Adaptive and context-aware scenarios for technology-enhanced learning system based on a didactical theory and a hierarchical task model

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Abstract. Among the main issues of future technology-enhanced learning systems, we can mention the following ones: the ability to reuse learning resources (learning objects, tools and services) from large repositories, to take into account the context and to allow dynamic adaptation to different learners based on substantial advances in pedagogical theories and knowledge models. In our framework, the goal of scenarios is to describe the learning and tutoring activities to acquire some knowledge domain (for instance physics) and know-how to solve a particular problem. The main contribution of this paper is an adaptive and context-aware model of scenario based on a didactical theory and closely related to a domain model, a learner model, a context model. These models are acquired from: i) the know-how and real practices of teachers in a problem-based learning approach in a particular framework: an institution IUFM, different categories of probationary teachers, a course about "the air as gas in its static and dynamic aspects: properties, theory and applications"; ii) the theory in didactic anthropology of knowledge of Chevallard [1]; iii) a hierarchical task model.

Keywords: Adaptation, context-aware, didactical theory, model of scenario, hierarchical task model, Task/Method paradigm.

1 Introduction

Among the main issues of future technology-enhanced learning systems, we can mention the following ones: the ability to reuse learning resources (learning objects, tools and services) from large repositories, to take into account the context and to allow dynamic adaptation to different learners based on substantial advances in pedagogical theories and knowledge models [2].We are interested in technology-enhanced learning systems using a problem-based learning approach, represented by scenarios. In our framework, the goal of scenarios is to describe the learning and tutoring activities to acquire some knowledge domain (for instance physics) and know-how to solve a particular problem. A scenario may depend on several dimensions which describes different learning situations (in some way): the learning domain (course topic), the learner (his know-how and knowledge levels), the tutor/teacher, the learning and tutoring activities (their typology, organization and coordination), the activity distribution among learners, teachers and computers, the learning "procedures" according to a particular school / institution / university and the didactical/pedagogical environment. In order to deal with the broadest range of learning situations, it is necessary to design adaptive learning systems which have the ability to take into account these dimensions. Nevertheless, research on the learning scenario models leads to the standardization of pedagogical approaches - for instance IMS LD [3]. These models require authors/teachers to produce generic and standard models which are neutral on a pedagogical and/or didactical point of view [4]. For instance, learner and tutor activities and adaptation cannot be sufficiently accommodated. It is not possible to specify the management of knowledge and know-how levels of the learners according to the knowledge domain and the context. In other words, these scenario models are unable to deal with the different dimensions previously introduced.

The main contribution of this paper is an adaptive and context-aware model of scenario based on a didactical theory and closely related to a domain model, a learner model, a context model. These models represent the different dimensions and are acquired from: i) the know-how and real practices of teachers in a problem-based learning approach in a particular framework: an institution IUFM[1], different categories of probationary teachers, a course about "the air as gas in its static and dynamic aspects: properties, theory and applications"; ii) the theory in didactic anthropology of knowledge of Chevallard [1]; iii) a hierarchical task model. A co-design methodology has been used to articulate teacher real practices, the Chevallard theory and the hierarchical task model to define the different models [5]. The hierarchical task model enables us to define the learning and tutoring activities, the activity distribution among learners, teachers and computers and also to transpose the main concepts of the Chevallard theory. The context model implements the didactical environment acquired from the Chevallard theory and the teacher real practices and know-how.

First of all, we briefly present the MODALES project in which our research takes place. Secondly, we present the main contributions of the didactic anthropology of knowledge of Chevallard theory in the acquisition teacher real practices and know-how. Thirdly, the computer-based model of scenario is presented and detailed. Finally, the conclusion highlights the main results of this study and point out the next research issues.

2. The MODALES Project

The MODALES project is aimed at designing an adaptive learning system for probationary teachers, based on real practices and teacher know-how. The course topic is about "the air as gas in its static and dynamic aspects: properties, theory and applications" for different categories of learners. They are probationary teachers:

[1] IUFM : Institut Universitaire de Formation des Maîtres

primary school teachers (called PE for “professeur des Ecoles” and secondary school teachers (called PLC for “professeur des Lycées et Collèges”: earth/biology sciences and physics. The teachers are considered as experts in education. In MODALES, scenarios may change according to the following features: i) the category of learners having intra and inter category variability; ii) the available resources from different domains - physics, didactic and epistemology - which can be determined by teachers iii) distance or face-to-face activity according to learner needs, learning policy and didactical environment constraints iv) the sharing of activities between teachers, learners and computers according to learner needs and learning policies. The main issue is to design a generic scenario which can deal with the broadest range of learning situations (from a computer science viewpoint).

3. Acquisition of teacher practices and know-how

Firstly, several scenarios based on a common learning scenario P_o (whose variables are learners, the expert teacher and the available resources) were built [6].

Secondly, we use the theory in didactic anthropology of knowledge of Chevallard to go further [6]. The praxeology system ($T/\tau/\theta/\Theta$) of the Chevallard theory enables us to acquire the scenario model and the didactical environment. According to Chevallard, teacher and learner activities can be described in terms of types of tasks T_c achieved by techniques τ which may be recursively achieved by subtasks $T_{c'}$. Thus, a Task/Technique system (T/τ) has a hierarchical structure. This hierarchical structure (T/τ) defines a know-how that leans on an environment composed of a technology θ (discourse that justifies and explains techniques) and a theory Θ justifying and highlighting the technology. In other words, a Task/Technique system (T/τ) describes a type of problem (T) to solve and the technique (τ) describes how to solve it (T).

We can observe six different moments in the didactical organization [1]: i) the first encounter with the type of tasks T_c (M1); ii) the exploration of the type of tasks T_c and the construction of techniques τ (M2); iii) the technique work that improves the technique and makes it more efficient (M3); iv); the construction of a Technology/Theory related to technique τ (M4) v) the institutionalization of the system ($T/\tau/\theta/\Theta$) by the teacher (M5); vi) the evaluation (M6) (cf. Figure 1). For a given technique, a task can be decomposed into sub-tasks which are achieved according to specified operators. At present, three different operators are used: sequence, alternative and parallel.

Moreover, the scenario analysis shows different categories of learning and tutoring tasks, organized at different levels of the task hierarchy: scenario, phase, moment, learning task, routine task and tutoring task. A scenario is generally composed two phases: 1) Phase 1: construction of professional references for teaching (cf.figure1), 2) Phase 2: development of a training sequence implemented in classrooms.

The adaptation of scenarios leads to choose the relevant technique according to the learners and the didactical environment. According to the Task/Technique system, the choice can be done by the computer, the learner or the teacher. The selection of the relevant technique depends on the following properties: the Task/Technique system, the learner category (PE, PLC, type of PLC, etc.), the learner curriculum and the didactical environment. From the Chevallard theory and the teacher real practices and know-how, we define the didactical environment as follows: type of classrooms (virtual classroom, scientific laboratory with or without computers and/or with or without internet access, associated CITT2 tools (chat, email, forum, etc.), technical instruments (thermometer, barometer, etc.), resources (documents, experiments, etc.) and face to face or at distance.

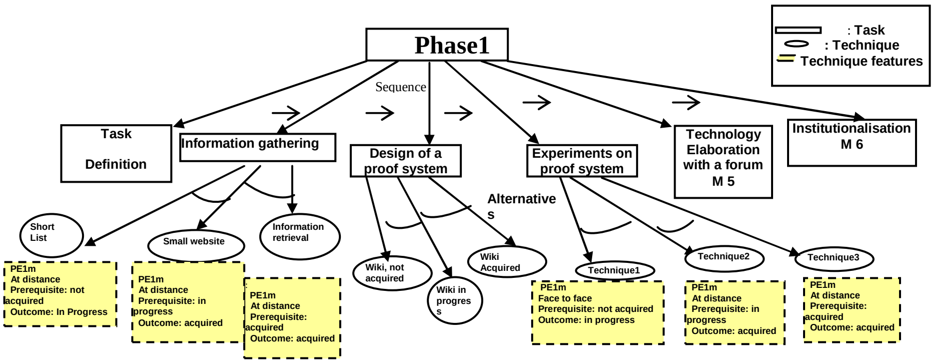

Figure 1. Description of the phase 1 for a PE learner.

First of all, we explain how the learner and the technique properties are used to choose the relevant technique in a given didactical environment. Secondly, we detail the different roles of the didactical environment features.

To illustrate the Chevallard's theory and its concepts, we choose a particular case study for a PE learner in which we detail the task "phase 1" composed of several sub-tasks. Some of them have alternative techniques. We assume the learner states for the concepts "P", "V" and "T" are "acquired" (otherwise more techniques must be added and consist of sub-tasks dedicated to the acquisition of the corresponding knowledge).

The course topic is about "the air as gas in its static and dynamic aspects: properties, theory and applications". In the Chevallard framework, the considered theory is thermodynamics. In physics, theories can be "evaluated" by means of different laws. In our case, it is the Boyle-Mariotte law which is represented as follows (PV/T = K) for PE Learners. The knowledge domain is composed of the thermodynamic theory, the corresponding laws, the related concepts (Pressure P, Volume V, and Temperature T) and their relationships. To deal with the learner knowledge and know-how levels, the knowledge domain entities (theories, laws, concepts and relationships) and the type of tasks may have three different states: "not acquired", "in progress", "acquired". For a given type of task, the state "not acquired", correspond to the moment M1 and the states "in progress" and "acquired" correspond respectively to the moment M2 and M3. After a successful evaluation task, a teacher or the computer can update the learner know-how and knowledge levels for some domain entities and for a task, for instance from "in progress" to "acquired" if the corresponding know-how is considered as acquired.

In Figure 1, several techniques are annotated with the knowledge and know-how levels: the prerequisite and outcome states of the learner. When it is the first encounter of the type of task "experiments on proof system", the corresponding

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learner state is “not acquired”. Thus, the relevant technique is “Technique 1”. After a successful evaluation sub-task, his outcome state will be “in progress” for the task. When the learner state for the type of task “experiments on proof system” is “in progress”, the relevant technique is “Technique 2”. After a successful evaluation sub-task, his outcome state will be “acquired” for the task. If the evaluation task fails, a remediation task is used (not described in figure 1). The type of task “experiments on proof system” can be worked several times a year in different modules about astronomy, thermodynamic, etc. in physics. Thus, the relevant technique may change according to the moment at which the type of task “experiments on proof system” is worked in a particular module. Thus, several alternatives are provided for a given type of task.

From the didactical environment, we firstly explain the role of the technical instruments. An historical and epistemological analysis of several historical and didactical situations shows that laws in physics are tested by means of technical instruments [7]; For instance, the technical instruments could be a thermometer and a barometer or a simulation tool. Thus, the learners must have or acquire know-how to use these technical instruments to solve the problem related to the task “phase 1”. Whether the learner state for these tasks “temperature and pressure measurements” are “not acquired” or “in progress”, the relevant technique must have the corresponding prerequisite states and must consist of sub-tasks dedicated to the acquisition of the corresponding know-how.

The “face to face” or “at distance” feature change the Task/Technique system and the activity distribution among learners, teachers and computers. It is the same for the type of classrooms and the CITT tools. Moreover, some specific know-how may be assumed (internet access and information gathering, forum, chat, etc.) to achieve communication tasks or information retrieval tasks. Thus, such know-how must be routine tasks or at least acquired. Otherwise, it is necessary to have sub-tasks to acquire such know-how.

In conclusion, we show that, it is necessary to describe the different techniques according to the learner and the didactical environment features to be able to choose the relevant technique.

4. Adaptive and context-aware model of scenarios

From the acquisition of teacher real practices by means of the Chevallard theory, the didactic-based scenario model is transposed into a computer-based hierarchical task model. Firstly, we describe and justify the transposition of the Task/Technique systems and their hierarchical structure. Secondly, we analyze the representation of the typology of learning and tutoring activities. Finally, we show how the adaptation is formalized according to parameters describing the learner, the context.

Teaching and learning activities of scenarios have been described in terms of type of tasks T_c and techniques τ. The type of tasks T_c describes the teaching and learning activities, while techniques τ describe a way of achieving the types of task T_c. We transpose the resulting Task/Technique system (T_c/τ) in the task/method paradigm of the hierarchical task model. Therefore, we can represent in these model, the Task/Technique system (T_c/τ) of Chevallard [1] fitted with its hierarchical structure and didactics properties describing scenarios while we preserve its initial properties and semantics.

Several research studies in AI[3] focus on the hierarchical task model using the tasks/method paradigm [8-12]. The mechanism of hierarchical and recursive decomposition of a problem into sub-problems is one of the basic characteristics of the hierarchical task model [8-12]. The hierarchical task model consists of abstract and atomic tasks and methods. In a particular task, a method represents the various ways of achieving this task. A method describes the decomposition of its task into sub-tasks. The execution of these sub-tasks is done through a control structure which is composing of the following operators: sequence, parallel, choice. Their respective specifications are quite the same as those of 'seq', 'par' and 'alt' presented in the paragraph 3. Thus, an abstract task can be broken down into abstract or atomic sub tasks through its associated methods. An atomic task is not composed of sub-tasks. It can be achieved by a simple procedure – for instance, an information retrieval process, a particular human computer interaction, etc. The task/method paradigm has respectively a semantic and a hierarchical structure similar to those of the Task/Technique systems (T_c/τ) of Chevallard. Moreover, we have to refine the task and method concepts of our model (specialization) to take into account adaptation and sharing of activities.

The typology of tasks of our computer-based model identifies the various types of tasks T_c which compose the scenarios described in paragraph 3: scenario, phase, moment, learning tasks, routine tasks, tutoring tasks.

These types of tasks are transposed in the computer-based model and are respectively named «ScenarioTasks», «PhaseTasks», «MomentTasks», «LearningTasks», «RoutineTasks», «RoutineTasks». One of the main criteria of the formalization of tasks is their atomic character or not - respectively abstract or not. The tasks «ScenarioTasks», «PhaseTasks», «MomentTasks», «RoutineTasks» are represented by abstract tasks since a scenario consists of two phases which are broken down into moments while each moment consists of learning tasks, routine tasks, and/or tutoring tasks. Tasks «LearningTasks» are also represented as abstract tasks, because they represent a Task/Technique system which can be broken down into others sub Task/Technique systems. Tasks «RoutineTasks» are only composed of atomic tasks. The tasks «TutoringTask» are atomic tasks. They correspond to tutoring activities of the teacher or of the computer system. In both cases, these tasks are seen as "simple procedures".

From the Chevallard theory viewpoint, the relevant technique must be selected according to the current learner and the didactical environment. From a computer-based viewpoint, the adaptation process can be viewed as the selection of the relevant method which represents the Chevallard concept of techniques. It aims at a dynamic selection of the relevant methods according to the context and the current learner. The know-how and knowledge levels of the learner are represented by an overlay model [13] associated to the learner model as described in the paragraph 3.

The context model represents the didactic environment as described in the paragraph 3. It is described by the type of classroom in which the learning activities will take place, the associated CITT tools and devices, a list of technical instruments which are a subset of those in the domain, "face-to-face" or "at distance". The domain

[3] Artificial Intelligence

model consists of the thermodynamic theory, the corresponding laws, the related concepts and their relationships. The learner is described by his curriculum, his category (PE, PLC, type of PLC, etc.) and his knowledge and know-how levels (an overlay model): a set of states ("not_acquired", "in_progress", "acquired") for some domain entities and know-how (tasks). These states are assigned to the learner and are updated.

The context, learner and domain models will be represented by means of ontologies within SCARCE (SemantiC and Adaptive Retrieval and Composition Engine) environment [14]. The adaptation process in SCARCE consists of two stages: firstly, resources are evaluated and classified in one equivalence class according to class membership rules. In this paper, we only need two equivalence classes ("good" and "bad"); secondly, one adaptation technique is chosen for the current learner (annotation, hiding, sorting, direct guidance, etc.). All methods, belonging to the class "good", are selected for the learner. The membership rules define necessary and sufficient conditions to belong to an equivalence class. Rules are declarative predicates using context, learner and method features (which are binary relationships).

Thus, let T_a be a task, Ci be a context, L be a learner, SL the current set of states describing the knowledge and know-how levels of L. The adaptation process is as follows:

1) If SL does not have a state for the task T_a, the corresponding state is added to SL with value: $SL.T_a$ = "not acquired" (the task T_a does not be worked).

2) Membership rules: all methods of T_a for which the context and the learner features match up to the corresponding method features (or "belong to" for multiple-valued features) belong to the class "good" and others belong to the class "bad".

3) If the class "good" is empty, it is considered as a problematic situation and required a teacher action to remediate or to provide a new method and context adapted to the learner and the task T_a. Otherwise, all methods, belonging to the class "good", can be provided to the learner.

5. Conclusion

The design of technology-enhanced learning systems must be considered as a transdisciplinary problem requiring the integration of different scientific approaches - from computer science, didactic, education, etc. It is also necessary to take into account real practices of teachers. We propose an adaptive and context-aware model of scenario based on a didactical theory and closely related to a domain model, a learner model, a context model. The properties of the model presented in this paper have been acquired by means of a co-design methodology in which the real practices of teachers, knowledge and know-how are acquired by means of the theory in didactic anthropology of knowledge. Nevertheless, the model is not finished. At present, we only manage one category of adaptation. In other word, we need to continue the co-design process in order to precise the other adaptation categories and to refine the different models.

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