fundamental for an effective improvement and innovation of a wide-ranging curricula, but mostly, guarantee the necessary conditions for its continuity through instruments that allow for monitoring the adequacy of curricula proposals, aiming to respond to GIS&Sc higher education challenges.

Thus, the current project is understood as a unique opportunity to reassess some of the assumptions that should guide the curricula design for GIS&Sc education, contributing to the definition and explanation of an encompassing approach, properly documented and structured, in order to support the process of developing flexible and relevant study programs, able to cope with different expectations of students. In this context the main goals of the project are:

- To analyze the main tendencies of evolution in higher learning, with an emphasis on the European context (the Bologna Process), in order to identify the main implications that should be considered in the current curricula development proposal;
- To frame the current curricula development proposal within the curriculum theories and curriculum development models;
- To identify the main questions raised by the use of Geographic Information Systems (GIS) and the main problems related to the advanced teaching of GIS&Sc.
- To establish a methodology of curricula development in GIS&Sc able to respond to a set of challenges of different nature (political, technological, scientific and educational);
- To develop and to introduce a curriculum proposal in post graduate studies in GIS&Sc, sufficiently wide and encompassing so as to integrate the different areas of knowledge and applications associated with the use of geographic information and related technologies;
- To explore, by way of the proposed methodology, the possibility to build alternative curricula paths in order to assess the flexible management possibilities of the curricula in accordance to the different needs and expectations of GIS&Sc education;
- To confront the new curriculum proposal in GIS&Sc with the results attained by well known international organizations in projects of a similar nature, in order to identify the main advantages and limitations of the proposed methodology, as well as its capacity to contemplate evaluation and improvement activities.

2. Conceptual Framework

Change is a characteristic that deeply marks higher education, and for which concur in a decisive way, technological and societal developments. The university as a place of knowledge production has always been a central institution in society, it is the mirror of some of the great transformations in modernity in the way in which they relate themselves to knowledge, its production, organization, function and

status in society [3]. The educational system is highly permeable to new visions and ideas. New models and teaching methods are being introduced in order to support increasing complexity of learning and to ensure the necessity to develop new and diversified professional and personal skills [4].

The alterations in higher education taking place in the past decades, have led to the evolution and change of educational paradigms with significant implications at various levels. The rethinking of the role of universities in current societies, the evolution of knowledge theories and its implications on curriculum conceptions and development, the need to diversify and make available more flexible programs of studies, and the advance of knowledge in GIS&Sc domains, are the main problematic axes that frame the current proposal for GIS&Sc curricula development.

Thus, the conceptual framework of GIS&Sc curricula development methodology was established around three major analysis domains:

1. evaluation of the implications stemming from the major reforms taking place in higher education leading to the implementation of the Bologna Process, particularly concerning the most significant measures for the establishment of an European area of higher education;
2. development of comprehensive appraisal tools for the identification of the fundamental and specific topics within Geographical Information Systems and Science education and training, enabling the inclusion of different students expectations and GIS professionals demands;
3. exploring opportunities and constraints associated with the use of new information and communication technologies in education.

3. Critical Issues in Curriculum Design

The process of curricular design involves a set of questions to which equal meaning or importance is not always given. Generally speaking, particular attention is given to objectives, teaching methods and educational strategies, neglecting the contents organization aspects and the global structure of the curriculum [5-8].

According to Pacheco [9] the curriculum organization "consists in the particular way of interconnecting and sequencing the elements that constitute the curriculum, in the range of the social (what to teach?), institutional (who's in control?) and didactic domains (how to teach?)". These three aspects are mutually dependent and have there most visible expression in the way the curriculum contents are organized and structured. Although there are several approaches and classification attempts to summarize curricular organization models, most authors recognize the existence of two essential dimensions orientating its contents structuring process.

3.1 Curriculum Articulation – Vertical and Horizontal Articulation

The first of those dimensions corresponds to the vertical articulation of the curriculum, i.e., the way in which contents tend to be organized with regard to the sequence and continuity of learning experiences promoted throughout the period of time of a study plan; referring to a thematic coherence grounded on epistemological and cognitive structures associated to a particular curriculum conception. The second dimension refers to the horizontal articulation, meaning the scope and integration of curricular contents of different disciplinary areas and knowledge domains in a certain level of teaching. When trying to improve the coherence of the studies within a course or subject area, what is at stake is the vertical articulation or the sequence of curriculum. When trying to improve the interrelation between different subject matters or knowledge areas, we are facing questions of horizontal articulation [7].

These two fundamental dimensions of curriculum articulation are represented in Figure 1. The horizontal plane represents the scope and extension of the subjects and topics taught in a given year or grade level and their articulation and integration amidst several other curricular units of the study plan. The vertical plane represents continuity and the sequential articulation of learning experiences within a given discipline. The scope of the curriculum, or its vital space, results from both the range of the horizontal articulation and the depth of the vertical articulation. The balance refers to a harmonious proportion between these two planes. According to this perspective, the process of curriculum organization represents an effort to improve the balance, scope, integration and sequence of the curricular subjects, in order to give the studies plan a harmonious proportion, comprehensive reach and a systematic continuity.

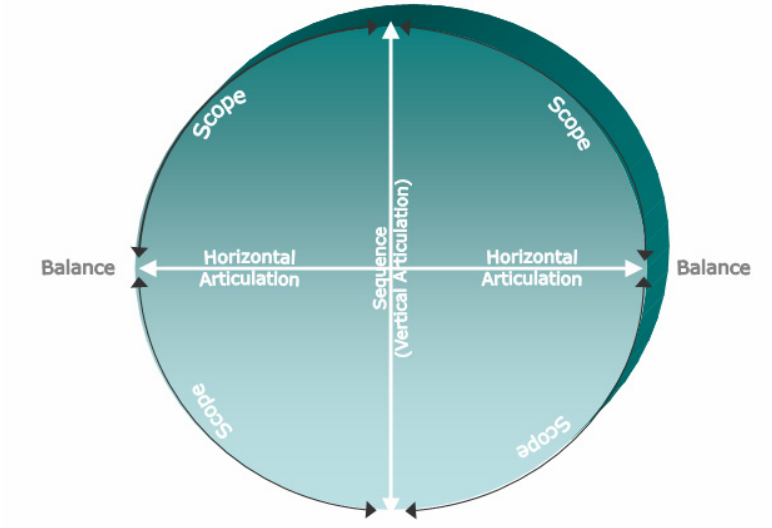

Figure 1 –The horizontal and vertical planes of curriculum articulation (Tanner & Tanner, 1995, pg. 374)

3.2 The Structure and Sequence of the Curriculum – The "Spiral Curriculum"

These two dimensions of curricular articulation are present in the "spiral curriculum" concept, introduced by Jerome Bruner in 19601 and systematized years later: [10]

> *"I was struck by the fact that successful efforts to teach highly structured bodies of knowledge like mathematics, physical sciences, and even the field of history often took the form of metaphoric spiral in which at some simple level a set of ideas or operations were introduced in a rather intuitive way and, once mastered in that spirit, were then revisited and reconstrued in a more formal or operational way, then being connected with other knowledge, the mastery at this stage then being carried one step higher to a new level of formal or operational rigour and to a broader level of abstraction and*

1 Bruner, J.S. (1960). The Process of Education. Cambridge: Harvard University Press.

comprehensiveness. The end stage of this process was eventual mastery of the connexity and structure of a large body of knowledge (…)".

This description points to the notion of a recursive curriculum that finds its foundations in constructivist theories. Stands on the idea that behaviors, learning processes and acquired competences are the result of a progressive construction of the subject in its interaction with the environment (*interactionism*), the spiral curriculum presents a sequential structure that promotes a continuous revisiting and in-depth contact with concepts and topics all through the process of teaching and learning, attributing a iterative nature to the modes of knowledge construction and reconstruction (Figure 2).

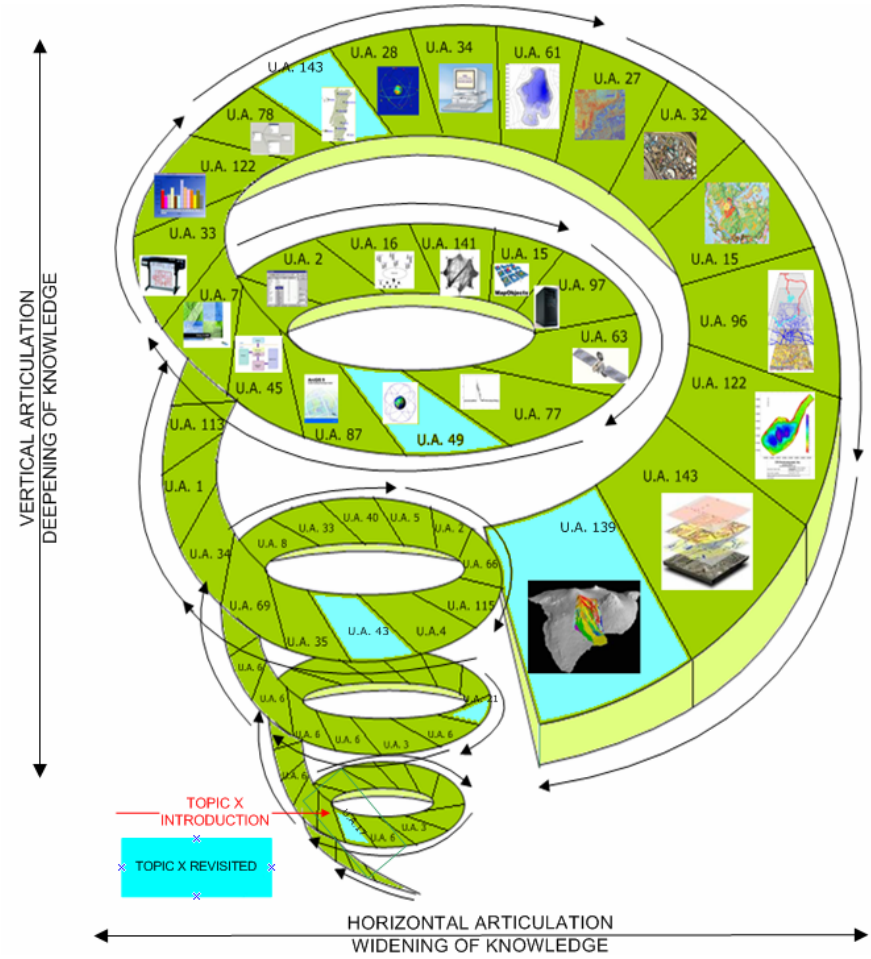

Figure 2– The spiral curriculum – The process of knowledge construction/reconstruction and its implications in curriculum organization.

According to Harden e Stamper [6] the four main characteristics of "spiral curriculum" are: i) revisiting of topics and concepts, ii) growing levels of difficulty , iii) Logical sequencing of learning experiences, and iv) increases of student skills .

Despite the advantages and characteristics of the "spiral curriculum" being easily perceptible, its process of implementation foresees a major effort in systematizing and organizing curricular contents in order to ensure that the curricular components are aligned with the learning activities, the curriculum global objectives and competencies to promote. This systematizing and organization process of the

curricular contents may assume various forms, with repercussions both in scope, width, integration and curriculum sequence. In fact, by trying to pursue a strategy of sequential and integrated organization of curricular contents, the different disciplinary areas may maintain its autonomy, become less individual or even disappear. The synthesis of the curriculum is reached when the divisions between the various approached themes are not perceptible.

4. GIS&Sc Curriculum Design - A Bottom-Up Approach

In recent GIS curricula proposals [11-13] the first step in curriculum development was based on the identification of educational needs. These approaches frequently referred to as top-down translate the need for adequacy between the teaching offers, the investigation requisites and the growing pressure form the industry and the labor market for qualified professionals in the area of GIS and associated technologies. In this context, the curricular development process is frequently pursued based on the identified academic and professional profiles, from which learning objectives and competencies are derived, which in turn provide indications on the contents that should be selected and the sequence of learning experiences that should be promoted.

These curricular development approaches meet the methodology proposed by the Tuning Project [14, 15] which, starting from a correct identification of academic and professional profiles, establishes the reference points for the design, construction and assessment of qualifications. The meaning given to learning outcomes, expressed in terms of competencies that should be acquired, is reached by "commonly agreed landmarks recognized within each of the subject-specific areas" [14]. In this perspective, the concept of profile, by translating the desired behavior, or the result that should be reached at the end of a teaching/learning process, refers to the notion of "curriculum as a product", with the curricular development becoming like a technical exercise, in which objectives are defined and contents selected, organized and structured to obtain measurable results. Like behaviorist theories this curriculum conception looks at learning essentially as an acquisition process of new competencies/behaviors (know how to do), that manifest themselves in a frame of specific answers to also specific stimuli, independent of the mental processes occurring in the student.

Although the results of learning are seen as the reflection of a paradigm change (from knowledge transmission to competencies acquisition) and as a contribution for a change in focus of the process of teaching/learning (from teacher to student), those curricula conceptions don't seem to offer answers to the way different characteristics and student expectations are considered in the process of curricular development.

In this context the methodology that guided the current GIS&Sc curricula proposal was sustained by an opposite approach, i.e., a bottom-up approach that puts in evidence the option of trying to go against the current trend of conforming and conditioning the curriculum development to predetermined ends and results.

Presuming that the options guiding the process of curricular development should not be subordinated to specific objectives that may limit or restrict the scope, the innovation ability and adequacy of the curricular process, the proposed methodology, based on a curriculum conception as a process or praxis, assumes as a fundamental point in the approach to be implemented, the meticulous identification of the knowledge likely to be contemplated in a variety of curricula proposals in post-graduate studies in GIS&Sc, able to answer the different academic, professional and/or personal necessities. Although this approach shares many of the concerns and presuppositions underlying the *GI S&T Model Curricula*

[13] the pursued methodology reflects the different conditions of the project development and places in evidence a range of possible future developments of the project that may contribute to its improvement.

On the other hand, and in view of the "Critical System of the Curriculum&Instruction Design" put forth by Petrina [16], this option assumed as imminently inclusive, is set on the presumption that the options considered on "What to teach?"/ "What to learn?" should not be put in practice in a early stage of the curricular development process, which would exclude at a starting point the main actors concerned in the processes of teaching and learning, but rather be shared by all those involved in those processes.

Thereby, the first stage of the process of curricular development consisted on an extensive bibliographical revision that led to an exhaustive, as much as possible, identification of a group of themes, concepts, technologies, analysis methodologies and investigation fields linked to GIS&Sc. In order to ensure that the bibliographical selection considered would cover the main themes the use of GIS requires, the research began by books of reference and of a generic nature, that, as much as possible, would allow the establishment of borders for a body of knowledge of GIS&Sc, and thus determining the scope and extension of the curricula. After that, another bibliographical research was made, this time taking into consideration works of a more specific nature, in order to allow for a more in-depth analysis of themes and subjects identified in the previous stage. The attempt to describe knowledge of a specialized nature led to a frequent transposition of the initially set border, highlighting the interdisciplinary nature of GIS&Sc. On the other hand, the identification of topics and subjects connected with different domains (Remote Sensing, Geostatistics, GeoComputation, Cartography and Topography, among others) has challenged the process of curricula organization not sought under one disciplinary or compartmentalized vision.

In total 130 books were analyzed, 20 of a more generic nature and the remaining 110 on more specific subjects. The information gathered in the first stage was subsequently treated to aggregate certain contents and topics via the creation of an adequate context to its problem. Through this process the intention was to create a set of learning units that allowed for a modular organization of the curricula. In total, 200 learning units were identified, which cover in a more or less extensive way the universe of GIS&Sc. In order to guarantee the adequacy of the curricula to the Bologna Process, for each of the learning unit the following descriptors were identified (in Portuguese and English): denomination, topics, objectives (learning outcomes) and student working load in hours.

5. A GIS&Sc Curriculum focused on the Intellectual Processes

The ever growing levels of difficulty and the increase of competencies associated with the "Spiral Curriculum" structure, seen as a result of a progressive construction of the subject in its interaction with the environment, put in evidence the necessity to consider the intellectual processes occurring in learning during the stage of curricular conception. For Johnson [17] the development of those processes is crucial in a time in which technological advancement is determining profound changes in intellectual competencies.

> "Increase levels of skills are required to maintain the complex equipment. There has been a switch from concrete (hands-on) tasks to abstract (minds-on) tasks which require mental skills such as symbolic and abstract thinking".

In this context an "*Intellectual Processes Curriculum*" (Idem) will be the one that tries to promote mental operations that allow the students the acquisition of new knowledge and its application in new non-familiar contexts and stimulates the understanding and resolution abilities of diversified problems. The five dimensions of thinking[2] proposed by Marzano et al. [18] could give the basis for an Intellectual Processes Curriculum construction.

Taking as a reference the generalized qualification descriptors developed by Joint Quality Initiative -JQI (Dublin Descriptors) [19], the conception of a curriculum centered on *"intellectual processes"* gives the necessary conditions for an effective implementation of the "*spiral curriculum*" revealing its adequacy for the prosecution of competencies associated with the second cycle of studies. By integrating these two curricular conceptions in the current proposal for curricular development it is possible to identify some of the critical aspects that determined the process of construction of the learning units its structure and organization, as well as the core thinking skills (Figure 3) associated with it:

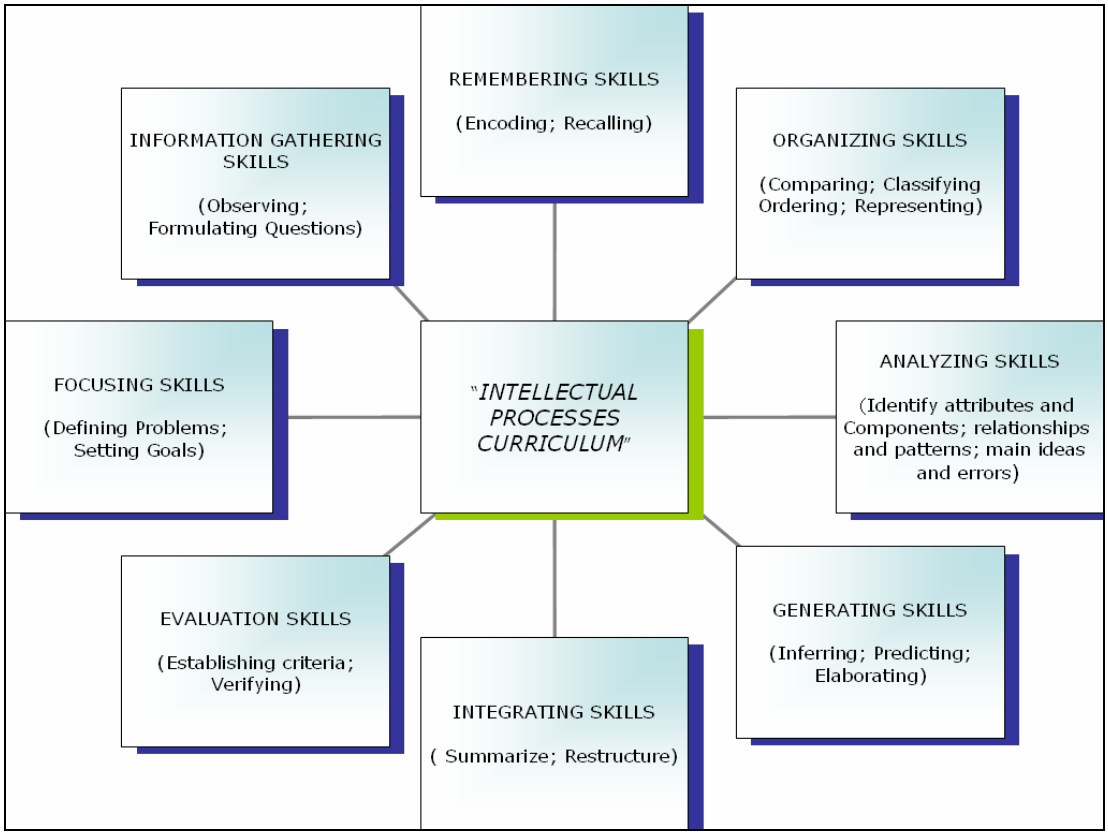

Figure 3– The Core Thinking Skills of an Intellectual Processes Curriculum. (Marzano et al. 1998, pg. 69).

1. Identification of the main problematic associated with a set of topics that integrate a certain learning unit;
2. Associate activities or exercises to a set of learning units that allow the application of acquired knowledge by way of problem solving;

[2] Thinking Processes, Core Thinking Skills, Critical and Creative Thinking, Metacognition and Relation of Contents to Thinking.

3. Identification of the nature of information (books, articles, inquires, geographical databases, census data, satellite imagery, etc.) main sources and acquisition methods, related to the approached themes and proposed activities;
4. Association of a group of concepts and key ideas to the set of learning units so as to facilitate the exploration of contents and their articulation, promoting metacognitive abilities through a GIS&Sc ontology;
5. Integration of learning strategies and activities that promote the ability to identify the characteristics and essential components of the approached topics and its organization, structure and articulation;
6. Revisiting of topics and concepts in broad and multidisciplinary contexts, that promote the ability to mobilize the relating of subjects, contributing at the same time for a deepening and widening of knowledge and for its representation in growing levels of complexity;
7. Inclusion of themes and approaches that promote analysis abilities, especially through the use of geographical information technologies;
8. Application of strategies that allow the exploration of uncertainty and error associated with spatial data and the considered analysis approaches;
9. Demonstration through examples or learning activities, of the need for critical and creative thinking to counteract and outgrow difficulties and adversity related to the use of geographical data and technologies of geographical information;
10. Integrate examples and situations that allow the exploration of ethical, political and social aspects related to the topics and subjects addressed;
11. Integrate evaluation methods adequate to the verification and demonstration of acquired competencies by the students in a given learning unit; and
12. Integrate the self evaluation mechanisms that allow the student, in an autonomous or self-orientated way, to monitor and develop metacognitive competencies related to the learning skills and acquired competencies.

Thus the process of topic aggregation into meaningful and cohesive learning units began by taking into consideration the multidisciplinary nature of GIS&Sc, leading to the adoption of a "broad field approach" [7], that aims to maximize the revisiting of topics and concepts in diversified contexts and through different approaches and problem perspectives. However this construction process of learning skills tried not to be bound to contents issues, which inevitably would create constraints for the continuity of the *Curriculum&Instructional Design*. In that sense specific learning goals were considered associated to the *Intellectual Processes Curriculum*, in order to identify the cognitive competencies to promote through the ongoing process of teaching and learning, as well as the possibility of exploring different pedagogical models, learning methods and educational resources that, in the context of the use of information and communication technologies in teaching, and in particular in distance learning teaching methods, assumes especial relevance. Thus it is thought that the variety of pedagogical and didactical models to be adopted in implementing the curricula may contribute widely to translate the fundaments of GIS&Sc into meaningful and relevant learning experiences.

6. The Integration of the Curriculum Components

Once the general methodology for the curricular design had been established, a database was developed in order to support the organization and management of a vast amount of information collected in the first stage of the project, as well as to enable a set of tasks to be performed in subsequent stages. Thus the current database design tries to provide an answer to the necessity of linking a vast amount of information in order to elaborate different units (and their subsequent aggregation into courses of study) which will embody the new curricular proposal on Geographical Information Systems and Science. The database model (Figure 4) enhances an integrated and articulated vision of the different areas underlying this curriculum concept, as well as its evolution or innovation in accordance with a broad and in-depth approach.

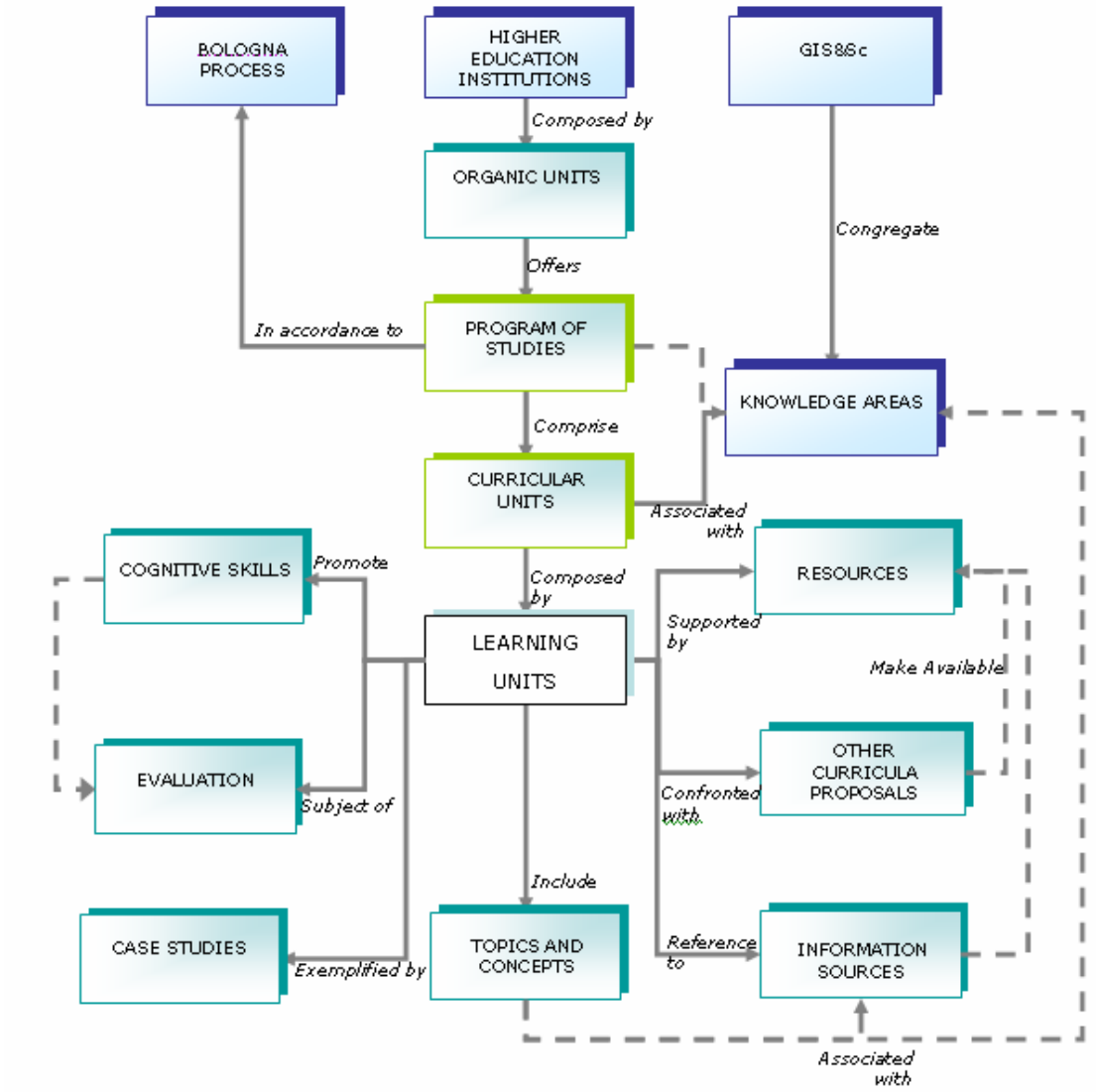

Figure 4- Conceptual Database Model

7. The Exploration of the Curriculum

In order to explore and expand the possibilities of the adopted methodology, in a third stage of the project, it was necessary to build up a repository of concepts connected with the general themes of GIS&Sc. The presumptions that led to the

definition of this strategy are linked to the previously enunciated objectives and reflect the need to frame the current curriculum development proposal, in a context of advancement of the information and communication technologies, which originated new teaching models pushed by new educational paradigms.

In fact the possibility of establishing multidimensional networks of concepts, through the construction of a repository of terms related to the problem in a given learning unit, increases a non compartmentalized and hierarchical idea of knowledge, by way of the establishment of semantic networks that tend to bring closer the association process and the mechanisms of knowledge exploration, to the ways human memory and thinking structuring and organization occur. As mentioned by Jonnhson [20] [21], semantic organization tools help students analyze and organize what they know or are in the process of learning, enveloping them inevitably in a process of critical reasoning regarding the subjects taught.

As put forth by the author, the two most common ways for semantic organization of knowledge are the databases and semantic networks tool. These last-mentioned tools sanction the construction of concept maps that are a method to represent information visually which not only facilitates the exploring of knowledge, the gathering and the sharing of information, but will also help the process of acquiring structural knowledge [22].

Miller [23] suggests that there are three singular characteristics in the Web environment that are relevant for teaching: the structure, the media and the communication. The associative, non-linear and hierarchic hypermedia structure of the Web, with unlimited capabilities for hyperlinking, is very similar to the associative human memory. The semantic network model of memory proposes a representation system composed by prepositions or concepts that are meaningfully connected. The relation between concepts in a non-linear and hierarchic way tends to form an organization of the human memory as a net. This structure reflects in the WWW, through its distributed hypermedia architecture, functions as an "associative memory", where the nodes (concepts) are tied in an associative, non linear and hierarchic manner.

Although there is a certain consensus between the cognitive memory models and the web structure, there are different visions about the application of this similitude in web base teaching. According to the goals of this project, a model of the way how the brain stores information is proposed, not only in the context of a web-based instruction, but also as an appropriate model for structuring and presenting information related to the components of the curriculum in order to support its development and implementation.

The singular characteristic of the media translates the nature of the information made available in the Web. In that sense Miller suggests the adoption of the term “hypermedia” instead of “hypertext” to translate the diversity, not only of documents or parts of documents, but of a set of means, such as illustrations, figures, animations, videos and sound. In teaching such means allow for more realistic and precise representations of information, in relation to the context of the real world, thereby producing meaningful and authentic teaching situations.

For obvious reasons, communication is particularly relevant in the context of a Web-based instruction. The implementation of new curricula will try to explore the synchronous communication tools, which facilitate real-time interaction in a virtual classroom environment, to achieve a bigger interactivity student/professor and student/student.

7.1 The Web Interface

The option for the development of a Web solution proceeded from the need to ensure that the faculty of the post-graduate course in GIS&Sc would have a set of adequate tools to organize, structure and put to practice their courses. Amid the current curricular design process, the commitment to develop a far-reaching e-learning curriculum that tries to be an answer to the identified challenges and opportunities, means that using Web technologies should not be limited to the processes of production, management, and course delivery, but should also be used in the student's perspective of trying to find the most adequate course for their own expectations and characteristics.

This technological solution has tried to take advantage of the two ways of exploring semantic organization of knowledge: through the association between a Web-based relational database and a visual data exploration tool. The solution presents significative advantages due to the dynamic integration capabilities and visualization mechanisms which are supported by knowledge-based tools for visual exploration of data that led to meaningful representations between entities, not perceptible in any other way.

7.2 Visualization Tools to support Curriculum Design and Exploration

The use of resources and tools associated with e-learning teaching models were analyzed in the perspective of the creation of an exploratory environment in which a student can construct less-constrained solutions and try out ideas without having a fixed path towards knowledge.

Therefore, the development solution for this project has tried to integrate some of the potential offered by the new tools of information visualization, which is founded on the establishment of ontologies, that may allow for the construction of interactive visualization systems supporting the instructional sequences design, and lead the students through the hierarchies of data and information process search, towards knowledge (Figure 5).

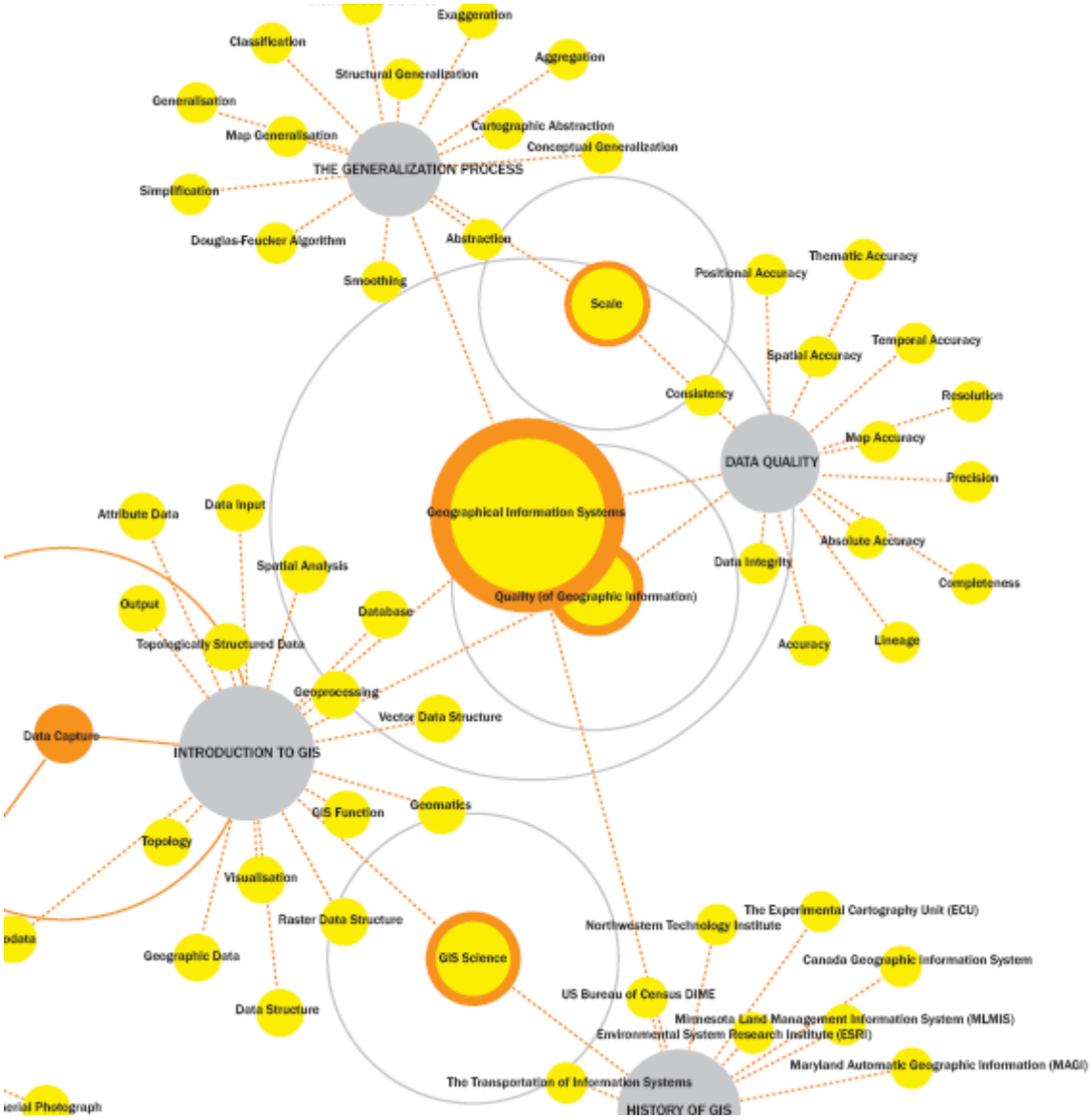

Figure 5– The Curriculum Visualization

8. Conclusions and further development

The achieved results translate some of the concerns related with the program contents, curricula articulation and integration and course organization and structure.

As mentioned by Gagné, Briggs & Wager [24] "a curriculum or course requires decisions about the sequencing of objectives; the goal of an educational institution is to establish sequences within courses that promote effective learning".

Nevertheless, if we take into account the scope and object of the project now being presented, the instructional sequences design responsibilities should be shared, in order to find more open solutions for a flexible management of curricula in accordance to the expectations and needs in education and training in the area of GIS&Sc.

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