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LEARNING AND PRACTISING BASIC DESIGN CONCEPTS. A KNOWLEDGE MODEL

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1. Introduction

Teaching as knowledge transmitting -data, rules, techniques and skills- between different persons, is one of the most classic and basic knowledge based activities. The teaching process, at its most traditional form, represents transferring knowledge from an emitter -the teacher- to a receiver -the learner-. This later is not at all a passive element; received knowledge is transformed by the student, adapting it to his/her personal characteristics, reasoning psychology and personal skills. The same objective knowledge is instantiated differently -using alternative formats- by both the teacher and the student, as shown in figure 1. A large part of this knowledge is not only factual, even operational for different matters (as CAD). All these characteristics are analyzed in depth by the cognitive psychology and related disciplines.

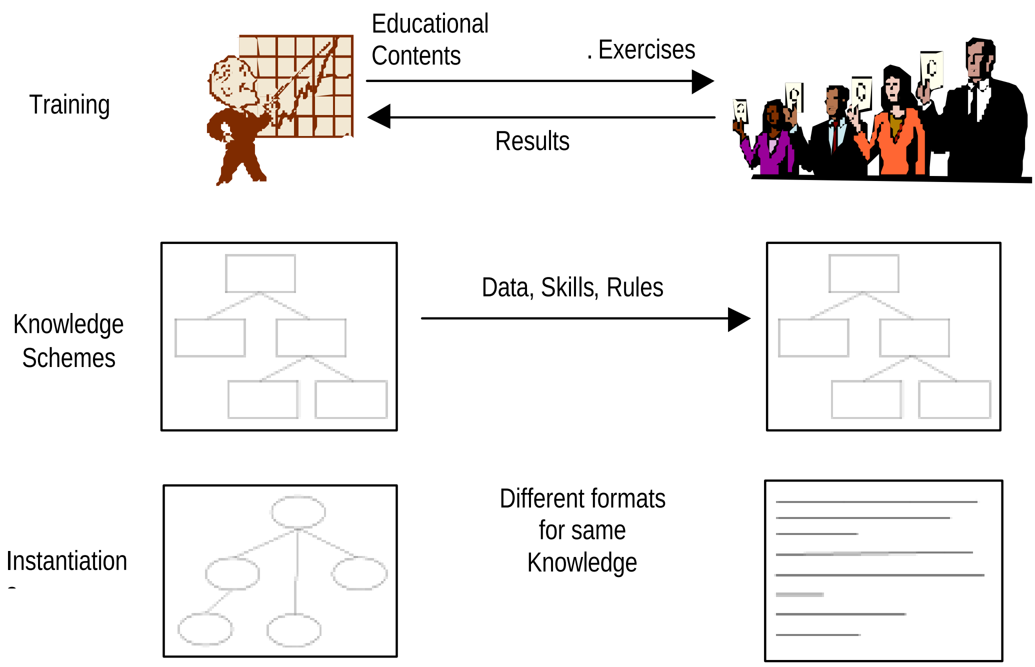

Figure 1. Knowledge interchange during the teaching process. Schemes and instantiations

Actually, with the massive implantation of Internet, one of the most active work lines of the educational informatics is the development of powerful and flexible training systems into the web. In this way, one of our work lines is formalizing the knowledge models used by the emitter, the teacher, in order to include into the web systems some of the teacher managing and customization abilities. Anyway, a full substitution is, from our point of view, extremely difficult because the large quantity of empirical knowledge used, the psychological reactivity and the effect of the human relation in order to motivate the student.
In this work, we have formalized the knowledge used by the teacher assembling three main models:

1. A matter model.
2. A model of the learning process.
3. A student model.

The first one, the matter model, supposes the existence of a block of knowledge specific of the design processes (and the use of the CAD tools), organized as a set of schemes, which specific format is a personal instantiation of the matter knowledge by the teacher. An adequate model generates comments as "the teacher had good knowledge of the matter" by the students (later, when they have improved their perspective). This model is composed mainly by domain knowledge elements (general schemes and specific models) and it is the same for all the different students.
The second model, or learning process model, is related with the pedagogic techniques used by the teacher. This requires clear objectives, a work schedule, some auxiliary materials and a clearly defined set of methods. The pedagogical model is matter dependent; we do not use the same pedagogical tools to teach geography, mathematics or CAD. When the students comment "…he/she knows about the matter but he/she does not explain fine…" , the teaching model is not adequate. Most components of this model are included into the task and methods models.
The third model, which is relative to the student, is associated with the adaptation of the pedagogical process to the specific characteristics of the students. It is linked to the learning process model, representing modifications of this later. Using an adequate student model shows a reduction of the number of not integrated student, in the sense of obtaining good academic results, because of lack of motivation, previous knowledge or skills. This model is composed mainly by domain knowledge elements.
Actually, great efforts are been done into the academic and industrial field in order to ameliorate the presentation tools and the accessibility of the information to the student, improving technical aspects as the connection rates, multimedia and network capacities of the systems, user interfaces and/or presentation standards (all of them associated to the computer systems and user/interfaces). In our case, we consider that it is equally important to improve the knowledge models of the course matter and the educational process, covering the three knowledge dimensions of the classic teaching process.
Our objective is to deepen into the three knowledge models of the teaching process in order to implement web educational systems. In this sense, we propose the development of flexible systems using a methodology based on the formal modeling of the three knowledge subsystems and the dynamic selection of methods. In this work, we present the matter model developed for the teaching of a course of CAD for engineers in our University. This have been modeled with an extension of the formalisms included into the CommonKADS methodology.

2. Methodology

In order to implement powerful and flexible tools for the teaching into the web, we propose to apply these principles:

1. *It is possible to model the teaching activity as a knowledge-based process.* We start with two main knowledge models: a) a model of the learning process, as the set of pedagogical techniques used by the teacher with a group of present students, and b) a model of the matter that it is explained to this group. These models are formalized (in our case, restricted to the basic concepts of CAD) using the techniques and representation systems of the knowledge engineering [Schreiber 2000], and specifically those of the CommonKADS methodology [Schreiber 1994] [Fensel 1998]. In our case, when the student learns the fundamentals of

CAD, he/she acquires, mainly, skills related to the use, refinement and developing of problem resolution methods.

2. *Different teaching alternatives can be modeled as possible problem solving methods*. For a given teaching area, as the basic CAD training, it is possible to develop alternative methods, taking account of: a) different basic models of the matter (as the models of resolution of problems using programs of [Stepien 1993] or those of [Hartman 1996]), and b) the knowledge and skills demanded to the student (knowledge about the domain and the problem, and the modeling, strategic, syntactic, semantic and communication skills).
3. *It is possible to develop, for each matter, a simplified model of the state of the student.* The different states of the student, which are defined taking account of its initial intrinsic characteristics (as its capabilities) and the abilities acquired during its learning process (as the acquired skills), are represented via a "student model", which is formalized using the user modeling techniques developed for the user-interface systems [Shneirderman 1997] [John 1994].
4. *The selection of the teaching method can be done using an automatic selector, which uses the elements of the student model as suitability criteria during a process of dynamic selection of methods*. A good option to implement the selection of the methods to use during the web teaching process is using the dynamic selection of methods used with diagnostic [Benjamins 1992] and design problems [Motta 1994] [Bienvenido 1999]. The specific characteristics, behavior and evolution of the student (as an individual) that are formalized and stored into the student model, condition the decisions, using in our case a multicriteria selection function. Requiring some skills in order to enter into some learning steps, as handling correctly the syntax for defining elemental objects in an specific CAD tool, it is possible to block (using suitability criteria of the type "necessary") the entrance to more advanced methods (as, for instance, using dynamic structures).

In our case, using de referred techniques, we have develop a knowledge model for the teaching of the fundamentals of Computer Aided Design. This model has been assembled using the experience acquired with previous courses at the University of Almería. This model has been developed using CommonKADS and it has been used in order to develop new handouts for these courses and on-line tutorial system of the course.

3. Matter model of CAD

This section resumes the characteristics of the knowledge model of the matter, in this case the "Introduction to CAD". We have defined a basic schema, "CAD Fundamentals", composed by the aggregation of different elements, which are mainly concepts, mathematical models, relations and rules.

Figures 2 to 5 show the basic concepts about CAD included into the model of the matter (design fundamentals) as aggregate structures (using the CommonKADS notation). These are refined later as more simple concepts, mathematical models and rules. All the elements are classified basically as context knowledge (general definitions and the global work framework characteristics), methodological knowledge (theoretical fundamentals as the set of design principles and CAD basic concepts) and operational knowledge (circumstantial aspects as the specific tool syntax and work environments). This root classification of the design knowledge is specified in figure 2.

Design context knowledge, which initial structure is shown in figure 3, includes CAD related definitions (concepts of design, industrial design, CAD, CAE and CAM) and the general concept of work paradigm (composed always by sets of steps, activities, technologies or methodologies, and tools). This is a general description without details of the matter and its engineering environment. This submodel presents the greater level of abstraction; it is related to the work fields and the most general work formula in engineering.

The methodological knowledge, presented in figure 4, includes a specific paradigm of design (useful when using CAD techniques), a proposal for the design project, and the fundamentals of the CAD technology (named as basics of CAD tools). This later part includes the characterization of the CAD tools and the basic concepts they implement usually (as layers, blocks or attributes). This block of knowledge about *CAD tools basics* represents the general knowledge about CAD, independent of any tool we could use. It presents a second level of abstraction about the design techniques and the processes CAD involves. Anyone developing a CAD tool would require using this specific block of knowledge.

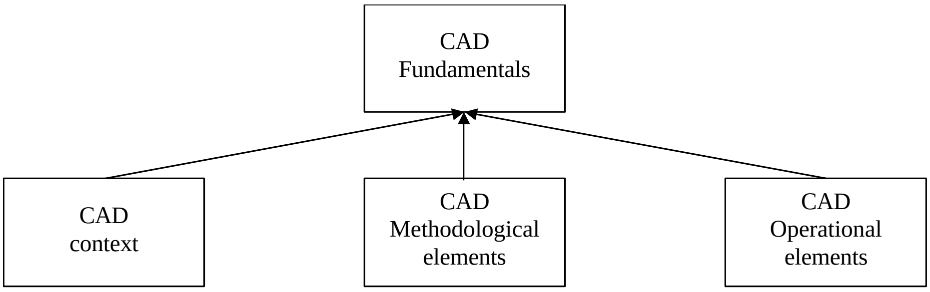

Figure 2. First level knowledge elements of the matter model

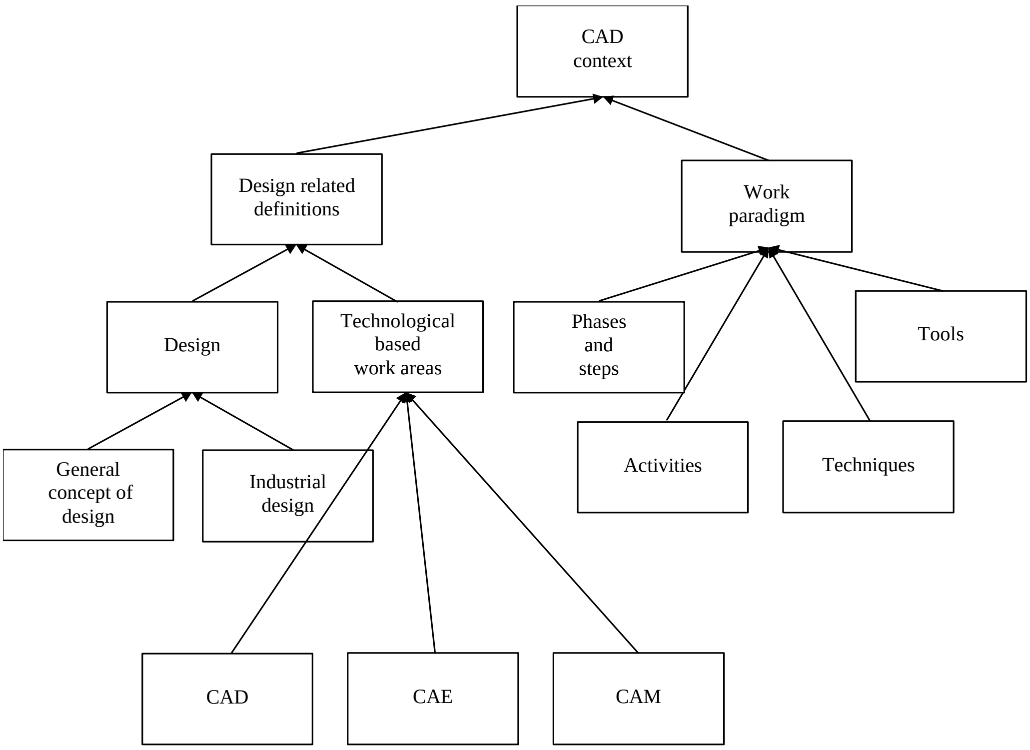

Figure 3. Higher level modeling of the CAD context knowledge

The knowledge about using specific CAD tools and design environments is presented in figure 5, as operational knowledge. This model presents how the methodological concepts modeled in figure 4 are implemented in specific tools. Knowledge is distributed in two groups, one containing the description of the instrumental elements (as operating systems or basics of programming), and a second one related to specific CAD environments (as AutoCAD, MicroStation or CATIA). This block of knowledge is purely instrumental, presenting the smallest level of abstraction; it would include a wide set of examples.

The matter model presented is a description of the state of the art, organized by levels of abstraction. How all their submodels are transferred to the student is matter of the learning model. Mainly there are two approaches; one by examples and a second one based on fundamentals. The first one supposes to train the students with a CAD tool, presenting general concepts using example cases. The second approach is more formal describing concepts previously to their application.

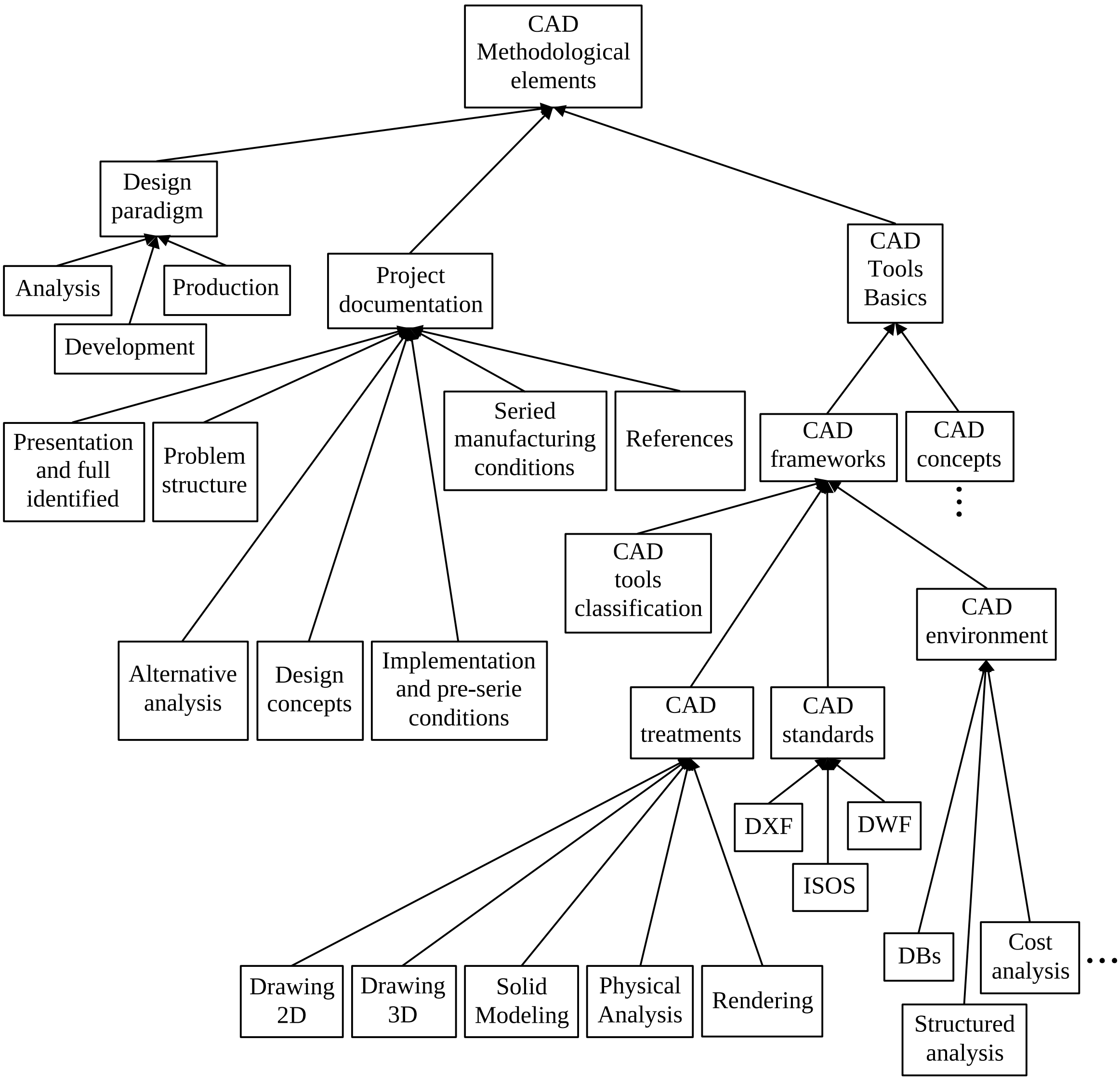

Figure 4. Higher level modeling of the CAD methodological elements

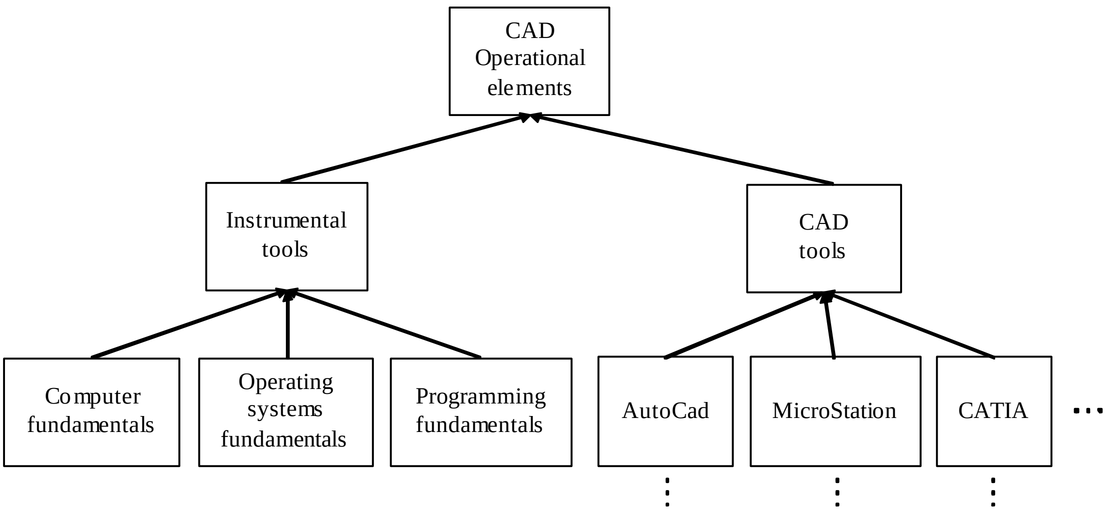

Figure 5. Higher level modeling of the CAD operational elements

4. Conclusions and future works

Main conclusions of the actual work are:

1. In order to implement efficient teaching systems into the web, it is a good practice to formalize and model the matter knowledge. This let us to surpass the interface oriented work model.
2. During the teaching process, three main knowledge models are used: a matter model, a pedagogical model and a student model.
3. Developing a matter model of CAD fundamentals requires including context, methodological and operational knowledge. It is possible to model different strategies ordering the student acquisition of these blocks of knowledge.
4. Operational knowledge is especially important in CAD training.
5. Web teaching let us to adapt the teaching process to the specific student conditions. This adaptation can be reached using the techniques of the dynamic selection of methods.

Actual and future developments include:

1. Modeling end domain structures with more detail and alternatives.
2. Developing autonomous teaching systems, using as a base the actual tutorial system.
3. Extending the scope of the models to other engineering areas as simulation.

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