INTED: AN INTELLIGENT TOOL FOR DESIGNING HIGHLY EFFECTIVE INSTRUCTIONAL ENVIRONMENTS

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Abstract:

Instruction may be seen as the intentional creation of conditions around learning so as to facilitate the achievement of determined goals. Normally, instruction is based upon certain educational strategies. It is well accepted in the field of educational technology that these strategies should be founded on a theoretical framework. However, the adoption of epistemological perspectives for instructional design is not enough. It would also be useful to count on the knowledge and experience of qualified instructional designers. The expert system introduced in this paper, called INTED, tries to capture the knowledge of instructional designers and so it is capable of recommending suitable strategies that facilitate the design of learning environments. For that purpose, the system developed is based upon a pattern of instruction which synthesizes theories, research results and experience in order to converge towards the accomplishment of an instructional design which will be highly effective in terms of achievement of its educational goals.

Keywords: instructional design, expert system, knowledge engineering, design patterns, learning environments.

1. Introduction

Instructional design may be understood as a related group of systematic procedures for educational environments development. It is highly recommended for the instructional design to be based on theoretical principles which justify the reason of procedures and strategies applied. Given certain characteristics of the learning environment, such as instructional objectives, content to be taught, learning peculiarity, learning context and so on, it is possible to establish which are the most adequate instructional strategies to be embedded in the design of learning settings. Thus, it should be possible to develop a computational tool such as an expert system that recommends appropriate strategies or teaching methodology for a particular instructional environment.

This paper intends to describe the design of an expert system that would assist project leaders, managers and in the complex task of defining the methodology and strategies that lead to the construction highly effective learning settings.

2. State of Art in Instructional Design

According to Reigeluth [1], the theoretical principles which sustain instructional design may be seen from a descriptive or prescriptive perspective. From the prescriptive point of view, the theory is considered as a related group of descriptions which results are observed as a a consequence of a given instructional pattern applied under certain conditions of the learning environment. From the prescriptive point of view, the theory is considered as a connected group of standards or prescriptions related to which the best instructional pattern will be in order to achieve the desired results under the conditions given by the learning environment. In summary, theory which grounds instructional design introduces a series of patterns and models which recommend adequate instructional strategies based on given characteristics of the learning setting to be designed.

Merril [2] describes the instructional design as a related group of prescriptions to determine the appropriate strategies so as to enable learners to achieve the goals of instruction. This theory basically refers to the strategies which do work, more than to a description of the steps to carry out in the development and design process.

Gagné [3] suposition sustaining that there are different kinds of instructional goals and therefore different strategies are required so as to let students achieve the goals of instruction in an effective way, it establishes the basis of Merril's instructional theory. Merril's theory is based on the premise that for the student to get an specific kind of knowledge, the instruction must use the right instructional strategy to promote the the attainment of that kind of knowledge.

Merril's suppositions are, in a way, questioned by Jonassen and his colleagues [5] through the argument that Merril has an excessively simplified view and reduces learning and human behavior to an element which can be easily manipulated.

Jonassen sustains that there are new scientific perspectives which question many of the traditional suppositions on learning. These new scientific perspectives comprise the herhermeneutics, the fuzzy logic and the chaos theory. Immediately afterwards, these theories will be considered separately, so as to understand their influence on instructional design.

The hermeneutics sustains that learning is an interpretation act. Knowledge, according to the hermeneutical perspective, is a social institution, an understanding which can never be set aside from those social or cultural conditions the learners belong to. When the hermeneutical principles are offered as a solution for an instructional design problem, the following perspectives should be included:

- The hermeneutical designer should grant the learner the possibility of giving his own personal meaning to a determined subject.

- Motivation strategies based upon the learner's own interests should be used.

- The use of a terminology which allows the learner a correct interpretation of contents.

Fuzzy logic tries to model the treatment of knowledge inaccuracy. For example, bivalent conceptions, true or false, right or wrong, are extreme values (and sometimes opposite) which define a connected group of infinite intermediate values. Therefore, fuzzy logic throws doubt upon the deterministic predictability assigned to the effects of instruction on learning. Instructional designers may use the principles of fuzzy logic in order to analyze the students' behaviors as well as their perceptions. Instruction should be concentrated in the student's affective domain in such a way that it can be adapted to promote self-confidence in the student.

The chaos theorists sustain that there are conditions we are not aware of which may have a significative impact on learning. There are so many variables interacting during any learning process that it becomes impossible to foretell the effects on it. Therefore, the real world chaos has such an impact on learning and the instructional process that it is impossible to determine it accurately. According to the chaos theory perspective, learning is not merely a cognitive process. Instructional design theory should not concentrate only in instruction's results, but bear specially in mind the uncertainty and unpredictability as a part of the world's complexity. Doing so, instructional design theory would become in a more probable and powerful one. The chaotic perspective recognizes that each human being has its own and personal mind, and so the instructional design should be concentrated in incorporating a wide span of conditions so as to reflect the probabilistic nature of instruction [6].

3. Domain characterization based on Instructional Patterns

Consistent with the non deterministic nature of the principles driving to an effective instructional design form the premises achievement point of view, it has been noticed that expert instructional designers tend to apply solution patterns or models to a given problem [7]. These patterns have been built (consciously or unconsciously) by instructional designers based on the experience gathered along the practice of their profession. In other words, instructional designers tend to repeat solution strategies (individually or combined) which did work in past similar cases.

As Christopher Alexander [8] asserts "...each pattern is a three parts rule, which expresses a relationship among certain context, a problem and a solution. As an element of the world, each pattern is a relationship among a certain context, a certain group of connected characteristics which repeatedly happen in that context and a certain configuration which allows its identification...". Starting from Alexander concepts, it comes out that a pattern may be understood as a connected group of interrelated elements as problem, context and solution.

Therefore, the fact of finding an adequate pattern to a given problem depends greatly on the identification of the individual problem and the context where it happens. This identification phase normally concentrates in gathering information about the requirements of the instructional system to be designed, along which they may come up many questions such as: Who are the instructional system users what do they want?. What kind of resources are available for the design?. In which context will the learning activity take place?

Through the application of this research process to different learning situations on an individual level as well as a group one [7], the following patterns to be used in instructional design have been identified:

Individual ones:

- Tutorial: Traditional instructional model. It is linear and based on stimulus-response actions. The student is passive. Good for training in processes where a quick reaction in a changing context is required.

- Research/Construction: Instructional model based on investigation. The student moves independently and normally it implies the creation of a concrete product or tangible device.

- Training: Instructional model based on the instructor's backing, according to the student's necessities. The instructor reduces his support as long as his student acquires higher skills. The instructor as "scaffold" in the process of "building" knowledge.

- Simulations: Instructional model based on the creation of artificial learning environments. It is useful in the situations where there are complex events interacting and the cause-effects relationships remain obscure. It is apt for cases where the real environments involve threaten or risk.

- Updated Information: Instructional models which provides for an immediate access to updated information. The student consults it unfrequently.

- Exploration: Instructional model which allows the students to explore and find out concepts, events or rules by themselves. It is convenient for this model to include a record of what has been done by the student so as to let him think about his own thinking processes (metacognition).

- Scientific Method: Instructional model based on experimentation and hypothesis formulation, analysis and verifying.

- Goal Based Scenario: Instructional model based on cases or problems, which looks for the strengthening or attainment of a goal or capability. It should encourage the student in the skill of recognizing the problems undertaking the strategies used before in similar cases (transference). It is highly dependent on the context.

Groupal Ones:

- Discussion Forum: Collaborative Instructional Model, based on the asynchronous communicational interaction among the students members of the group, with participation of the instructor.

- Conversation/Debate: Collaborative Instructional Model, based on the synchronous communicational interaction among the student members of the group, with the instructor participation.

- Expert's Vision: Instructional model based on the interaction with experts. It is useful to facilitate the entrance to a scarcely dealt knowledge ground or domain. It should try to induce on the student the way the expert has to undertake problems or situations, trying to make the student develop the expert's thinking mechanisms and mental models.

• Multiple Perspectives: Instructional collaborative model based on the undertaking of subjects, problems or situations from many different points of view or perspectives, and in many different contexts.

• Informal Collaboration: Instructional model based on the observation of behaviors or abilities hard to transmit to words, because it implies a huge amount of tacit or implicit knowledge on behalf of the instructor. It provides opportunities for brain-storming. It can lead to expertise or the control of an ability.

• Best Practices: Instructional model based on the adoption of a highly effective solution in a situation very similar to the one the student faces. It generally requires the support of the expert who knows the solution which works in this case in particular.

• Intelligent Agents: Instructional model based on customized instruction. It has filtering properties and a high adaptability for adjusting its performance to the different variables which have to be considered in an instructional setting. Intelligent tutorial systems are an example of this kind of learning environments.

4. Instructional Patterns and Learning Theories

It is possible to set up a relationship between instructional patterns and the learning theories upon which instructional design should be based. So, in order to explain this correlation between patterns and theories, the following theoretical paradigms for defining general strategies in instructional design will be considered: behaviorism, cognitivism and constructivism.

Behaviorist learning theory is restricted to external observations which try to explain why behaviors occur. This theory is based on the premise that learning results from the association between stimulus and response.

On the other hand to the former, cognitivism tries to determine how learning occurs, based on the cognitive processes which are believed to happen in the student's innermost being. Therefore, from the cognitivist theory point of view (as a contrast to the behaviorist), four kinds of knowledge have been identified [9] which are the most representative when doing an analysis to the kind of knowledge present in a variety of topics and tasks: factual knowledge, based on images, procedural knowledge and mental models. The association of instructional strategies (inference, interpretation, proceeding/tracking out/sequence, simulation) come forth as a result of the result of the kind of knowledge embedded in the content to be taught.

Otherwise, constructivism is a learning philosophy based on the premise that knowledge does not exist as something external to the student (as a contrast to behaviorism and cognitivism), but that is internally built through a reflection process based on the student's own experiences [5][10]. Under the constructivist perspective, the student makes up his own meaning of the world he lives in. In agreement with this theory, the learning context plays a very important role in the internal process of knowledge construction. Instructional strategies consist of giving the student real experiences in relevant contexts which may allow for the successful transference of academic or schooled acquired knowledge to real-world contexts.

Learning theories are partial visions in the sense that, in general, they watch certain aspects of the whole learning situation. Depending on the characteristics of the learning environment to be designed, it is the instructional designer's task to determine the combination of adequate instructional strategies to be embedded in the design. The learning theories commented in this section are related to the individual instructional patterns previously identified in this article, as it is shown in Table I.

Based upon instruction requirements and the strategies recommended by different learning theories, instructional designers can make up learning environments which will be highly effective in the accomplishment of their educational goals.

Learning Theory	Instruction Characteristics	Associated Instructional Patterns	Recommended Instructional Strategies
<u>Behaviorism</u> *Learning by Imitation*	Traditional Linear Reactive Student is Passive	• Tutorial • Training	Repeating Stimulus and Response Association Reinforcement Contiguity
<u>Cognitivism</u> *Learning by Association*	Reasoning Stressing High level of cognitive processing	• Simulation • Updated Information	Inference Rule Testing Mental Models Construction
<u>Constructivism</u> *Learning by Experience*	High level of Conceptual Complexity of the Learning Domain Experiential Context Dependant	• Research/Construction • Exploration • Scientific Method • Goal-based Scenarios	Knowledge Construction, not Reproduction Acquisition of Expert's thinking mechanisms Experience Designs Collaboration

Table I: Relationship between Instructional Patterns and Learning Theories

5. INTED : An Expert System for Selection of Instructional Strategies

Unlike traditional computer programs, intelligent applications of computational software try to emulate human thinking processes and therefore, it may be useful as an extension of creative abilities and problem solution approaches inherent to human beings. So, the expertise present in expert instructional designers and their knowledge in the application of instructional theories and models may be captured by an intelligent system, which will be a computer program that can be used whenever it is required. More specifically, intelligent systems act as a combination of theories which try to emulate or reply human behavior in specific, sufficiently limited contexts [11]. Thus the selected context could be constrained to learning environments design and particularly, to the definition of which will be the most

effective instructional strategies to be embedded in this design, depending on the educational goals and characteristics of the instruction to be implemented.

Instruction involves student interaction with didactic experiences, support materials, tools and people in the educational environment, so as to facilitate learning. The purpose of an instructional system is to exert and provide instruction. Instruction consists of a connected group of learning activities, which are normally framed in well-defined specific strategies. These activities are designed to facilitate in the students the achievement of those goals specified in the curriculum design. Any educational environment provides for different kinds of activities to be carried out by the student.

The problem that instructional designers have to face is the great number of interacting variables that should be taken into account for an effective design of instruction. The main variables that affect learning are in some way related to the characteristics of:

- the one who learns, who is generally called “student”
- curriculum
- learning context

Success in the attainment of a new learning depends also greatly on the student previous knowledge, that is to say, if the student has the required knowledge and abilities to assimilate that very learning.

The instructional strategies embedded in a highly effective design consists of achieving the adequate interaction among the elements which take part in the instructional scenario, so as to get the best attainment of educational goals.

As an illustration, it may be considered the situation of a student whose learning style is predominantly visual and must assimilate a content which involves many associations of text-image type. In presence of a learning scenario like this, investigation recommends [9] an instructional strategy tending to give meanings to the images so as to get high effectiveness in the process of incorporating this new knowledge to the learner’s cognitive structure.

The system assists instructional designers to identify the best instructional strategies to be employed, according to the educational environment which is defined by learner’s characteristics, curriculum and learning context. The definition of the methodological aspects of the problem was dealt establishing: goals, scope, members and environment where the system is used.

INTED, the expert system designed to identify the best instructional strategies in a given learning environment, receives as input a description of the instruction desired and the characteristics of the learner. Once all these data are known, INTED identifies the pattern or its combination which best adapts to the instructional situation introduced by the user, recommending thus, instructional strategies to be employed for the design. In selecting the most suitable strategies to be adopted by the designer, the sytem outputs those general strategies recommended by the learning theory to which the selected instructional pattern/s or model/s are related, as it is done on Table I.

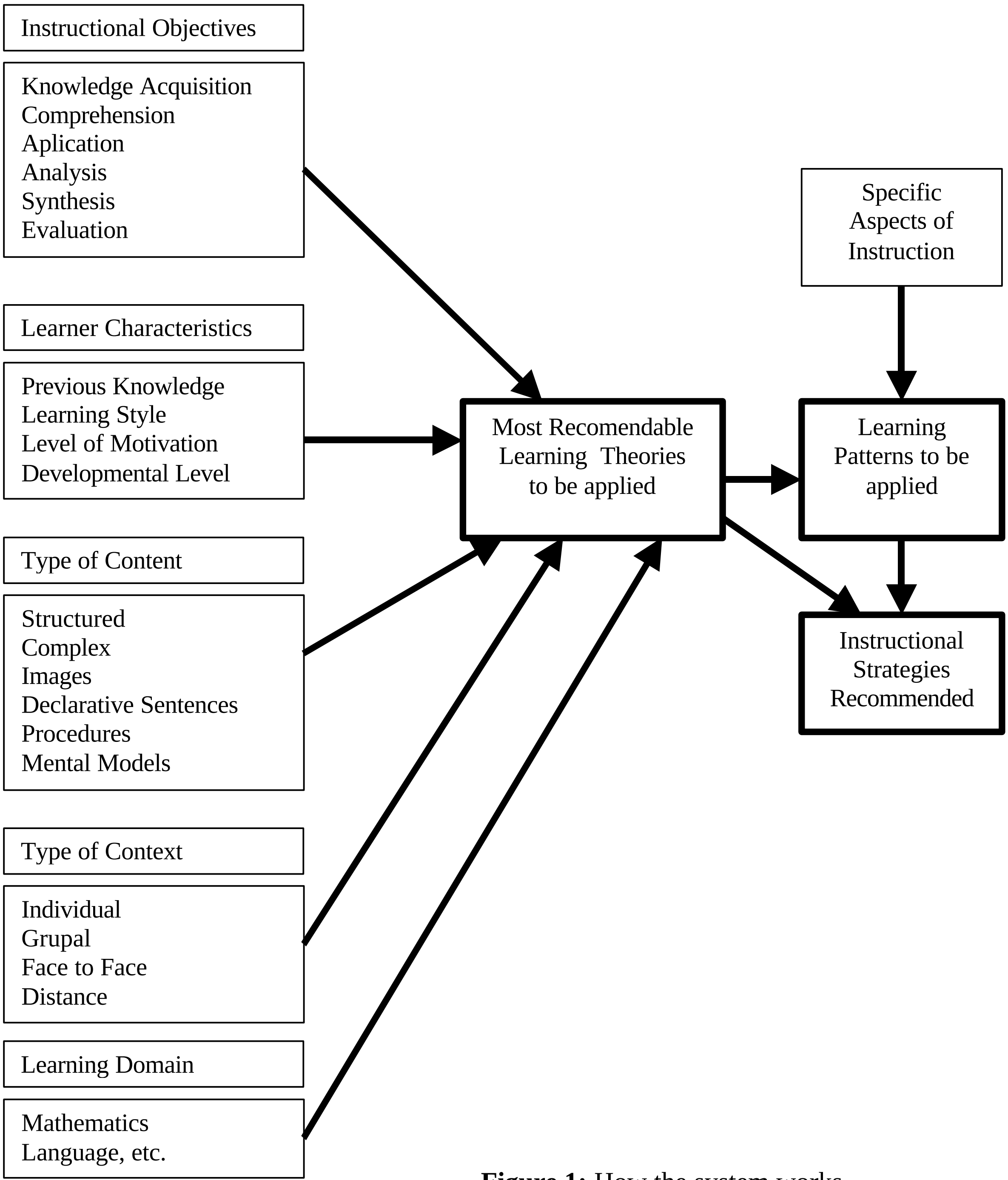

Figure 1: How the system works

In addition, specific instructional strategies are presented to the user, taken from those suggested by the chosen patterns or models. In Figure 1 it is shown the way the system works. Thin line rectangles represent inputs required by the system, while thick line rectangles represent inferences made up by the expert system by applying its reasoning mechanism. Rules are fired within the knowledge base by following a forward chaining strategy. For example, the level of cognitive processing required by the task as defined in the instructional objectives combined with the level of learner previous knowledge of the content or subject to be taught helps the system to identify the most suitable learning theory to be applied in this particular situation. The realationship between patterns and learning theories as it is established in Table 1 contributes to determine which patterns or combination of them are applicable in this particular case. Based on learning theories as well as learning patterns the system recommends instructional strategies, as it is depicted in Figure 1. Accordingly with this idea, Figure 2 shows the interface displayed by the system when working within the Kappa shell environment. INTED is also prepared to identify if the learning setting entered by the user is beyond the limits of what the system can handle.

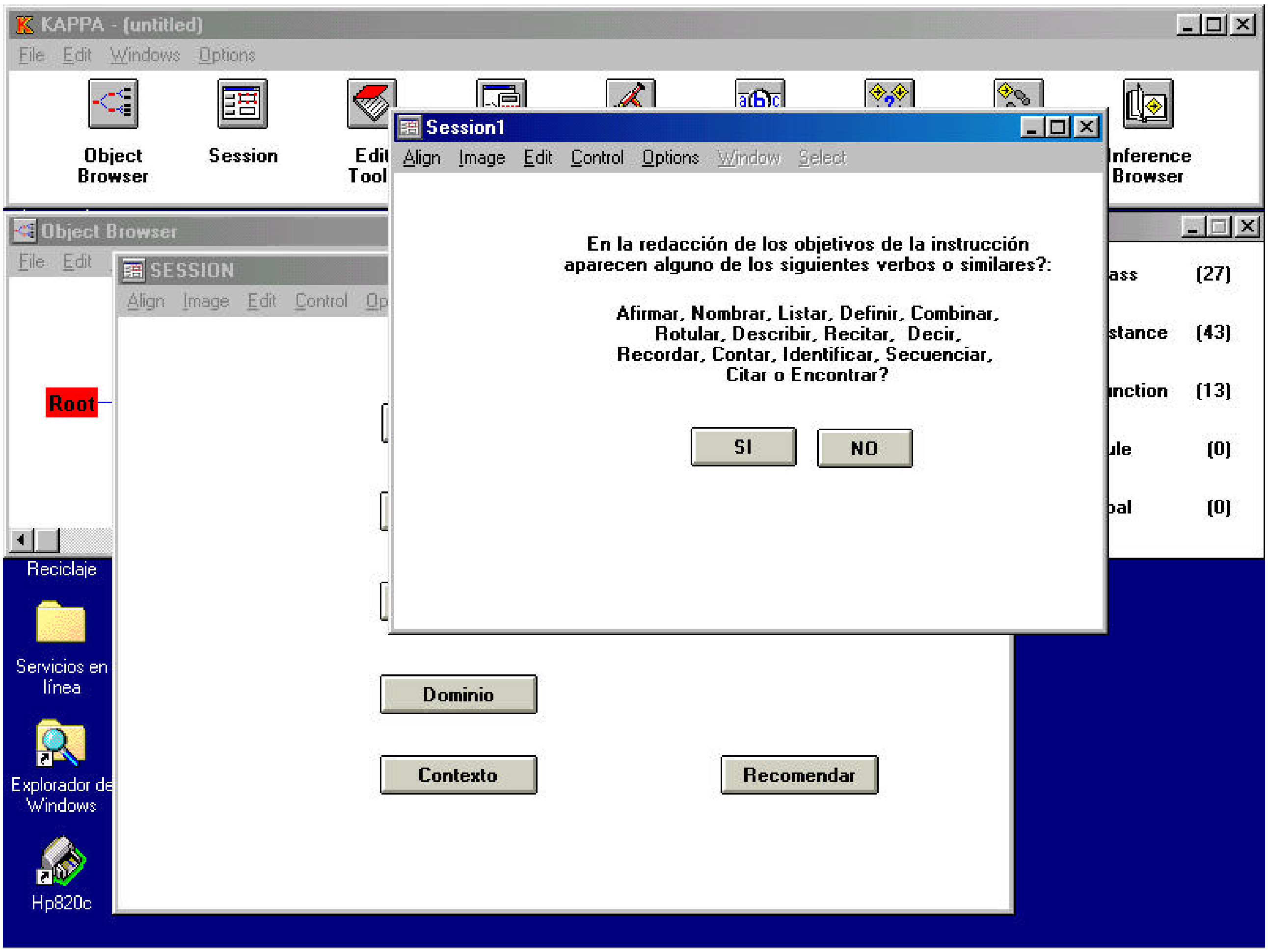

Figure 2: Interface displayed within the Kappa environment

5. Conclusions

INTED, an expert system intended to assist designers in the selection of instructional strategies described in this article is at a development phase, having at this stage a prototype which is able to recommend strategies provided a great variety of design problems. The application of several test cases to check out the system's effectiveness has thrown results which have been considered satisfactory, according to expert instructional designers criteria. However, the process of knowledge acquisition in order to improve the system goes on. This is accomplished by continuously incorporating new theoretical models and instructional patterns in it. This permanent improvement strategy allows for getting the best of the system's effectiveness, and contributes to provide valuable assistance in the difficult process of designing highly effective learning environments.

Based upon preliminary results of the previously described work, we believe it is possible to build an expert system which, given the elements that converge to coexist in a learning environment supported by technology (learner, curriculum, goals, context), would be able to establish prior and secondary instructional strategies and recognize the learning activities
that make these strategies effective in the practice of instruction, founded in a model of instruction that best synthesizes the learning theories adopted.

6. Discussion

The project described in this article entails the development of an expert system aimed at instructional designers. The main purpose of the developed system is to provide recommendations for instructional decisions that lead to the design of learning environments highly effective in terms of achievement of their educational goals. The main
contribution of this expert system relies on its own internal structure. Based on identified instructional patterns and models, the system focuses on recommending the most suitable educational strategies to be embedded in the design for a given case. System recommendations are given according to the identified pattern or model that best fits the instructional situation defined by the user. Different instructional models have been set up based upon the experience of expert instructional designers. Therefore, the output offered by the developed system intends to reflect the guidance that an expert instructional designer
would provide in the implementation of a system with similar instructional requirements as those imposed by the user. Other expert systems for instructional design have been built so far, but they were not constructed taking into account the way instructional designers deal with their design problems. As stated in this article, this way of finding solutions does seem
to match quite well with what most learning theories recommend as effective for a given instructional setting. However, solutions based upon specific patterns and models can capture more details taken from real life learning situations that will contribute to enrich the whole instructional development. The originality of the idea that supports the design of this
expert system tries to overcome difficulties derived from the unpredictability and chaotic nature of instructional environments. By relating adequate strategies with design cases where they did work out well, the system emulates the complexity of the human expert brain when it retrieves a similar previous case and the solution that was effective in that context. To some extent, the developed system simulates a cognitive model commonly observed in the way experts approach design problems and search for solutions. Another outstanding feature of the developed system worth to be mentioned concerns its flexibility. New patterns and models can be easily incorporated in order to respond properly in those cases where existing models do not apply entirely. Future work can take advantage of this flexibility to improve this design tool. Instructional environments developed by using it will

reflect this enhancing process by properly dealing with complex, unexpected and uncommon cases in instructional design.

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