# Generator of Adaptive Learning Scenarios: Design and Evaluation in the Project CLES

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**Abstract.** The objective of this work is to propose a system, which generates learning scenarios for serious games keeping into account the learners' profiles, pedagogical objectives and interaction traces. We present the architecture of this system and the scenario generation process. The proposed architecture should be, insofar as possible, independent of an application domain, i.e. the system should be suitable for different domains and different serious games. That is why we identified and separated different types of knowledge (domain concepts, pedagogical resources and serious game resources) in a multi-layer architecture. We also present the evaluation protocol used to validate the system, in particular the method used to generate a learning scenario and the knowledge models associated with the generation process. This protocol is based on comparative method that compares the scenario generated by our system with that of the expert. The results of this evaluation, conducted with a domain expert, are also presented.

**Keywords:** Scenario generator, serious games, adaptive system, evaluation protocol.

## 1 Introduction

Our work is situated in the context of adaptive generation of learning scenario. We define a learning scenario as a suite of structured pedagogical activities generated by the system for a learner keeping into account his/her profile in order to achieve one or more educational goals. We are more specifically interested in the learning scenario generation in serious games [1]. In this area, we propose a system capable of generating dynamically learning scenarios keeping into account the following properties:

- The ability to be utilized in any serious game taking into account its specificities.
- The use of interaction traces as knowledge sources in the adaptation process.

Along with the above mentioned properties, we also aim our system to be reusable with different learning domains and different games as well. Therefore, the different kinds of knowledge presented in the system are organized and separated in a

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multi-layer architecture. These layers represent the learning domain in the form of: *domain concepts*, *pedagogical resources* required to teach these concepts and *serious game resources* that are used to present pedagogical resources to the learner. This separation means that the aspects of any particular layer can be modified without necessarily modifying other layers, hence, rendering the system more reusable.

A trace [2] is defined as a history of learner's actions collected in real-time while the learner is using the serious game. It is considered to be the primary source for the updating of a learner's profile and the domain knowledge. It also serves as knowledge sources in the scenario generation process. Formally, a trace is a set of observed elements temporally located [2][3]. Each observed element represents the learner action on computer environment such as interacting with an educational resource, clicking on a hyperlink, etc.

The idea of automatically generating learning/pedagogical is not new and has been investigated previously by many authors [4][5][6]. However, these systems focuses only on the pedagogical aspects of the problem and do not consider serious games as a potential medium of delivering these scenarios to the learner. Furthermore, not every system defines clearly the separation of the conceptual layer and the pedagogical resource layer which makes them difficult to reuse. Likewise, these systems don't exploit, in general, the learner's traces in the generation process.

Our contribution is situated in the context of the Project CLES[1] (Cognitive Linguistic Elements Stimulation). CLES aims to develop a serious game environment, accessible online, which evaluate and train the cognitive ability for children with cognitive disabilities. In the context CLES, we conducted an evaluation aimed at:

1. Validating the working of the system generator of learning scenario, and
2. Validating the knowledge models that are used by the system to represent different kind of knowledge.

The learning scenario generator is evaluated to confirm the algorithm used to select the different resources (concept, pedagogical resources & game resources). Moreover, the knowledge models are evaluated to verify their functionality in the generation.

The rest of the paper is organized as follows: in section 2 we detail the project CLES, in section 3 a literature review on course generators and serious games is presented. Section 4 presents a brief presentation of our architecture system and section 5 presents the scenario generation process. Section 6 details the evaluation protocol of knowledge models and generator working. We will present the results of the evaluation in Section 7. The next section presents the discussions and conclusions.

## 2 Application Context

The work on project CLES (Cognitive Linguistic Elements Stimulation) was conducted in collaboration with different partner laboratories. These partners are specializing in serious games development for children with cognitive disabilities, ergonomic design and the study of cognitive mechanisms. This project aims to provide

[1] `http://liris.cnrs.fr/cles`

serious game for training and evaluation of cognitive functions. Eight functions are considered in CLES: perception, attention, memory, visual-spatial, logical reasoning, oral language, written language and transversal competencies.

The serious game developed, in the context of CLES, is called “Tom O’Connor and the sacred statue”. This is an adventure game. The protagonist of this game is a character named *Tom,* his task is to search for the sacred statue hidden in a mansion. According to the session, Tom is placed in one of the many rooms in the mansion. Each room has many objects (chair, table, screen etc.). Hidden behind these objects are challenges in the form of mini-games. The user has to interact with these objects to start these mini-games. To move from one room to another and progress in the game, the user has to discover all the mini-games in the room.

Thus, for each of the eight cognitive functions, we have about a dozen mini-games and for each mini-game we’ve nine levels of difficulty. A more detailed description of games developed in this project is presented in [7].

The role of the scenario generator is to select (according to the learner’s profile, his/her interaction traces and his /her therapeutic goals for the session) the mini-games with appropriate difficulty levels, and to put these games in relation with the objects of different rooms of the mansion. This generator should therefore keep in to account:

- What the practitioner has prescribed for his patients
- The knowledge base of the available treatments for the pathology
- Histories of the previous exercises of the learner, stored in the form of traces.
- Specificities of the serious game

The module we develop has to be validated on its theoretical properties (meta-models, models and processes) in the context of the Project CLES (see the sections 6 and 7).

## 3 Literature Review

The purpose of this section is to present the existing approaches regarding the generation of pedagogical scenarios and serious games, and to show what lacks in the theses approaches and where we are contributing. This literature review is done keeping in mind, among other, the following characteristics of our system, namely:

- General architecture independent of the pedagogical domain and application,
- Usable with serious games, and
- The use of interaction traces for the updating of learner profile and adaptation.

This section is organized in two sections. The first section presents the course generators and the second presents the serious games for learning.

### 3.1 Course Generators

Learning scenario generation can be divided into two broad categories: course sequencing and course generation. The former selects the best possible pedagogical resource at any time given the performance of the learner and the latter generates an structured course in a single go before presenting it to the learner [8]. A course sequencer by the name of DCG (Dynamic Courseware Generator) is presented in [9]. DCG selects the next pedagogical resource (HTML pages) dynamically according to the current performance of the learner. DCG is heavily dependent on web-based resources and are not suitable for other mediums like (serious games). In WINDS [4], the learner has to either manually navigate through the course or choose from the recommendations offered by the system. However, a complete learning path is not generated for a particular learner, which is required in games like CLES. An expert-system type approach is presented in [10], forcing to enter all the rules beforehand, therefore making it difficult to maintain for a large knowledge base. Statistical techniques are employed in [11] in order to generate a course most suitable to the learner, however, in addition to the relations between the concepts relation between different resources are also maintained. The relations between pedagogical resources are necessary for different resources to be included in the same scenario. This requirement is a limitation where different pedagogical resources are not related (like in project CLES). Case based reasoning is used in a web based system [12] called Pixed (Project Integrating eXperience in Distance Learning). PIXED uses the learners' interaction traces gathered as learning episodes to provide contextual help for learners trying to navigate their way through an ontology-based Intelligent Tutoring System (ITS). They rely on the learners to annotate their traces which can be difficult for cognitive handicapped persons.

A system which combines the techniques of course sequencing and generation is presented in a system called « Paigos » [13]. The authors use HTN-Planning and formalized scenarios to deliver adaptive courses. The manner of construction of Paigos makes it difficult for persons unfamiliar with HTN techniques to use it.

In general, course generators focus on the pedagogical aspects and do not target serious games for delivering their courses. Therefore, it is difficult to use them with serious games. Moreover, the interaction traces are, generally, not used for updating the learner profile & domain knowledge.

### 3.2 Serious Games

Systems have been proposed to use games for planning and management of business simulation games in [14]. The pedagogical scenario is presented as a tree, providing adaptation according to different learner actions. The construction of tree becomes difficult as the scenario becomes complex. An authoring tool for the creation of 2-dimensional adventure games is presented in [15], personalization is done by predefining the decision tree. A pedagogical dungeon to teach fractions in a collaborative manner is presented in [16]. The interaction traces are used here in the adaptation process. The scenarios are static and the tight coupling between the pedagogical scenario and the gaming interface deprives the approach from reusability. C programming language is taught in [17]. The teachers present to the learner a sequence of learning activities in a Bomberman type game. The manual presentation of learning activities sequences is not practical in case of hundreds of learners. A role playing game is also proposed for the purpose of osteopathic diagnosis [18]. This game also relies heavily on manual teacher intervention.

These systems tightly couple the pedagogical aspects with the gaming aspects i.e. we cannot reuse neither the pedagogical nor the gaming aspects with other games or pedagogical domains. Furthermore, a structured pedagogical scenario is not well defined, mostly; therefore, there isn't a generated personalized pedagogical scenario as well. The learners' interaction traces are also not exploited as well, in general.

## 4 System Architecture

In this section we present the different kinds of knowledge used in our system and how we've organized them in order to increase reusability. Furthermore, the modeling of this knowledge is also presented along with the general working of the system.

### 4.1 Knowledge Representation

As mentioned earlier, our objective is to develop a generic system capable of generating dynamically adaptive learning scenarios keeping into account the learners' profile (including their interaction traces) and the specificities of serious games. For this, we propose to organize the domain knowledge in a multi-level architecture. We have considered three types of knowledge (as shown in the figure 1): *domain concept, pedagogical resource* and *serious game resource*. The separation of this knowledge on three layers helps in using change the aspects of one layer without forcibly changing the other layers.

As the name indicates, the first layer contains the domain concepts. These concepts are organized in the form of a graph where the nodes represent the concepts and the edges represent the relation between the concepts.

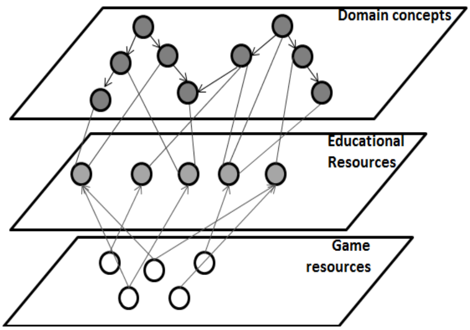


**Fig. 1.** Knowledge Layer

Formally, the domain knowledge is modeled as <C, R > where, ‘C’ is the concepts of the domain and ‘R’ represents the relations between the concepts. Each concept ‘C’ is defined by <Id, P>, where: ‘Id’ is a unique identifier and ‘P’ is the set of properties that describe the concept like the author, the date of creation, description of the concept, etc. ‘R’ is defined by $< C_{From}, T, RC+ >$, where: ‘$C_{From}$’ is the origin concept of the relation, ‘T’ Is the type of the relation and ‘RC’(Relation Concepts) = $<C_{To}, F, Value >$ where: ‘$C_{To}$’ is the target concept of the relation, the direction of relation is from $C_{From}$ to $C_{To}$, ‘F’ is the function that allows propagating the information in the graph in order to update the learner profile. The semantics of the function may differ depending on the type of relation. And ‘Value’ is the value between the concepts of the relation. This value is used as default in the absence of function ‘F’.

We also have created many types of relations [7]. For example, we present here two types of relations:

- Has-Parts (x, $y_1$ … $y_n$): indicates that the target concepts $y_1$ … $y_n$ are the sub-concepts of the super concept x. For example: Has-Parts (Perception, visual perception, auditive perception).
- Required (x, y): indicates that to study concept y it is necessary to have sufficient knowledge of concept x. For example, Required (Perception, Oral Language).

In the context of the project CLES, the domain concept models the eight cognitive functions and relationships that may exist between them.

The second layer contains the pedagogical resources. In general, a pedagogical resource is an entity used in the process of teaching, forming or understanding allowing learning, convey or understand the pedagogical concepts. The pedagogical resources can be of different natures: a definition of a concept, an example, a theorem, an exercise, etc. Formally, each pedagogical resource is defined by a unique identifier, a type, the parameters, an evaluation function, and a set of characteristics (like name, description, name of author etc). As shown in figure 1, each resource can be in relation with one or more domain concepts and vice versa. This relation shows that a resource can be used to understand the concept with which it is related. In the context of project CLES, the pedagogical resource layer contains the mini-games.

The third and final layer contains the game resources. They are static objects that are initialized with dynamic or proactive behavior. In our model, we only consider the game objects that are related to a pedagogical resource. Formally, each game resource is defined by an identifier, the relations with the pedagogical resources with which it is related and a set of characteristics like name, description etc. In the context of project CLES, these resources are the objects of the serious game which are used to hide the pedagogical resources (mini-games).

### 4.2 System Working

The architecture of our system is shown in the figure 2.

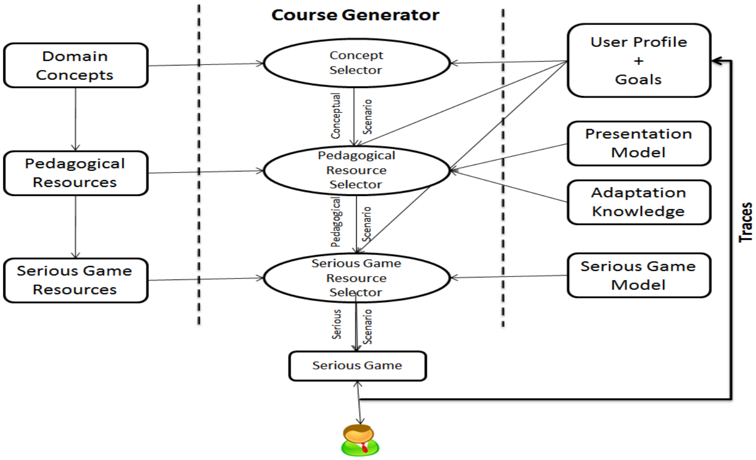


**Fig. 2.** System Architecture

The process of the system's operation is as follows: (1), the domain's expert(s) feeds the system with the domain's knowledge according to our proposed models and the learners' profile. These models were presented in the previous section. In each learning session, the system is fed with pedagogical goals. These goals are either selected by the learner or are predefined by the system from his/her profile. (2), the system, according to the selected goals and the learner's profile, selects the appropriate concepts from the domain model. This selection is done by the module 'Concept Selector'. The output of this module is the 'Conceptual Scenario'. This conceptual scenario is comprised of concepts along with the competence required to achieve the pedagogical goals.

(3), the conceptual scenario is sent as input to the module 'Pedagogical Resource Selector'. The purpose of this module is to select for each concept, in the conceptual scenario, the appropriate pedagogical resources. These resources are selected according to the 'Presentation Model' and the learner's profile. The latter is represented by a set of properties in the form of <attribute, value> pairs where the *attribute* represents a domain concept and the *value* represents the learner's mastery of that concept. The purpose of the presentation model is to organize the pedagogical resources presented to the learner. The structure of the scenario can be for e.g. starting a scenario by presenting two definitions followed by an example and an exercise. The selection of this model can either be done by the learner or by the teacher (expert) for the learner. The structure of the scenario model can fit the form defined in [13].

Furthermore, the pedagogical resources are then adapted according to the 'Adaptation Knowledge'. The adaptation knowledge is used to set the parameters of pedagogical resources according to the learner's profile and pedagogical goals. The output of this module is a 'Pedagogical Scenario'. This scenario comprises pedagogical resources with their adapted parameters.

(4) The pedagogical scenario is sent as input to the module 'Serious Game Resource Selector'. This module is responsible for associating the pedagogical resources

with the serious game resources. This association is done based on the 'Serious Game Model'. The 'Serious Game Model' is used to associate the type of serious game resource with the types of pedagogical resource. This module produces the 'Serious Scenario' (5).

The learner interacts with the learning scenario via the serious game. As a result of these interactions the learner's interaction traces are generated. These traces are stored in the learner profile and are used to update the profile and consequently modify the learning scenario according to the learner traces, if necessary.

# 5 Scenario Generator

As mentioned in section 4, the process of learning scenario generation given pedagogical goals and learner's profile is handled by three modules namely 'Concept Selector', 'Pedagogical Resource Selector' and 'Serious Game Resource Selector'. The general functionality of these modules is already defined in section 4. In this section we'll present the textual description of the working of these algorithms.

## 5.1 Concept Selector

The purpose of this module is to generate a list of domain concepts required to achieve the learning goals. This generation is performed keeping into account the learner's profile. The learning goals are defined as the set of target (domain) concepts along with the competence of each concept required. The generated list of domain concepts is called 'conceptual scenario' in our system. The generation process works as follows; first for each target concept (TC), it is checked (by consulting the learner profile) whether or not this TC is sufficiently known by the learner. If it is sufficiently known by the learner then this TC is ignored and the next TC is looked.

Then the module checks whether or not the TC has some concepts related to it. Some of these concepts, in relation with the concept in question, can be selected to be added in the conceptual scenario. This selection depends on the type of relation between the concepts. In fact, we've identified, for each type of relation, a **strategy for the selection** of concepts. For example, if a learner has chosen a target concept A and A is in a relation of type 'Required' with another concept B (Required (B, A)), then the generator will verify that whether the learner knows sufficiently the concept B. If it's not the case then the generator also includes concept B in the conceptual scenario.

## 5.2 Pedagogical Resource Selector

The purpose of this module is to select the appropriate resources for every concept in the 'Conceptual Scenario' given a 'Presentation Model (PM)' and learner profile. This selection is outputted in the form of a "Pedagogical Scenario". This contains a list of resources associated with each concept along with their appropriate parameters.

The selection process goes as follows; firstly, for each concept in the 'conceptual scenario' the process searches for the resources of type 'T' as described in the PM. If there is more than one pedagogical resource of type ‘T’ associated with the concept, then the resource which is not already seen by the learner or not sufficiently known by the learner is added to the list. The process also consults the adaptation knowledge to select the parameters of the resources (in order to adjust the level of difficulty).

### 5.3 Serious Game Resource Selector

This module associated the pedagogical resources in the ‘Pedagogical Scenario’ with the serious game resources according to the learner’s profile and Serious Game Model (SGM). The result of the execution of this module is a list of game resources called ‘Serious Scenario’ which contains resulting concepts and the serious game resources initialized with the pedagogical resources and their parameters.

The working of this module is as follows; firstly, for each pedagogical resource in the ‘Pedagogical scenario’ the serious game resources related to the pedagogical resource are searched. Then for each selected serious game resource, the process consults the learner profile to verify whether the selected resource is appropriate for the learner. If yes then this resource is added to the list.

## 6 Evaluation Protocol

The first evaluation of our system was conducted in presence of a domain expert. This expert has been a practitioner of cognitive sciences for more than 20 years. The objective of our evaluation, as mentioned earlier, is the validation of:

- The scenario generator’s working: more precisely, this means the validation of the concept **selection strategy** which we’ve defined for each type of relations, and
- The knowledge models: it means to validate the concepts and the relations that we’ve introduced into the system in the context of project CLES.

For this, the basic strategy that we’ve adapted is comparative evaluation [19] i.e. it consists in comparing the learning scenarios created manually by the domain expert with the learning scenarios generated automatically by the system for the same input. This input corresponds to the domain knowledge and profile types. Furthermore, during the evaluation process we conduct an Elicitation Interview [20] with the expert. The purpose of this interview is to help the expert in explicating (as much as possible) his/her thinking process, how s/he reasons while creating a learning scenario.

Before conducting the interview we came up with a protocol of evaluation. This protocol is designed to guide us in conducting the evaluation and help us in validating our models and to identify any problems and their source.

This flow of this protocol is depicted in the figure 3. At first, the expert is asked to create a certain number of learner profiles (1). As the expert has a vast experience in his/her respected field, s/he can give us the profiles that are pretty much closer to the.

Ideally, we would like the expert to create a certain number different profiles. The more are the profiles the more it is beneficial for our evaluation. Furthermore, the profiles should also be diverse i.e. different profiles should contain different competencies. This will help us in determining whether our system can handle diverse cases or not. Apart from these profiles we ask the expert to fix some learning objectives for the profiles. Afterwards, we ask the expert to create learning scenarios for each learning objective and each profile.

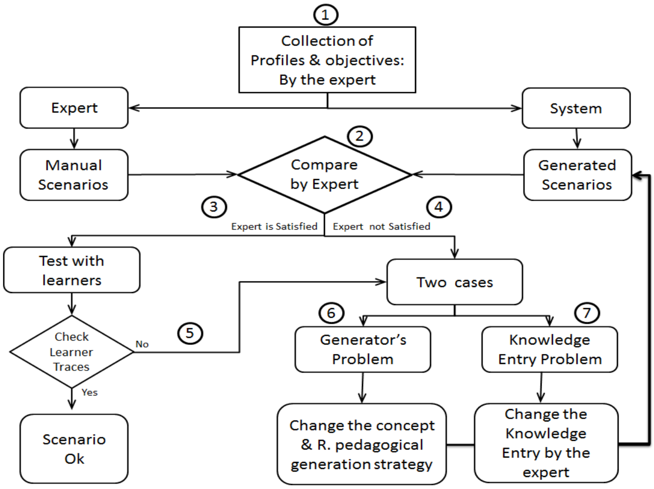


**Fig. 3.** Evaluation Protocol

Once the expert has identified the profiles and the objectives, we introduce them into the system in order to generate the learning scenarios. Then the two sets of scenarios are compared by the expert (2). This comparison is done by the expert (by an interview of explication where we demand the expert to verbalize his/her thoughts. The expert is filmed during the whole evaluation process.

The result of this comparison will be either the expert will find the scenarios similar or not. If the expert is sufficiently satisfied with the similarity of the scenarios (3), then the scenarios will be presented to real learners. Ideally these learners should've the same profiles as entered in the system. The scenarios will then be presented to the learners. If possible, the learners should be filmed during their interactions with the scenarios. The learners should be asked how difficult are they finding the scenarios. The learners' interaction traces will also help us in answering this question. By analyzing the traces we can determine that a learner is finding the scenario very difficult if s/he is failing constantly in the exercises. Similarly, if the learner is answering the exercises very quickly and correctly then we can conclude that the learner is finding the exercises very easy to solve.

If the learners say that they are finding the scenarios too easy or too difficult (5), then this will imply that either the knowledge entered in the system by the expert can be improved or the system is not generating the scenarios properly. In either case, the protocol to be followed to resolve the problem is defined next.

If as a result of the comparison the expert is not finding the scenarios similar enough (4), then two cases are possible: 1/The system's generator is not working properly (6). 2/ the knowledge entered in the system by the Expert is not correct (7). If the system's generator is not working properly, then we review the following:

1. Concept selection strategy: This means we've to review the selection of concepts based on different relations and the calculation of percentages based on them. Currently we've four kinds of relations.
2. Pedagogical Resource selection strategy: Here, we've to review the pedagogical resource selection strategy. Currently, we select, according to the presentation model, all the resources related to a concept. Then we verify whether a particular resource is already seen & mastered by the learner. If this is the case we ignore that resource and proceed on the next one.

If none of the cases are applicable, then maybe the expert has made some error in entering the knowledge in the system. Furthermore, we can tell the expert that there are either some relations missing between the domain concepts or some of the relations do not have the right type i.e. maybe a relation should be of the type has-parts whereas it is marked as required in the model.

Following the above mentioned protocol we conducted our evaluation.

## 7 Experiments and Results

We started the evaluation by introducing the domain models in the system. Since the original model of Project CLES is very large, the expert would have found the evaluation of the whole model quite tedious. In fact, there are 8 super concepts and each super concept having at-least 5 sub-concepts and each sub-concept has at-least 5 pedagogical resources. Furthermore, there is also the serious game resources associated with the pedagogical resources. Therefore, we created three mini-models of the original model. All these mini models contain the eight main domain concepts of CLES. The initial arrangements of these concepts are shown in figure 4. All the links between the super concepts are of the type '*Required*'. The relation between perception and its sub concepts is of the type *Has-Parts*.

These super concepts are present in each of the mini-models. In each mini model, in addition to the super concepts, one concept is further detailed. The detailed concepts are: written language, perception and memory. We also prepared six profiles for each model. The profiles are as follows: *Profile 1*: 8 years, no deficiency in concept x/ *Profile 2*: 8 years, deficiency in concept x / *Profile 3*: 14 years, no deficiency in concept x/ *Profile 4*: 14 years, deficiency in concept x / *Profile 5*: 18 years, no deficiency in concept x / *Profile 6*: 18 years, deficiency in concept x.

The concept 'x' is the detailed concept in each model. The choice of these 18 profiles is not arbitrary but they are logically selected, Project CLES targets children between 6 years and 18 years. So the choice covers almost all the age groups. The expert was in agreement with us over the choice of the profiles.

Afterwards, we asked the expert to give sufficient values to the concepts in each profile. The expert defines the values keeping into account the type of the profile for example: lesser values are assigned to the profile with deficiency than those profiles without deficiencies. Afterwards, the objectives for each of the profile are also fixed. These objectives are a bit higher for the profiles without deficiency and vise-versa.

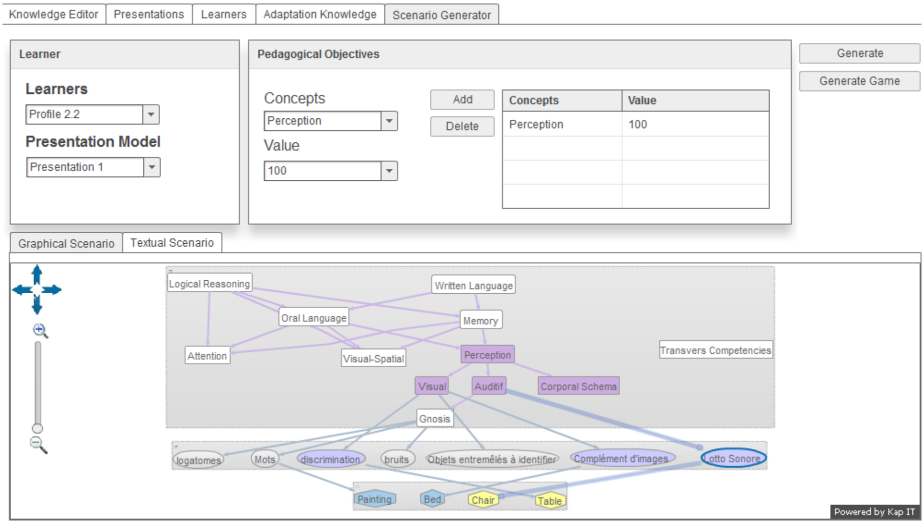


**Fig. 4.** One of the mini-model on the concept Perception

The whole time the expert was being filmed, with his permission, when he was fixing the values of the profiles. We were also asking the expert question regarding how he was assigning the values and why. Afterwards, we asked the expert to fix the pedagogical objectives for each profile. During this process we also asked questions about how and why he was choosing the pedagogical objectives. As a result of these questioning we discovered many things about the modeling of the domain model and how to select the right pedagogical objectives for a profile.

As soon as the profiles are created and the objectives are set, we introduced them into the system and generated the scenarios via the system. In the meantime, we asked the expert to create the learning scenarios manually. We asked the expert how and why he is selecting the concepts and the pedagogical resources for every profile. Afterwards, we asked the expert to compare the scenarios he created manually with those generated automatically.

The film that was made during the experimentation process is then analyzed by the video analyzing and annotation tool called ADVENE (http://liris.cnrs.fr/advene) [21]. The film made was about two hours long we saw it again and again annotating the important events in the video. These annotations were than analyzed and as a result we discovered some very interesting information. We found out some modifications to be performed in the domain model and some troubles were also detected in the concept selection strategy. In the domain model, we added 5 new relations between concepts, for example the addition of prerequisite relation between Memory and Oral Language. We modified also some concept selection strategy.

Furthermore, we also found that our system only takes into account the learner's profile while setting the pedagogical resources' levels; whereas; the expert was taking into account the *gap* between the profile and the pedagogical objectives. As a result of this evaluation we updated the knowledge models, and corrected the problems with our system. Finally, after the results shown to the expert, the expert seems sufficiently satisfied with the results. He also seems satisfied with the working of our generator.

## 8 Conclusion and Perspectives

In this paper we presented the working and the architecture of our system. This system is conceived to generate dynamically adaptable learning scenarios for serious games while keeping into account the learner's profile, learner's traces and specificities of serious games. The learner's interaction traces are used in the scenario generation and adaptation process and also while updating the learner's profile. This work took place in the Project CLES where the objective is to develop a serious game for children with cognitive disabilities. In this context, we conducted an evaluation for the verification of the scenario generation process. To conduct this evaluation, we presented an evaluation protocol that we've followed during the evaluation process. Our evaluation was based on comparative strategies and is designed to identify whether the problem exists in the expert's knowledge introduction into the system or in the generation of the scenario, when the expert is not satisfied with the scenario. Moreover, there is also the possibility that the problem exists in both the expert's knowledge introduction and system's generator. However, we pinpointed the problem correctly. However, we can face this problem with future evaluations.

For our future evaluations, we'll like to repeat the process with a number of experts to further verify the system. The tests with real learners will also be conducted to generate real learner traces and then use them to update their profiles. Furthermore, we'll also use them to adapt the scenario if necessary.

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