Learning Objects: an approach in engineering education in a cognitive perspective

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***Abstract* - This paper presents the methodology underlying the teaching of Descriptive Geometry according to a cognitivist approach. This teaching methodology is based on the Ausubel's Assimilation theory or meaningful learning, a theory which cornerstone is the student's prior knowledge. Meaningful learning is a process by which new information relates to relevant aspects of the individual's cognitive structure. The implementation of such methodology required modifications in the organization and presentation of course content, teaching procedures and didactic resources selection. The approach that uses learning objects contributes with the cognitive perspective, therefore it allows offering educational materials differentiated, in minor or greater granularity, using different types of digital resources, taking care of the necessities of the students. The learning objects are developed in the hypermedia learning environment, called HyperCAL GD on-line. The insertion of the information and communication technologies resources together to the new learning theories has brought great contributions for the improvement of the quality in engineering education**

Key Words- Cognitivist approach, Descriptive geometry, Hypermedia learning environment, Learning objects.

INTRODUCTION

The Descriptive Geometry consists in a conceptual base needed to student's formation in several courses, among them the different engineering courses. The subjects that compose this conceptual base besides of being rigid about the teaching methodology utilized, also is based on mass-produced educational materials. Therefore becomes difficult to deal in different ways with the specifics of the courses regarding to the interdisciplinary character of these contents in the different curricular programs.

However, has been noticed a quest for changes, aiming to restructure the education process of the engineering graduation courses, especially with the introduction of computation resources and use of information and communication technologies (ICT's). In consequence of the introduction of these technologies, the conventional education systems need to transform teaching methodologies and work process organization, benefiting from the experiences of distance learning regarding to the utilization of non direct methodologies.

Therefore, stands out the importance of investigating new pedagogical approaches supported in learning theories, which in conjunction with the introduction of these technologies could bring significant changes to the teaching process in order to improve learning of Descriptive Geometry.

THE COGNITIVIST PERSPECTIVE – MEANINGFUL LEARNING THEORY

According to [3] the teaching-learning process can be explained by models based in theories coming from different knowledge areas, such as biology, psychology and sociology. Specially sociology, through positivism had and has strong influence on the educative process. The pedagogical methods represented for the teaching-learning relation are guided for an epistemology and are made evident in the pedagogical practice through a process that can focus the teacher, the student or the relationship between teacher and student. These models characterize, respectively, the directive pedagogy, non directive and relational, having direct consequences on the construction process of knowledge. The model of relational pedagogy presents itself, in practice, through a cognitive approach that emphasizes cognitive processes and scientific investigation. According to this approach, the education includes research, investigation and problem solving, not just the transmission of knowledge, demonstrations and model applications. The fundamental aspect of education is the construction of knowledge, through process and not through learning products.

For [9] several theories conceive learning and education as an interactive process, through which the character builds up its own knowledge, offering different alternatives with regard to how such process is produced. Among these theories can be highlighted the meaningful learning theory developed by David Ausubel. This theory considers the learner's intellectual construction related to the usage of concepts as organizers of new information. Thus, this new information acquires significance for the learner and contributes to consolidate and develop the existent cognitive structure. The meaningful learning consists in relate new

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knowledge to the prior knowledge or prior experiences, including them in a coherent way organizing knowledge into the learner's cognitive framework. Thus, the factor that influences the most on learning is the prior knowledge that the student possesses.

In the learning context of descriptive geometry, the learner's cognitive framework corresponds to the knowledge of concepts and organization of ideas that one possesses in this particular knowledge area. Therefore, it consists in a system of concepts in a hierarchical organization, in which more specific knowledge elements are related to broader concepts. In this system, [8] consider learning and relation, or remaining of logically meaningful material, are influenced by three variables, as follow: availability, differentiation and stability of the learner's ideas in the specific knowledge area of the subject. Availability refers to the existence of relevant ideas in the learner's cognitive structure serving as inclusive concept for the new material. Corresponds to prior knowledge, its organizational properties, and also, to the learner's cognitive development, or suitability of cognitive structure to the learning activities. Differentiation, regards to learner's capacity to distinguish the new material from prior knowledge, seeking to establish the difference between them, in order to produce meaning for the new concept. And, the stability and clarity of the ideas make possible to remain information in memory and the reutilization on learning new knowledge meaningfully related to the inclusive concepts in the long term memory.

For [1] meaningful learning includes key aspects as: concepts formation and assimilation, progressive differentiation of concepts and integrative reconciliation. Concepts formation corresponds to the internalization of concepts produced through a spontaneous and inductive way, based on specific contextual experiences and through discovery learning, or as a problem solving procedure. It Consists in discover the defining attributes of objects through observation, involving selective analyses, abstractions and generalizations for the concepts formation. Respectively, in the conceptual assimilation that occurs on reception learning, the criterial attributes of concepts are presented by the teacher, allowing the learner to establish relation, differentiation and integrative reconciliation with the previous concepts already available in his cognitive structure and attach meaning to the new material. This process is carried out through explicit definition of relation between ideas, assimilating differences and similarities between them, and reconciling real or apparent inconsistencies.

Considering the specific knowledge area of descriptive geometry, the development of concepts is facilitated when more general ideas (concepts more inclusive) are introduced initially. And then, through a progressive process, the ideas are introduced, distinguished by its details and specificity. This process of progressive differentiation establishes conceptual hierarchies in the learner's cognitive structure, allowing the concepts to acquire more and more complexity.

Reference [8] state that the majority of concepts is acquired by the learner through reception learning. In this sense, the Ausubel theory contributes to make significant this sort of learning. Therefore, it is the active student involvement, its cognitive activity that differentiates the reception as a personal re-elaboration, from the one that consists in a repetition. Considering that concept assimilation requires interfacing (by supplying criteria attributes) in order to permit a process relation, differentiation and integrative reconciliation with the previous student concepts (internalization of concepts in the cognitive structure), it makes evident the relation of the pedagogic poles in the education process.

In the learning context, [12] consider the intentional manipulation of relevant attributes of the learner's cognitive structure can facilitate the meaningful learning by reception. This occurs through identification of concepts and propositions more wide-ranging of the subject, and identification of the principles (progressive differentiation and integrative reconciliation) utilized in the sequence of the contents for the organization of learning material. This way, the meaningful learning theory has important educational implications referring to: the learning methodologies and evaluation, the strategies to be implemented for reception learning, and the utilized resources.

EDUCATIONAL STRATEGIES AND PROCEDURES FOR MEANINGFUL LEARNING BY RECEPTION

From the educational planning point of view, the educational resources should be prepared based on the characteristics of each educational unit of the subject. Reference [4] presents the previous organizers and the empirical supports, as educational strategies and procedures important for meaningful learning by reception.

Previous organizers are introductory materials, relevant and inclusive, used to facilitate learning of a specific content or subject unit. They offer an overview of this material, but don’t consist in summary or introduction (which doesn't present conceptual hierarchy: generality and inclusiveness). They act as a cognitive bridge between student prior knowledge (includers) and the new contents, facilitating learning. This strategy is utilized when the conceptual relation doesn't establish itself in a clear and direct manner for the student. When the subject unit is not very familiar to the student is utilized an expository organizer, constituted by relevant concepts and propositions, in a superior level of inclusiveness close to the new material. When the subject unit is relatively familiar to the student a comparative organizer is utilized to offer a conceptual structure that serves as an anchor and enhances differentiation of the new learning material with similar ideas available in the student cognitive structure, which could generate learning conflicts [4]-[12].

The empirical supports, in general, are related to tangible elements of reality around us as genuine objects or figures representing them. Words expressing particular examples or attributes of a concept also are empirical support adequate for learning abstract propositions and secondary concepts. In case of learning the relations between secondary concepts expressed in a complex proposition, the teacher must be sure that the student know these concepts. Just then, presenting the empirical support, assisting in the comprehension of relations between the secondary concepts by the student, who is entering in a whole new and complex learning field [4].

The expository class is a learning strategy substantially valued by Ausubel's theory, bringing subsidies to the human communication theory, establishing that the emitter's message should get to receptor with some meaning to be relevant, not being just a mere information transmission. Considering the principles of meaningful learning, one's should verify the existence of prerequisites or subsumers concepts, to allow the utilization of written materials containing the necessary concepts to the new content, acting as a previous organizer for each class. It should be verified, as well, the necessity of using the empirical support, which in conjunction with examples and illustrations of the concepts should follow the content sequence. During the expository class, the principles guiding the meaningful learning theory should be observed.

Considering the importance of the principles worked in Ausubel's theory, which has a great explanatory power and breadth in the areas of learning and cognitive human development, also contributing in the organization of education, [13] elaborated techniques based on this theory. Among them, stand out the conceptual maps, which represent a reference system for the preparation of learning material facilitating meaningful learning by reception.

According to [12], the conceptual maps are diagrams presenting the concepts and hierarchical relations between them. These relations are significant and established in form of propositions, expressed in lines connecting concepts included in the maps, shown in Figure 1.

Superordinate concepts, more general and inclusive

Subordinate concepts, intermediate

Specific concepts, less inclusive, examples

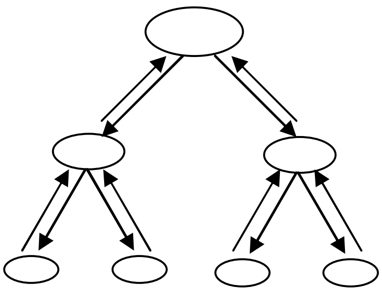

FIGURE 1
A MODEL FOR A CONCEPTUAL MAP.
FONT: [12]

The conceptual map presents a hierarchical form, but it is a resource that can be utilized in bidirectional movement. For this, learning should be organized in such way that could allow the exploration of relations included in the map, promoting integrative reconciliation when a new piece of information is presented. Subordination occurs when learning a new concept or proposition that can be related to more inclusive and relevant concepts, existent in the student cognitive structure. Superordinate occurs on learning a new concept or proposition that can include relevant ideas, less inclusive, present in student cognitive structure.

The conceptual map is a pedagogic resource assisting the learning process. It offers to the teacher a way of planning and organizing activities directed towards a meaningful learning using the student prior knowledge. It helps the student to be conscious about his own personal constructions based on the explicitness of prior knowledge, aiming to establish relations with the new knowledge, restructuring the cognitive frameworks and schemes already existent.

According to [12], conceptual maps are instruments capable of:

- highlight the conceptual structure of the concepts on a subject or unit, and the role of conceptual systems on its development;
- showing that concepts of a subject differ regarding to inclusiveness and generality, and presenting these concepts in a hierarchical order of inclusiveness, facilitating their learning and retention;
- promoting progressive differentiation, explicitly exploring relations between propositions and concepts, stressing meaningful similarities and differences and reconciling real and apparent inconsistencies.

Another contribution of this technique for the learning process refers to development of the student's ability in establishing relations among concepts when drawing his own conceptual maps, besides the possibility of discovering mistook ideas of a concept [8].

TEACHING DESCRIPTIVE GEOMETRY UNDER A COGNITIVIST PERSPECTIVE

Descriptive Geometry presents a long curricular history in higher education, especially in engineering and related areas. Reference [2] when analyzing some aspects of the Brazilian engineering education at 19th century, realized that the intellectual world was organized under positivism influence, which treats scientific knowledge as a last and necessary instance to achieve the intellectual intentions of the human kind. According to [7], in the positivist model, perception and induction are fundamental elements in educative process, being necessary the teacher's intervention in this process to structure student's educative experiences. The teacher assumes a central role, being responsible to indicate learner's perception to obtain the expected results. Thereby, the importance of classes organization to achieve the pedagogic objectives and discipline (behavior), considered as necessary to learning. The positivist perspective considers knowledge as a result of direct observation of the concrete experience, not intending investigation via experimentation.

For [14], studying Descriptive Geometry requires a knowledge base of elementary Geometry at two and three dimensions. Therefore, using definitions, concepts and properties impose a deductive sequence in order to study this subject. Also, [10] point out that learning Descriptive Geometry, most of the time, is centered in an axiomatic method and correct terminology, as the geometry deductive structure. Spatial and Plane Geometry are under influence of Hilbert's axiomatic method, which establish point, line and plane as its three basic geometric elements (primitives), as well the relations established among them. The set of 21 axioms are the fundaments which all Euclidian Geometry theorems are proved by. These theorems are obtained from the axioms, which are accepted without proof and demonstrated with logical principles. While in Euclides, geometry eliminates experimental procedures e creates an interface on reading the reality with geometric elements and their properties (geometric figures), in Hilbert, geometry eliminates geometric figures and establish the axiomatic method [5].

In general, the learning methodology of Descriptive Geometry still is performed by traditional means with expository classes, manual drawing instruments, following teacher instructions with a text book as reference. This methodology is sustained by the axiomatic method hindering the student learning process, due to the absence of the object on his studies. The axiomatic method make impossible investigation of objectivity from the perceived occurrences in the object, because sustains itself in the level of primitive geometric elements which have a metaphysical nature. Thereby, for each worked concept exist different meanings and procedures developed by the students. These results don't really reflect the desired meaning to the referred concepts. The same object could mean anything for each student, not being then self indicative. Therefore, every student presents his own understanding and solution, however, without reaching the production of scientific knowledge due to a lack of objectivity [15].

As stated by [15], in the traditional approach of teaching Descriptive Geometry, the elementary psychological processes involved refer to the perception and imagination. On perception, the object is what is presented to the character (an appearance), in this case is represented in two-dimensional form by its mongean projections (quadrants), physically the object is absent (Figure 2). To comprehend this object in its three-dimensional form the student have this perception sustained by a reason (axiomatic theory). Thus, is in the imagination, implying a relation between the imaginative conscience and the "object in image", that the student moulds the understood object. Therefore, the "object in image" being ruled by spontaneity of student conscience, allow changes on this object that wouldn't be physically possible (in case of the presence of the object).

Then, [15] state that the Descriptive Geometry learning inconsistencies could be related to axiomatic theory as well as the absence of the object in analyze. As Descriptive Geometry is fundamentally spatial (three-dimensional) with a certain degree of complexity, it requires procedures and learning resources more adequate for its better understanding. That's why, teaching this subject limited to using just mongean projections of the objects becomes very difficult.

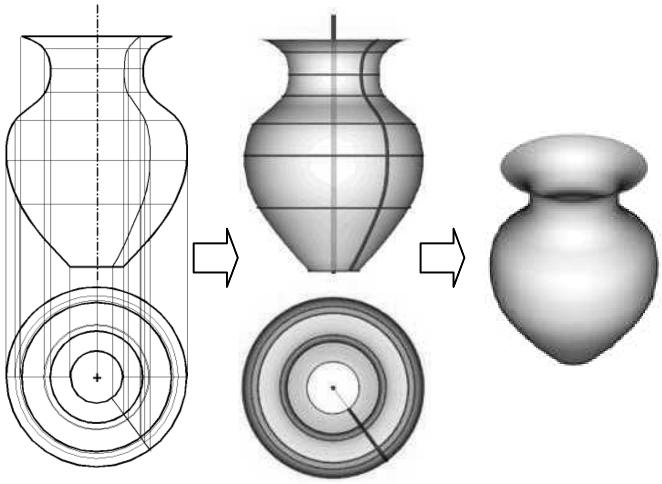

FIGURE 2
TRADITIONAL EDUCATION: STUDENT IMAGINES THE OBJECT FROM ITS PROJECTIONS. FONT: [16].

Answering this need, HyperCAL^{GD} was developed in a way to offer a wide range of resources (virtual reality models with animations, non-interactive animations, illustrations, and contents using a hyper textual form). The virtual models utilized on this computational environment are an economic alternative in relation to real models, and mainly, an add-on to the use of mongean projections of the object. Therefore the virtual models can be visualized from any point of view, allowing a better comprehension of the object. These resources work like empirical supports.

HyperCAL^{GD} is a hypermedia environment for Descriptive Geometry learning that has been developed by UFRGS teachers, forming a research group called Virtual Design (ViD), which the authors are members. The first version of hypermedia environment begun to be used at 1999 in the ARQ 03320 subject – Descriptive Geometry III. At that time, it was still in a direct learning mode. This first version presented limitations regarding to its usage by the student, that in order to use HyperCAL^{GD} in his personal computer, he should download the system to his machine. This used to cause inertia on utilization of available contents for learning and limitations in the control of education process. Facing this limitation, the research done by ViD and the demands for a system more interactive pointed to use information and communication technologies in developing an internet version of HyperCAL^{GD}.

While in the traditional learning methodology the line of reasoning is done from abstract to concrete, HyperCAL^{GD} allows the inversion of this reasoning. The student can understand the tri-dimensional object in details, build plane projections of the object, and from them, solve problems related to its properties.

Figure 3 presents the potentiality of HyperCAL^{GD} in offering the didactic resources already mentioned, assisting the student on understanding the objects and graphic operations involved. In this example, the intersection of a plane with a toroidal surface is studied. Only after the student knows the object and understand the problem in case, the object will be presented through its orthographic projections in order to be solved.

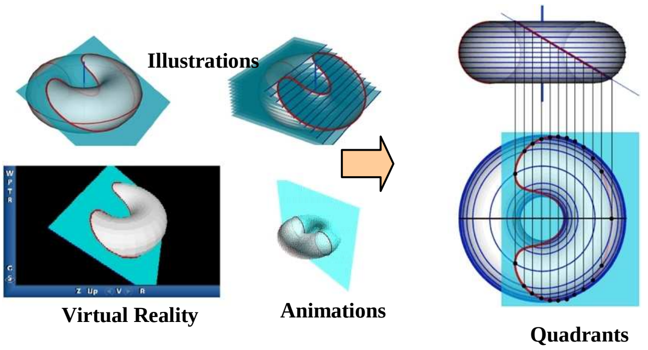

FIGURE 3
HYPERCAL^{GD}: KNOWING THE OBJECT AND REPRESENTING IT IN PROJECTIONS. FONT: [16].

In accordance to [15], HyperCAL^{GD} utilization in Descriptive Geometry learning brings the possibility of an objective interface, it assist the student on understanding the object through the synthesis of its mongean projections. Being so, hypermedia environment contributes to rescue the objectivity (using virtual reality models and animations) on producing knowledge in Descriptive Geometry.

Besides the utilization of HyperCAL^{GD} environment, [15] proposed alterations in organization of contents presentation, intending to improve meaningful learning by reception. It was necessary to adopt a planning process of coherent learning with a cognitive approach. This process followed the model proposed by [11], presented in Figure 4.

Following this model, the introductory tasks deal with the determination of conceptual and propositional structure of the subject; with identification of subsumers (relevant concepts) that should be present to learn the content; and also deal with mapping the student cognitive structure. The conceptual structure and identification of subsumers were established from the subject contents analyze, representing the structure through a conceptual map. The student cognitive structure was mapped through tests of written association of concepts, graphic association of concepts (conceptual maps) and, tests of prior knowledge.

The organization and expositions of the subject concepts followed Ausubel's propositions (progressive differentiation and integrative reconciliation) and the dependency relations among the many units. The first classes had a wide-ranging and introductory character. The previous organizers technique has been used in many classes, treating the subject in a general level, reviewing concepts already known and relating them to the new concepts. This technique allows positioning the student in the global context of the subject. Besides of previous organizers, it is also used conceptual maps to integrate the subject contents.

The utilization of HyperCAL^{GD} was facilitated by its hyper textual form (hyperlinks), allowing a non linear navigation, therefore, can be used with any organization defined by the teacher.

The evaluation of learning and teaching occurred alongside the whole process. At the beginning, it is determined what the student already knows (mapping the student cognitive structure) intending to prepare the adequate previous organizers to the student learning process. During the whole time, evaluation goes along with learning process, being able to correct, clarify and consolidate the mechanisms in order to occur meaningful learning. At the end of the process, the evaluation verifies the efficiency of the teaching strategies utilized, also the organization and order of the contents in order to feed the process back and make necessary corrections.

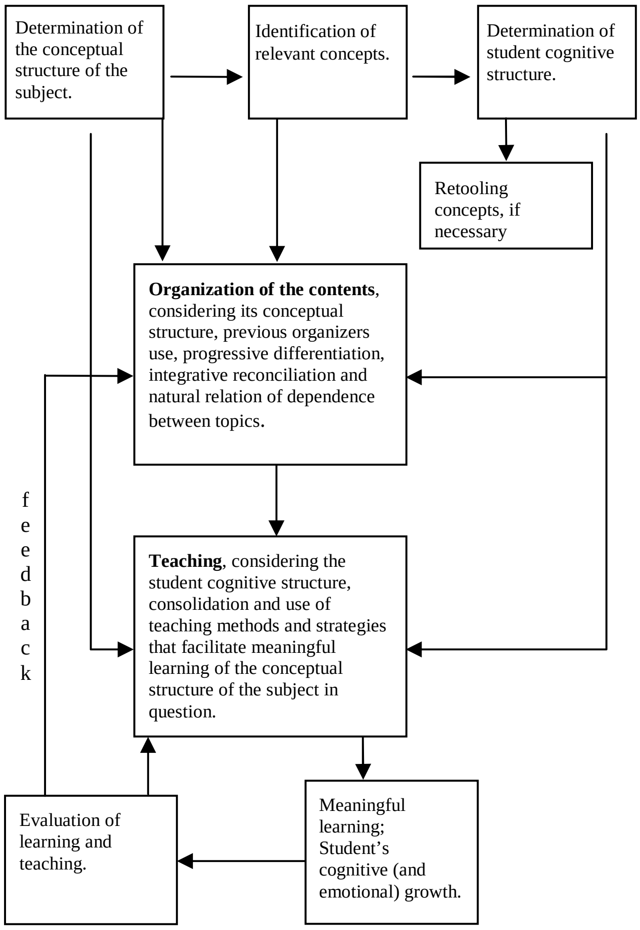

FIGURE 4
MODEL TO ORGANIZE LEARNING ACCORDING TO AUSUBEL'S THEORY. FONT: [11].

As shown by [1], meaningful learning will lead to increasing relevant subsumers in the student cognitive structure, improving the problem solving capacity once progressive differentiation and integrative reconciliation of the concepts has occurred. The learning evaluation will be a function of the quality of existent or developed relevant subsumers, and also of the learning motivation. Transferring knowledge to new problem solving situations it will be a function of the reached level of concept differentiation, superordinate learning and integrative reconciliation.

THE HYPERCAL^{GD} ON-LINE ENVIRONMENT

HyperCAL^{GD} on-line doesn't consist of a closed and static tool, because its main content is centralized and stored in a data base with dynamic access and constant actualization via internet. The content pages are dynamically generated, getting text, images, models and animations from the data base. The generation of these pages is done by a set of general parameters that considers the theme topics and objectives. The development of HyperCAL^{GD} is aiming to include specific parameters of each user, considering his prior knowledge, rhythm and learning style.

The HyperCAL^{GD} on-line environment has tools of synchronous and non-synchronous interaction. In non-synchronous mode, the discussion forum allows the student to formulate questions regarding to the concepts developed in class, receiving the teacher answer. And in synchronous mode, the discussion about the topics of the contents is done via Chat.

Looking at the learning methodology of Descriptive Geometry through the cognitive approach, which needs to determine the conceptual structure of the subject and the student cognitive structure, it was developed a tool in Java language, to build conceptual maps, that is integrated into HyperCAL^{GD} on-line environment. This tool allows visualizing the conceptual map using graphic representation and an XML file.

The conceptual maps made by students with assistance of this tool are stored in the data base of HyperCAL^{GD} on-line environment, allowing monitor the learning performance of the students from the conceptual relations established in the maps. Therefore, the introduction of this tool in the learning methodology has permitted an additional resource in the learning evaluation.

This way, the cognitive perspective demands a dynamic learning plan, facing the individual necessities of the student, verified from following his learning. It is up to the teacher to prepare previous organizers that meet student demands. From this point of view, the learning objects can contribute to the flexible production of these materials.

THE LEARNING OBJECTS

Learning objects are educational materials built from the adoption of the strategy utilized in the object oriented methodology. These materials created with multimedia and hypermedia interactive resources made more effective the education environment supported by information and communication technologies (ICT's).

The “learning objects” expression has been chosen by the Learning Technology Standards Committee (LTSC) of the Institute of Electrical and Electronics Engineers (IEEE) to describe the minor instructional components, consisting in any material utilized in a learning process based on technology.

Reference [20] adopted a narrower concept, being as “any digital resource that can be reused on learning support”. These resources are delivered through the net on demand, and they can be little or big. Examples of minor digital resources include digital images, input data, live or recorded videos, text, animations and little applications delivered on the web. Examples of major digital resources are: entire web pages combining text, images and other medias or applications to deliver complete experiences, as a complete instructional event.

Based on the object oriented approach, some concepts of learning objects stay limited to the technical aspects of this method, linking some characteristics, such as self-contained objects and modules that can be ordered or combined. Reference [19] consider the necessity of incorporating pedagogic ends to the educational material. Thus, they define a learning object as a digital file used to reach pedagogic ends, which has, internally or through association, suggestions about the appropriate context for its utilization.

In accordance to [18], the learning object corresponds to a little piece of information that can be delivered on-line. Where each one of these objects is self-contained, allowing the student to achieve a specific performance objective. Therefore, learning objects must be well structured, being composed by three elements:

- The learning objective is the root maintaining a instructional order, presenting to the student what he will be able to learn, and what is the prior knowledge necessary to have a good performance in the study;
- The instructional content support the objectives and promote the realization of learning results, including a combination of text, graphics, video, animation, etc;
- The practice and feedback permit the learner to verify his performance in relation to the objectives and expectations, evaluating his success and allowing to remedy his performance using the object as many times as needed.

Reference [17] adopted the taxonomy suggested by [20] on the production of learning objects to Descriptive Geometry, being made learning objects (images, animations, virtual reality models, text) fundamental to several worked concepts in the subject. And, from them, the combined learning objects were developed according to the model proposed by [18], compounding the class units. The development of combined objects was oriented by the conceptual structure of the subject, allowing build learning objects in different granularities from the relation established among them, as presented in Figure 5.

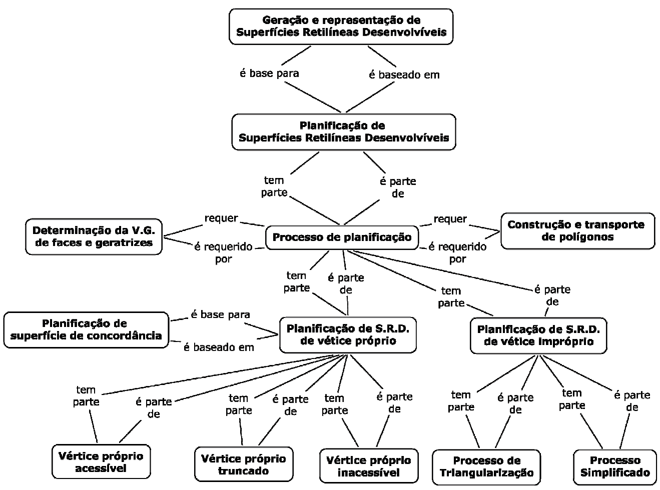

FIGURE 5
CONCEPTUAL MAP FOR THE CONSTRUCTION OF COMBINED OBJECTS.
FONT: [17].

Beside these three elements integrating the main structure of combined objects, additional elements were added to it, as prior knowledge and specific examples to the graduation course of the student. The learning objects were generated dynamically in XML files and stored in the data base of HyperCAL^{GD} on-line, as shown in Figure 6 [17].

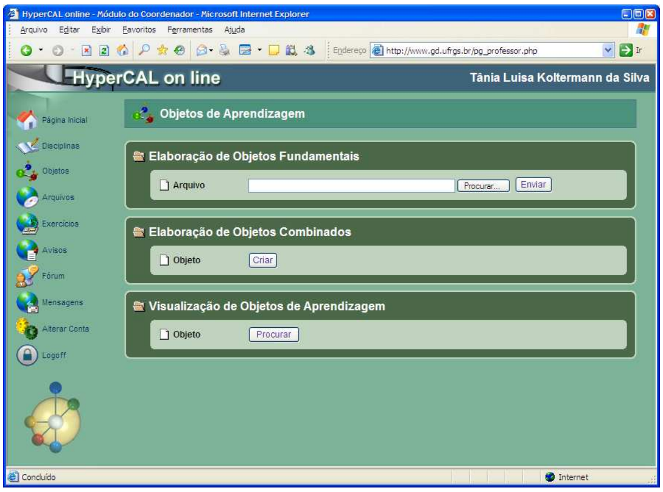

FIGURE 6
DEVELOPMENT WINDOW OF THE LEARNING OBJECTS.
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Aiming the interoperability using standards for storage and distribution of learning objects, metadata consist in storing necessary information for indexation and searching, corresponding to a complete description of the learning object. The objects can be recovered by search engines or utilized by Learning Management Systems (LMS) compounding the learning units.

In the scope of this work it was used the specification Learning Object Metadata - LOM [6], that proposes attributes organized in categories compounding the metadata structure. Besides the attributes suggested by LOM, some information were added to the learning object metadata related to the graduation courses which is destined and related to the characteristics of the learning style of the student [17].

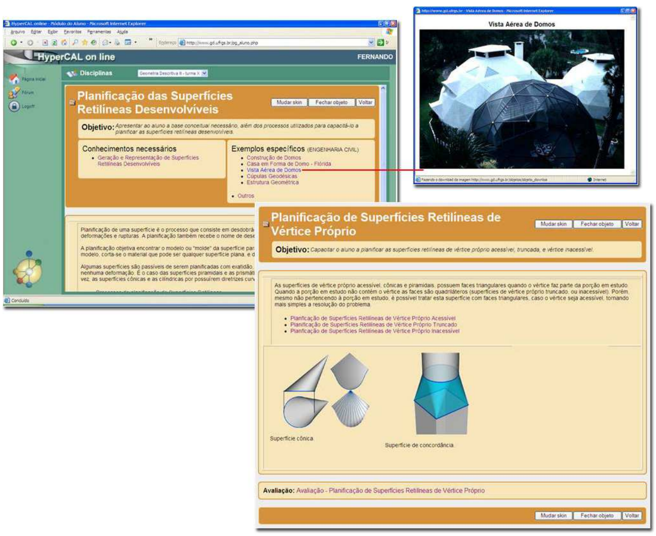

FIGURE 7
LEARNING OBJECTS EXAMPLES. FONT: [17].

When the learning object is presented to the student, the system requires the following information from him: name; learning style; graduation course and preferred skin (in case of not having any preference, the object is presented with standard skin).

Depending on the learning style of the student, the combined object is presented in a learning direction from concrete to abstract (showing first examples and applications, and just then, approaching the concepts). The same structure of combined objects takes another presentation form to the student that presents the learning direction from abstract to concrete (being first worked the concepts to later show the examples). Beyond that, each learning style has a preference in the presentation order of the examples, where the student can choose among skin options to customize the visualization of learning objects. The presentation form of learning objects for the student on HyperCAL^{GD} on-line environment can be seen in Figure 7 [17].

FINAL CONSIDERATIONS

The adoption of the cognitivist perspective on Descriptive Geometry education highlights the conceptual relations in the student cognitive structure that can be verified through the conceptual maps developed and meaningful learning propitiate a better performance on solving problems graphically.

The introduction of HyperCAL^{GD} on-line in the learning methodology of Descriptive Geometry represents the possibility of working the subject concepts with the objectivity offered by the utilized resources (images, animations, virtual reality models), assisting on the comprehension of the concepts developed in the subject and on the graphic operations used to solve the problems.

The learning objects approach brings great contributions to the Descriptive Geometry learning in accordance to the cognitivist perspective, allowing the student to adopt a proactive posture, being sensible to his necessities and learning preferences. The systems using learning objects are benefited from the potentialities offered by ICT's that allows changes in the way the educational materials are designed, developed and delivered to the students. Therefore, making possible the customization and personalization on the engineering education process.

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