The OrBITal Map: A New Design Tool for an Effective Representation of Knowledge Systems and Instructional Objectives

Gaetano Bruno Ronsivalle, Simona Carta, Marisa Orlando

WeMole s.r.l., Italy

0738

The Asian Conference on Society, Education and Technology 2013

Official Conference Proceedings 2013

Keywords: map, instructional design, knowledge, objectives

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1. Introduction: instructional designers and content analysis

When designing any kind of training program, you necessarily need to represent the new knowledge system that the learner will have to acquire at the end of the learning process.

Indeed, the content analysis is a crucial step during which instructional designers define and propose an interpretation of the mental model (according to P. Johnson-Laird's view) corresponding to the topic of the course. In other terms, they outline the logic and substantial architecture of the information to be acquired by the learners.

Everything starts with the analysis of the contents of the course. These contents are produced by experts and/or scholars; they are usually related to a general learning objective, but they are often shared without a pre-established logical order and in different formats (slides from face-to-face lessons, textbooks, clips, audio files, images and sometimes also hand-written notes). It is a transition process from chaos and confusion to an organized structure of information.

During this process, instructional designers read and analyze all these contents, select the distinctive concepts, start marking them according to their importance (main, dependent or correlated) and then connect them by explicit relationships. What do they do? With the goals of the course clear in their mind, they start to organize them according to a structure that will be the starting point for the design of the training program. Therefore, this activity is not limited to pure analysis and synthesis of content, but it is already characterized by a first reasoning on the instructional objectives and on the possible related teaching strategies to use. When instructional designers decide to structure the contents according to a specific hierarchy, to organize them in sub-groups, or even to break them into small pieces, they are already reasoning on the best way to support the learner's learning process.

What is the most suitable sequence to present information in order to effectively achieve the main objectives of the course? What are the contents that need to be broken into small pieces in order to support knowledge acquisition? What are the contents that should be considered "subordinate" (or only for additional reference) because they could generate a cognitive overload and then compromise the learning process? These are only some of questions instructional designers ask themselves during the analysis.

It is clear, then, that this initial step is not a simple textual analysis, but that many other aspects characterize it, when dealing with instructional design activity. We need a method of analysis that allows us to effectively and quickly analyze large amounts of content, but we also need a clear and concise way to represent the output of this analysis that can simply convey all the initial reasoning to the rest of the team (for example, content expert, other instructional designers or customer).
Is there a tool with all these features?

2.1. Tools for knowledge representation

Today instructional design teams, and, in general, teachers and trainers, mostly use two kinds of tools for knowledge representation: concept maps and mind maps.
Let us briefly analyze their main features.

2.1.1. Novak's concept maps

The concept map was developed in 1972, during a J. Novak's research project. It is a logical-visual and static representation of a knowledge system related to a specific content area. This structure is composed of concepts (represented by blocks of text enclosed in boxes or circles), that are linked by connecting lines (arrows), according to different kinds of logical relations made evident through linking words (verbs, conjunctions, etc.). The concepts are organized according to a hierarchical order, so that the most general and inclusive concepts are at the top of the map and the most specific and detailed ones below.

Cross-links usually complete the map, by connecting "far" concepts that are in different segments or belong to different domains.

Inspired by D. Ausubel's theory on meaningful learning, the concept map is very effective to represent and archive knowledge systems, but also to promote and evaluate learning.

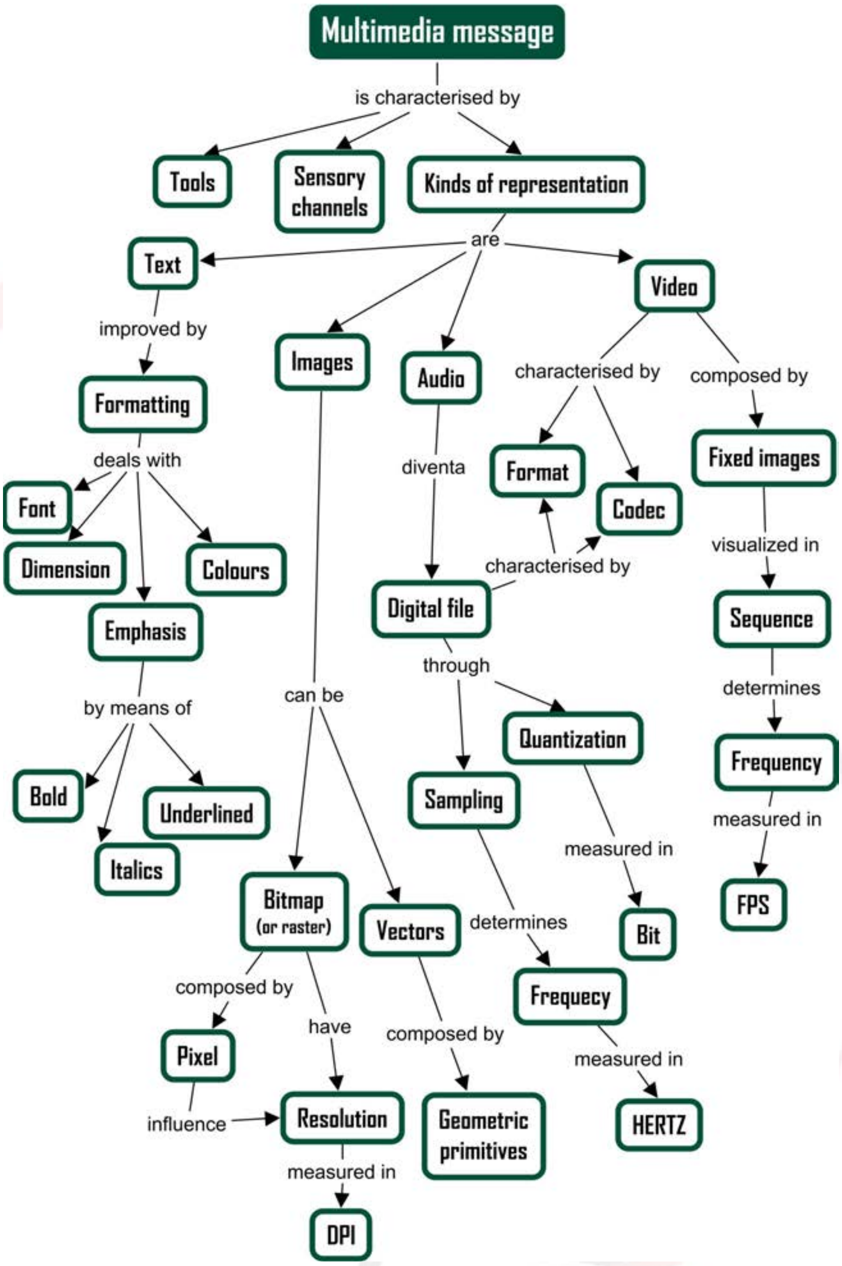

Fig. An example of a concept map

2.1.2. Buzan's mind maps

Mind maps are another interesting tool. Developed by T. Buzan at the end of the Seventies, mind maps are graphic representations of the associations that our brain makes between the concepts. They have a radial structure that starts from a central concept (preferably represented by an image) and spreads with main branches (curved lines) divided into sub-branches. On each branch, there is a concept, represented by an image or a key word. The map is even more appealing thanks to the use of colors.

This type of map "mimics" the radiant thinking and tries to reproduce the way the brain thinks and generates ideas. By virtue of this feature, it is an effective tool to support and facilitate creative thinking, learning and memory, problem solving, decision-making and many other forms of reasoning.

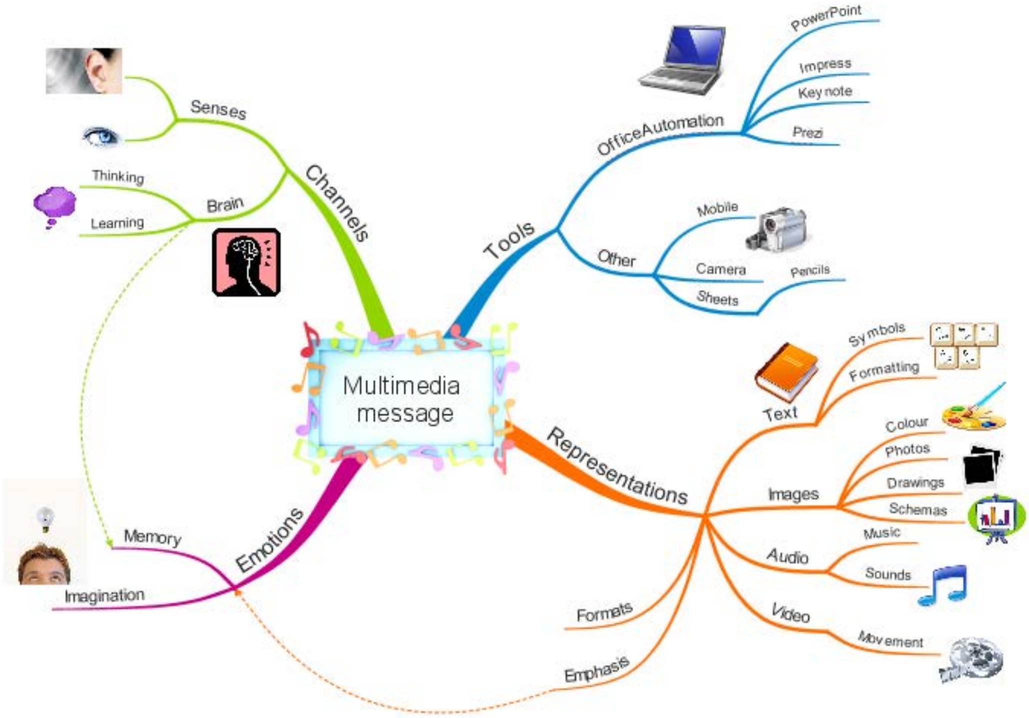

Fig. An example of a mind map

Since they were developed, these two types of map have been used with excellent results in many different fields, and they have considerably influenced the creations of other types of maps (like, for example, flow-charts or causal maps) or of hybrid forms (like solution maps).

Can they effectively answer instructional designers' needs, too? Unfortunately, only in part, and let us see why.

2.2. Shortcomings of the maps for instructional designers

Despite their visual impact, their ease of use and reading, these maps have some shortcomings if we think about the specific needs of Instructional Design. Let us examine the most relevant ones.

First: they are too much dependent on the subjectivity of their creator. This feature is extremely evident if we think about mind maps, where the representation follows the flow of mental associations evoked by each single concept. It is present also in concept maps, even if in a lighter form. Indeed, the experiences and prior knowledge of the person who designs them, his/her training path, way of representing reality and language influence the selection of concepts (in particular the secondary ones) and the choice of linking words.

Second: they are poorly oriented toward knowledge system formalization and ontologies construction. Indeed, they are hardly compatible with an effective standardization because they are too much dependent on the subjectivity of their creator. For example, the use of synonyms or the insertion of information and elements that are too much detailed or sometimes even unnecessary can compromise the whole architecture and make it seemingly more complex or difficult to access.

Third: they describe the relationships among the concepts; however, they are ineffective in representing their hierarchical structure. Indeed, these two types of maps give partial information on it. On the one hand, the concept map tries to make the hierarchy among concepts explicit by disposing them from the top down, according to Novak's guidelines. On the other hand, the mind map gives this information by representing the concepts on the same branches, with different sizes. In this manner, apart from their graphic appearance, this kind of information is difficult to formalize and get across, without requiring any further comments or explanations.

Fourth: they do not include instructional objectives that are usually listed in a different file. This division is insidious, because it can provoke a split between the two design activities of content analysis and reasoning on the possible structure of the related training program: a real dualism between knowledge and observable behaviors! The consequent risk consists in not thinking on the best teaching structure to promote the acquisition of those contents in an effective and creative way, but in following always the same process characterized by a too linear and didactic presentation of the information, and in the end reaching a foregone conclusion.

In the light of these shortcomings, for years we have been using maps that, even if defined as concept maps, already represented a synthesis between the two types of maps we have just described. Indeed, they were characterized by nodes, arrows and linking words (like concept maps), by radial shape and colors (like mind maps), and often enriched by numbers to show processes or the logical sequence of contents. Nonetheless, they still did not perfectly meet our needs.

That is why we decided to create a new tool that should be inspired by the good features of the existing maps, but also be able to fully meet all the requirements characterizing the delicate and peculiar activity of Instructional Design.

3. The OrBITal maps

The OrBITal maps are innovative maps, developed by a group of instructional designers with decades of experiences.

These maps are an effective solution to the problems we have described so far, because they allow to have a single output that gathers all the information instructional designers need to have in the initial phase of macro-design. Thanks to this tool, they can: 1) analyze, map and represent a knowledge system with graphics; 2) define the relationships among the different concepts and the hierarchical structure that ties them together; 3) identify the related instructional objectives, their complexity levels and, in an initial state, their semantic density, too. How is this possible?

"This concept orbits around that other one." This way of saying that we often use and hear in educational settings when talking about the relationship between different topics provided the inspiration.

It "orbits." Like satellites orbit around planets, planets around stars, star systems around other star systems.

Therefore, we drew inspiration from nature and decided to represent the knowledge system as a gravitational system. An open space where concepts are planets of different sizes, bound together by forces that push them on different orbits. A complex, distributed and netlike system, governed by rules, cause-and-effect and dependency relationships that "force" (or, rather, help?) us to follow well-defined routes in order to give everything a logical meaning.

3.1. The structure of the OrBITal maps

As in a real solar system, in the OrBITal maps there is a central *nucleus* (the Sun) that represents the main concept of the knowledge system to be represented. Around this *nucleus*, there are the planets (the other concepts) that orbit at different distances, according to the nature of the relationship that ties them to the *nucleus*. This relationship is expressed not only by the distance of the concept from the *nucleus*, but also by a logical operator on the connecting arrow.

On an orbit, there can be a single planet, but even many more. This second case occurs when there are concepts that are connected to the main *nucleus* by the same kind of relationship, and, then, can be considered like "brothers".

Sometimes orbits can cross one another, in correspondence to a planet. This happens if there is a "cross-link" between distant content areas and then, if that planet is simultaneously related to two different *nuclei*.

Moreover, orbits do not develop only concentrically around the central *nucleus*. Indeed, the general architecture can be enriched further because each planet in the system can be the *nucleus* of another solar system (a "secondary" one) and then be surrounded by further orbits and satellites.

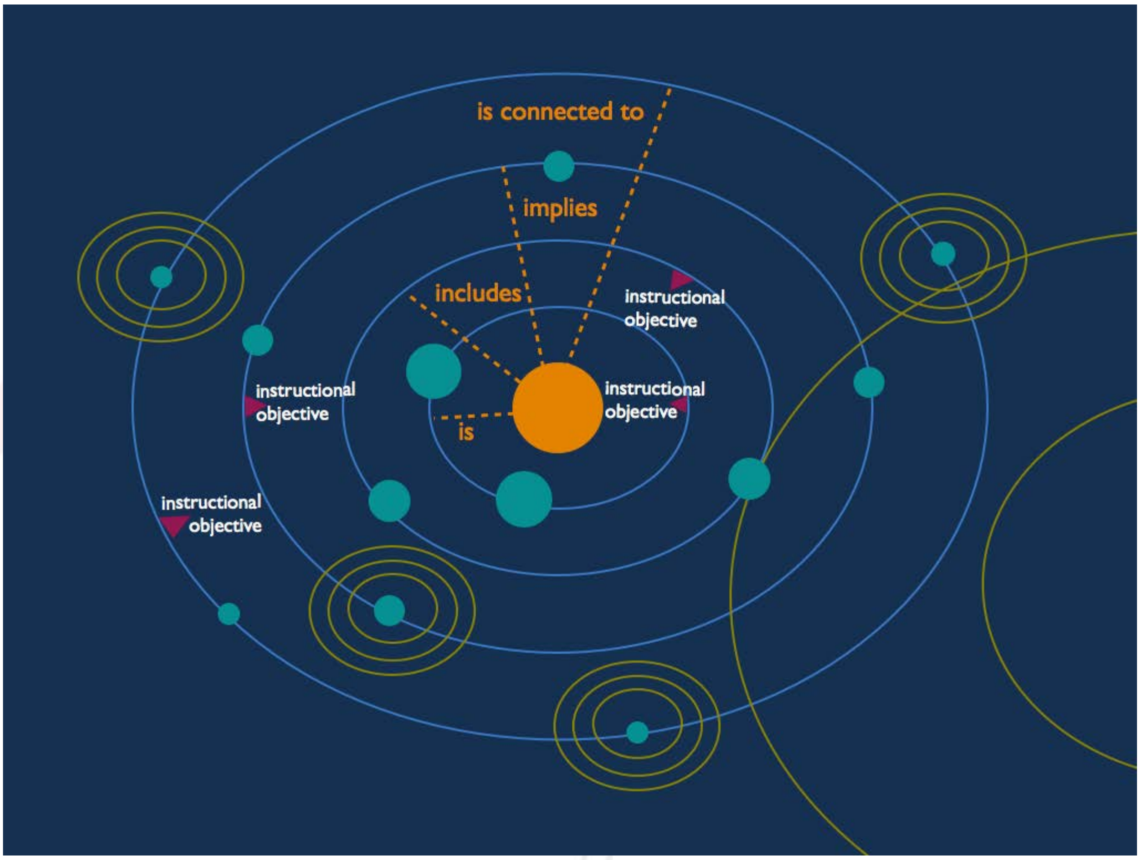

Fig. The structure of an OrBITal map

In such a structure, orbits play a fundamental role because they outline a real "semantic space" where there are two other crucial pieces of information: instructional objectives and complexity levels.

The objectives are the behaviors the learner will have to carry out in order to be considered competent on that portion of the map, represented from a *nucleus*, a variable number of planets and its related logical operators.

The complexity levels are defined according to Bloom's taxonomy and convey the complexity degree of the relationships among the concepts. They translate the information conveyed by the logical operators into "instructional" terms. Indeed, they communicate the cognitive complexity that is required to carry out that specific behavior and, as a consequence, they influence the choice of the teaching strategies.

Therefore, the OrBITal map is structured in a way that allows, on the one hand, to "take a picture" of very large and complex knowledge systems, with particularly detailed descriptive levels given by a variable number of systems and sub-systems. On the other hand, it allows to draw a learning path from the central *nucleus* toward the outer areas, with instructional objectives that show increasing difficulty.

3.2. Beyond the shortcomings of the traditional maps

How can these new maps overcome the shortcomings related to the use of the traditional maps that we have described before?

First: traditional maps are too much dependent on the subjectivity of their creator. With the OrBITal maps, we can solve the problem of the personal interpretation. Indeed, by using the logical operators, we can formalize and standardize some key steps in the process of map construction.

In concept maps, instructional designers can describe the relationships between two or more concepts by means of verbs or conjunctions that they freely choose and place on the various vectors. On the contrary, in OrBITal maps their choice is limited to one of the six logical operators available (i.e. *is, and, or, implies, includes, is connected to*). In this way, instructional designers do not start "from scratch": the logical operators provide useful tracks that guide them not only in the activity of description and explanation of the relationships, but also in the definition of the hierarchical structure and in the positioning of the different concept nodes within the system itself, thanks to the presence of the orbits. Consequently, the risk of generating many different interpretations from the same content structure is considerably reduced.

Second: traditional maps are poorly oriented toward knowledge system formalization and ontologies construction. The use of logical operators and orbits standardize the description of the relationships and guide the process of construction, positioning and organization of the concept nodes. In this way, we get maps that can be easily translated into ontologies, namely formal representations that, instead of using graphic elements, define a hierarchical structure of data by encoding it by means of semantic languages according to the laws of formal logic. Ontologies make knowledge systems understandable to computers, thanks to a language (OWL) that, in addition to content (data), conveys also information that describes the collection of data (metadata) and make their correct interpretation possible.

This last feature is certainly the most promising one. The OrBITal maps could be easily translated into ontologies, not only in order to "encode" the training programs, with all the information on their structure and related educational materials, but also to promote the "dialogue" between maps from different and apparently distant contexts. In this way, we could automatically create more complete and complex structures that go beyond the boundaries of the single "course" and that could be the track for professional growth or life-long learning paths.

Third: traditional maps describe the relationships among the concepts; however, they are ineffective in representing their hierarchical structure. On the other hand, the structure of the OrBITal maps allows displaying a lot of information that might otherwise remain in the mind of the instructional designer who created the map.

The position where a concept is unequivocally expresses the hierarchical relationship that ties that same concept to another one. For example, if the concept B is subordinate to concept A, then A will be the central *nucleus* around which B orbits. If the concepts A and the concept B have an equal relationship, then they will be planets on the same orbit. If the concepts B is related at the same time to concept A and to concept B by a cross-link, then it will be positioned on two orbits that reciprocally revolve around A and C.

That is not all. Even the size of the nodes gives an important information, because it conveys an immediate idea of the "distance" between the different concepts and the main *nucleus*. Therefore, as you move away from the central *nucleus*, the smaller planets will be the more "distant" ones conceptually.

Taking advantage of the reference to the orbital system, this visual "code" succeeds in conveying a large number of basic information, while keeping a great simplicity and representative clarity at the same time.

Fourth: traditional maps do not include instructional objectives that are usually listed in a different file. With the OrBITal maps, you have a single output of the macro-design phase that, in addition to the graphic representation of the knowledge system, includes also instructional objectives, complexity levels and semantic density.

As we have seen, the instructional objectives and the related complexity levels are positioned within the orbits. The semantic density is the quantity of information related to the instructional objective, and it is given by the number of concepts/planets positioned on the corresponding orbit.

With this single output, instructional designer have all the information to go ahead with the design activities at their fingertips.

4. A case description

Our team of instructional designers has already used the OrBITal maps in many training courses. Among them, the most interesting case concerns the one for the Universities of Verona and Salento (Italy).

Our goal was to design the course of Information and multimedia technologies for approximately 800 students from Training Sciences, Education Sciences and Childhood Pedagogy faculties (1st, 2nd and 3rd year). The project included the design of the teaching activities (lessons, labs and seminars), the teaching materials (documents, slides), the textbook and the final evaluation system.

The project showed some critical aspects in the beginning: the great number of students, only two months at disposal, and a team composed of instructional designers from different cities.

In such a situation, we really needed to generate and share a clear, simple and complete output that allowed each instructional designer to go ahead with the micro-design activities (design of face-to-face lessons, teaching materials, textbook and items of the final test) simultaneously with the rest of the team. The OrBITal maps were an extremely useful and effective tool to manage the project, ensure the achievement of all goals on time, maintain a very high standard and rationalize the work process.

4.1. The work process

How did we work? The process consisted of five main steps.
The first four ones did not follow a linear flow, but they actually carried out through an iterative cycle. Indeed, we repeated these steps as far as we reached a certain "balance" in the map. Only in that moment, we proceeded with the last step.
Let us describe the phases of creation of the OrBITal map step by step.

STEP 1. Concept selection

We started from the central *nucleus* of our knowledge system (GET, i.e. Foundations of Education Technology) and tried to collect all its related concepts. As in the case of a concept map, we started with a focus question (in our example, "Which are the concepts a learner has to acquire in order to have an adequate knowledge on the topic of Education Technology?") and we looked for answers in a first group of concepts collected on our worksheet. This focus question arose from the general instructional objective of the course: "at the end of the course, students will be able to list and precisely describe the various information and multimedia technologies used to support teaching, by adopting a scientific terminology and making a constant reference to examples, case studies and best practices in the fields of education, public administration and companies."

In this first step, we did not care about hierarchical relationships or uniformity in the levels of analysis among the selected concepts, but we simply followed the ideas and associations that came out from our minds, without a specific order or constraint, like in a classic brainstorming.

You can see the output in Fig. 4: a main concept/*nucleus* surrounded by many concepts/nodes, with the same size, positioned around it without a specific logic or order.

Fig. The output of the first step of concept selection

STEP 2. First concept organization in content macro-areas

The rough outline we got from the first step was our starting point to reason about the position of each node within the "system". We moved and organized the concepts so that the ones related to a specific content area were all close to each other. While trying to put everything in order and arrange a first draft of hierarchical structure, we put the concepts with a strong and direct relationship near to each other; on the other hand, we moved away the concepts with a weaker relationship.

In this way, we succeeded in identifying and making the content macro-areas evident, through the simple principle of contiguity: the closer the nodes, the stronger and more direct their relationship.

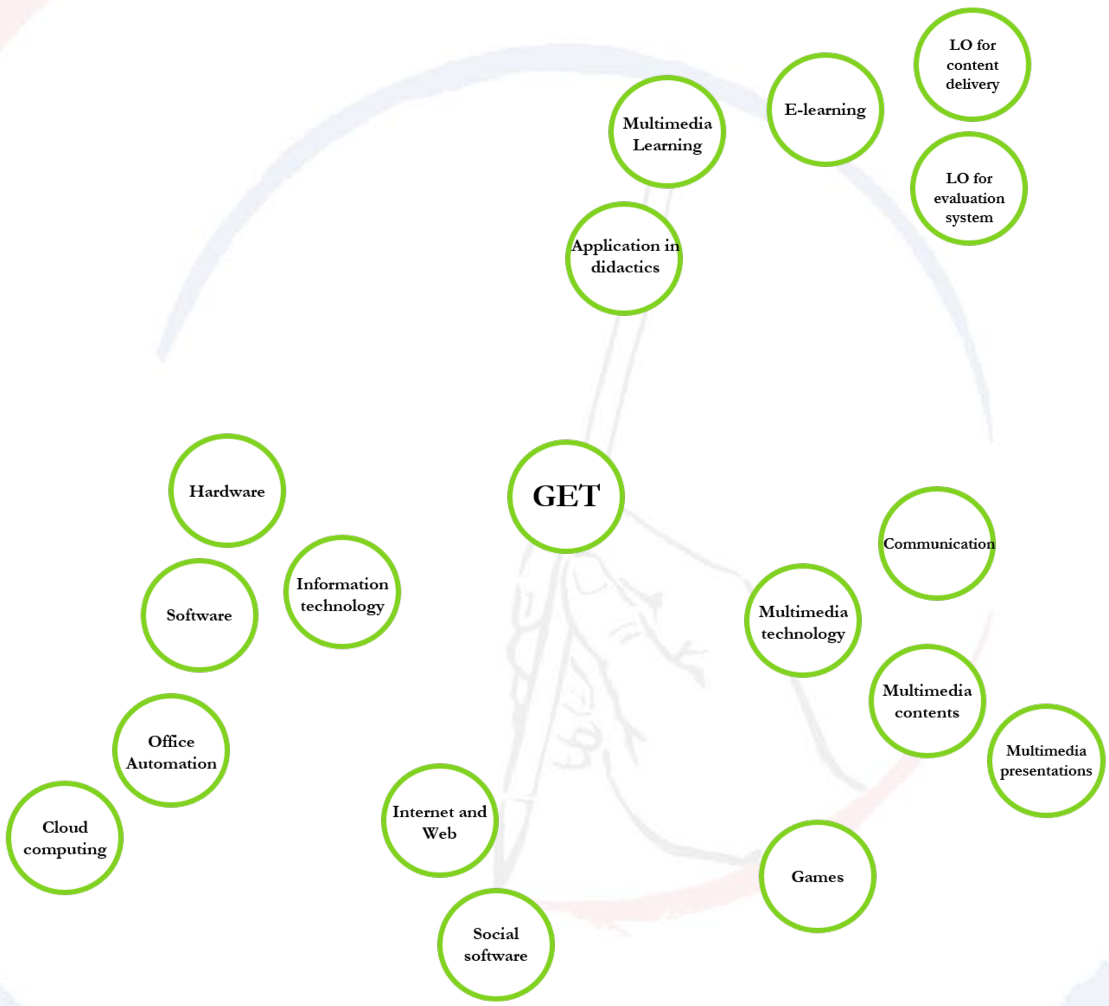

Fig. Concepts organized in content macro-areas at the end of the second step

STEP 3. Integration of orbits and logical operators

After the creation of the overall structure of the solar system, we focused on the description of the nature of the relationships among the various concepts. Indeed, the spatial arrangement of the contents, even if already quite clear in defining a first hierarchical and relational architecture, needed a more evident "meaning". For this reason, we decided to put some connectives in our structure, like the linking words in concept maps. They allowed us to make the logical connections between the concepts clear, and to avoid the risk of misunderstandings, especially when sharing information with the rest of the team.

Therefore, in each content macro-area, we inserted orbits at different distances from the related *nucleus*, and put the concepts on them. During this activity of "sorting" and positioning of the various concepts, we added a logical operator on each orbit in order to make the relationship between the concepts much more clear. We chose the logical operators from a fixed list, adequate, in our opinion, to express the main logical relationships between concepts.

Logic relationship	**Standard term**	**Explanation of behaviour and objective**
IS	is	He/she is able to define a concept
IN ß	includes	He/she is able to define the relationship between two distinct element
OR	or	He/she is able to define the relationship between two distinct element
AND	is connected to	He/she is able to define the relationship between two distinct element
IF THEN à	implies	He/she is able to define the conditional connection between two elements

Tab. 1. The logical operators used for OrBITal maps

The choice of the logical operator inevitably influenced the sequence with which the related orbits were positioned around their corresponding *nucleus*. Therefore, if the orbits describe a "strong" relationship (e.g. "is" or "includes"), then they are much closer to the *nucleus* than the orbits with logical operators of "weak" relationships (e.g. "is connected to" or "implies").

In this way, we succeeded in further detailing the hierarchical structure of contents, by distinguishing or merging the different concepts according to the type of relationship they had with the corresponding *nucleus*. This distinction is evident also graphically: sizes change according to the position of the nodes.

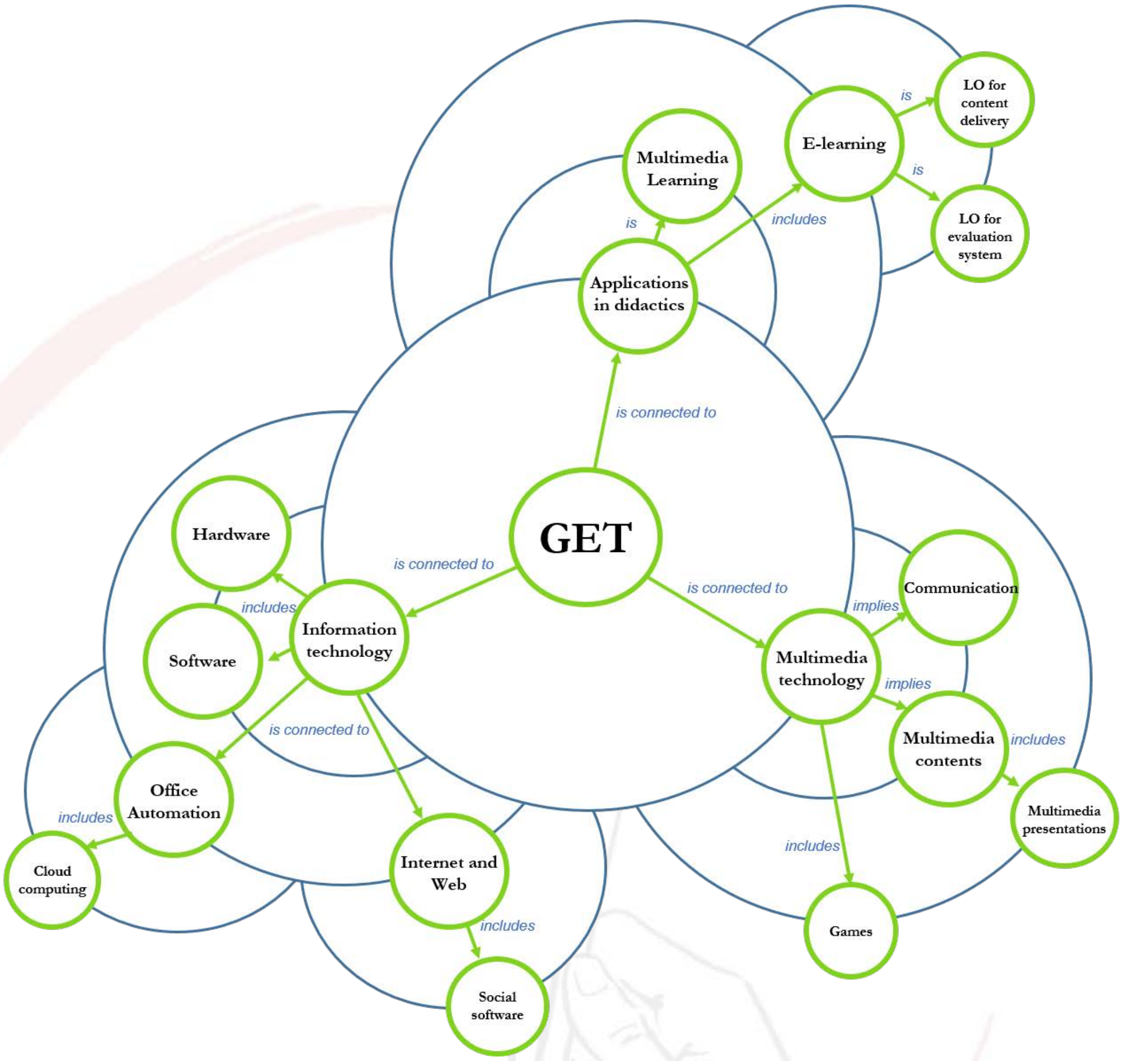

Fig. Concepts, orbits and logical operators at the end of the third step

STEP 4. Revision and reconfiguration of the positions

At this point, after defining the concepts, making all their relationships explicit and putting them within the system according to a precise order, we needed to stop for a while. We realized that our map needed a revision, a sort of "calibration". Therefore, in this step, we analyzed it again, identified the "flawed" areas and then made all the necessary corrections to make the system more stable and balanced. In general, most of the revisions concerned the following aspects: 1) we inserted new concepts that filled some "conceptual gaps"; 2) we eliminated the redundant concepts, sometimes by merging similar nodes; 3) we put new cross-links by adding further orbits, where we found out some missing connections.

This step was characterized by an iterative cycle of the steps we have described so far. Only when our map reached a certain balance, showed no "conceptual gaps" or repetitions, and had a coherent, solid and logic structure (also to the content expert's eyes), we went on with the definition of the objectives in the last step.

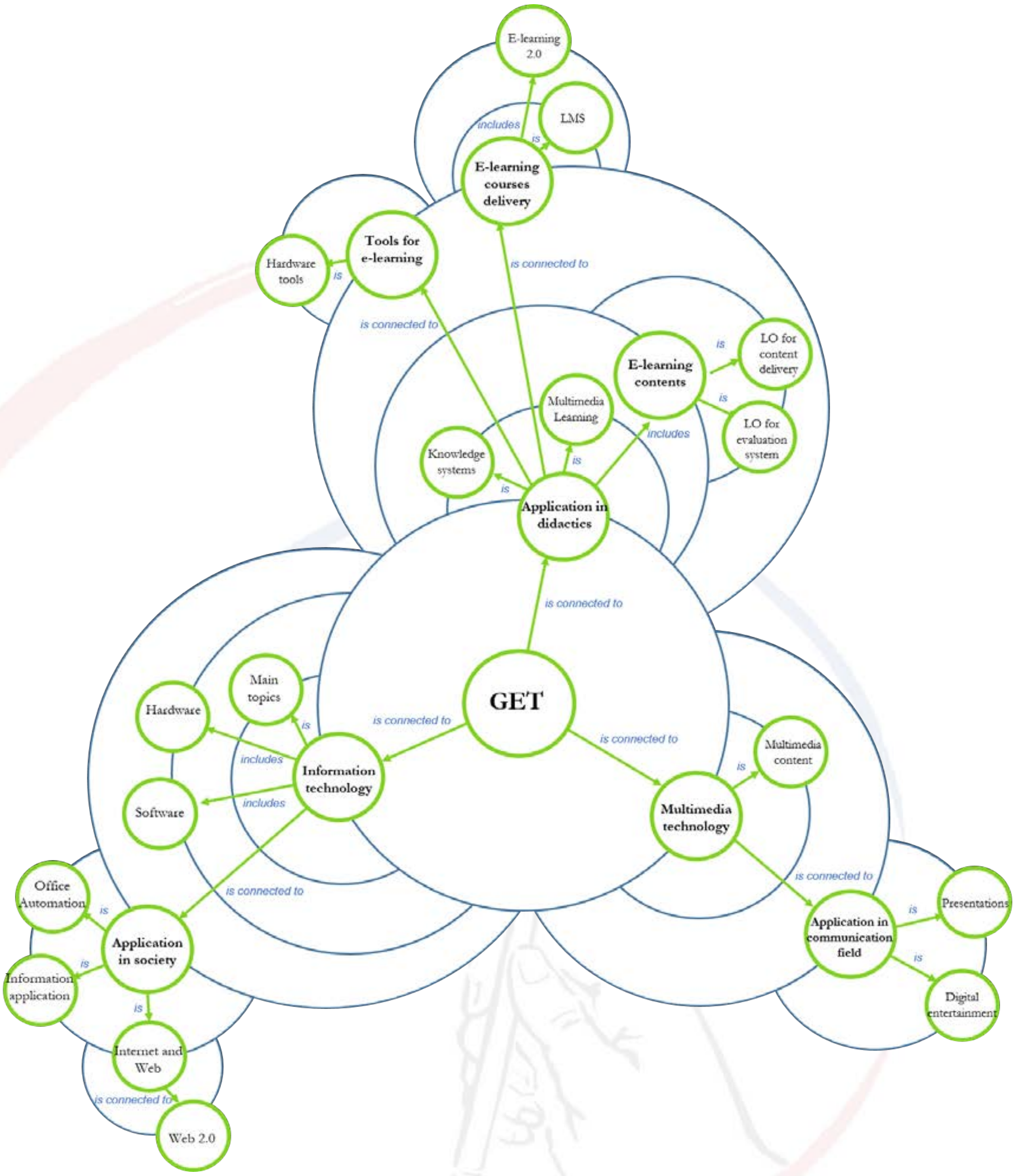

Fig. The map after the revision at the end of the fourth step

STEP 5. Definition of instructional objectives and complexity levels

After organizing our orbital system, we started thinking about the way a competent learner could move within this space and show us his/her acquisition of knowledge on that structure of contents, by performing some specific behaviors. Therefore, by taking inspiration from Mager, we defined the instructional objectives, in terms of observable behaviors.

With the OrBITal map in hand, the definition of clear, effective and measurable objectives was easier to do. Indeed, orbits and logical operators provide a sort of implicit guidance in choosing the behaviors to be measured. In this way, we started from each *nucleus* and while moving to the outer orbits we defined the objectives that marked the way to the furthest areas of the map.

In correspondence of each instructional objective, we then put the complexity levels, by reasoning on the required cognitive activity, according to Bloom's taxonomy.

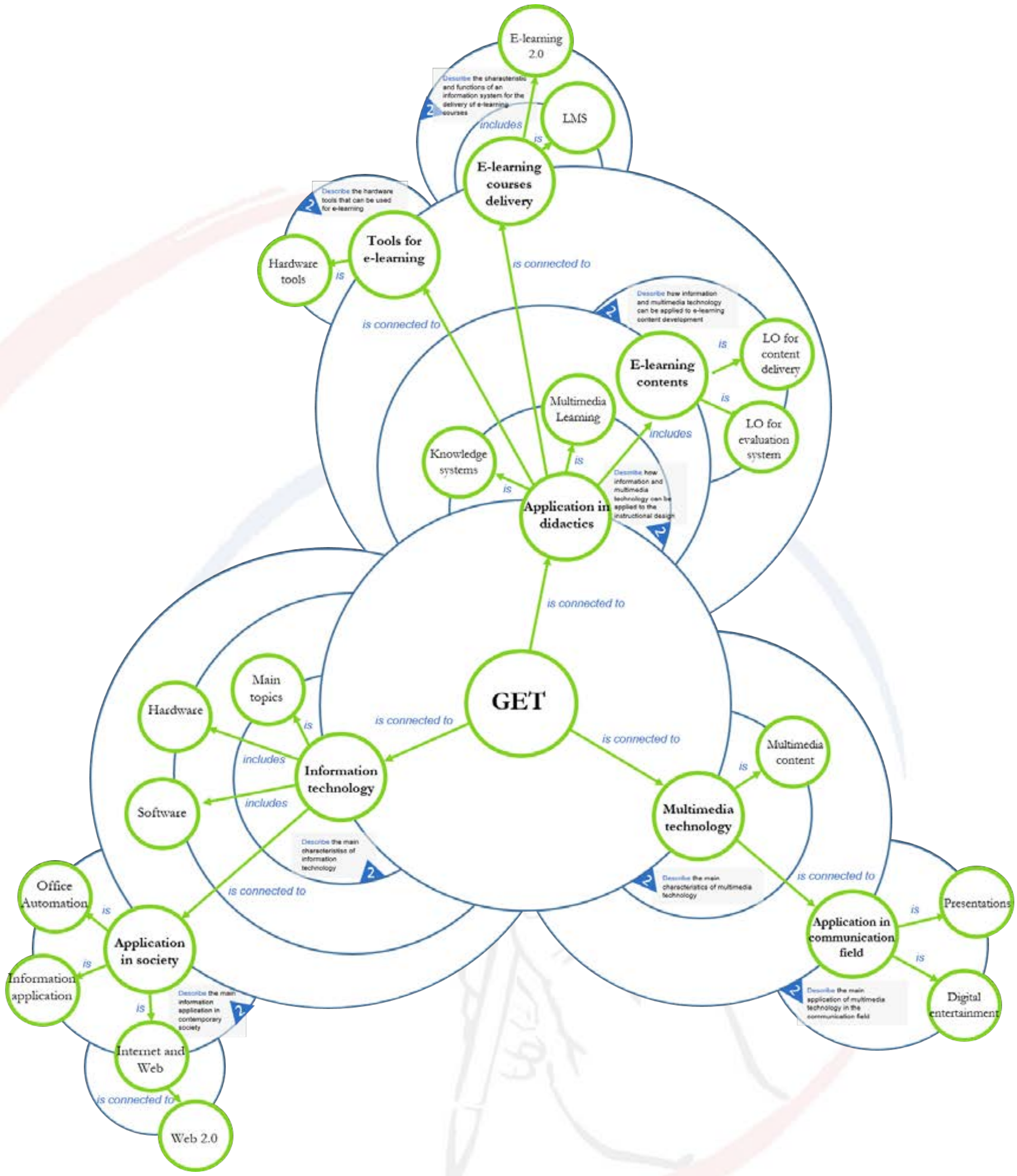

Fig. The completed OrBITal map

4.2. The final output

This work process allowed us to optimize the design times and to reduce the number of outputs in this first phase. Instead of a concept map of the contents and a list (or tree) of instructional objectives, where the correspondence between the various elements often results unclear, we had a single and clear output with all the information we needed: the representation of the knowledge system together with its related structure of observable behaviors.

The OrBITal map facilitated and reduced the time of macro-design and helped instructional designers focus on the design activity with a more holistic, creative (in fact, by reasoning on a non-linear structure, it is more natural and simple to search for new training solutions) and effective approach.

This output simplified also the organization of the micro-design activities: instructional designers could work simultaneously by focusing on specific content areas and their related orbits.

Moreover, in order to simply share the map with all the members of the design team, we used Prezi, a cloud-based software for presentations. This software was particularly suitable for the creation of the OrBITal maps, not only because it lets you share the map online and collaborate with other people simultaneously, but also because it lets you explore the worksheet in a very effective way. Indeed, thanks to Prezi innovative interface (called ZUI, Zooming User Interface), you can arrange textual and graphic elements in a large space, similar to a giant whiteboard, and then move freely in all directions, from overview to the smallest details, thanks to zoom in and zoom out functions.

Among the tools currently on the market, Prezi is the best one to navigate in the space of our OrBITal maps.

5. Conclusions

The results of these early applications show some of the strengths of the OrBITal maps in the instructional design process.

The first benefit relates to the capacity of the OrBITal map of expressing in a schematic, but surely creative, way a set of decisions on what is important and what plays a marginal role in the economy of the course. These maps are an effective tool to identify, select, organize and represent contents, thematic areas, theoretical issues, relationships of dependence, logical implications, in other terms, the core information that are important for the learner to know. Without letting the instructional designer's subjectivity too much free, thanks to the use of standardized rules and logical connectives.

Secondly, with the OrBITal maps, instructional designers can outline with precision a set of explicit and/or implicit recommendations on the nature of prerequisites, i.e. the information the learners need to know before starting the course, in order to understand the topics of the lessons. This property is crucial during the macro-design of the training program, the selection of the different target groups and the integration of preparatory modules for a homogenization of the initial knowledge.

In addition, unlike Novak's concept maps and Buzan's mind maps, the OrBITal maps integrate knowledge systems and instructional objectives of a course into a single output. In particular, they map in detail what will be evaluated in terms of observable behaviors, of "things" that the learners should be able to do in order to demonstrate their comprehension and acquisition of the right information. With a significant impact on the choice of the measuring tools and different tests.

Fourth, the OrBITal maps provide precise information to instructional designers to set the limits of a training program, and influence the strategies and the tools to be adopted. Indeed, the hierarchical structure of the contents and the logical and functional architecture of the instructional objectives guide the creation of teaching materials, the methodology and the entire flow of activities characterizing the course in a strong and direct way.

In the end, we should remember that knowledge does not appear like something isolated or pulverized, but like a “system”, that needs to be described in an aggregated way. In this sense, the netlike dimension of the OrBITal maps allows to represent information in a systemic form, by reproducing the relationships among concepts and instructional objectives, according to a descriptive logic oriented to the details and particularly adequate – both in epistemological and operational terms – to the variability and complexity of knowledge systems.

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