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A Pervasive Learning Design Methodology

Jihen Malek, Mona Laroussi, Alain Derycke, and Henda Ben Ghezala

A methodology to design innovative pervasive learning scenarios is essential since pervasive learning is a very innovative field and most pedagogical designers and teachers are unaware of its key concepts and utilities. Such a methodology requires radically new thinking about how and when using new mobile and pervasive technologies can enhance learning and teaching. We can present the challenges of designing pervasive learning on three levels: (1) the proposition of a modeling language; (2) the specification of a design process; and (3) the development of a supporting tool. Our research seeks to provide solutions at all three levels and proposes an innovative pervasive learning design methodology that aims to support pedagogical designers and teachers to model, generate and simulate pervasive, context-aware and adaptive learning scenarios. Our methodology is model-driven, iterative and incremental.

Keywords: Pervasive Learning, Adaptation, Context-Aware, EML - Educational Modeling Language, IMS-LD, MDD - Model-Driven Development, Technology-Enhanced Learning Design.

1 Introduction

Learners have changed radically with the arrival and rapid evolution of wireless networks and mobile technologies in the last decades of the 20th century. Nowadays students are no longer fitting into the classical educational system. Now, they spend most of their time surrounded by and using laptops, smart phones, video games and the toys and tools of the digital age as well as the pervasive environment in which computing systems are seamlessly integrated into their lives. It is now clear that as a result of this pervasive environment, nowadays students or digital natives [1] think and process information in a fundamentally different way from their predecessors.

If teachers really want to reach the new learners of today, they must take into account their new skills and need to reconsider both their methodologies and the content of their courses. Teachers need to be thinking about how to teach future content and adapt materials to the language of those new learners. But unfortunately a review of existing educational modelling languages - MISA [2], IMS-LD [3][4][5][6], EML [7][8], CPM [9] and their content authoring tools MOT+LD [10], RELOAD [11][12], LAMS [13] - shows that none of them supports pervasive and mobile computing related concepts. Our proposed methodology aims to help pedagogical designers and teachers invent, model, generate and simulate (without necessarily having the knowledge and skills of IT programmers) innovative context-aware adaptive, challenging and pervasive learning scenarios with an added value from a pedagogical standpoint.

Those new scenarios aim to ensure learners’ autonomy, motivation and challenge by experiencing various learning scenarios indoors and outdoors. They also aim to enhance interaction and collaboration through collaborative and chal-
Challenging context-aware learning activities that take place in different locations and at many stages and levels. Our methodology is model-driven, iterative and incremental. It is based on three components: the CAAML language, the pervasive learning design process, and the supporting tool (ContAct-Me).

This paper is organized as follows. Section 2 introduces a case study. Section 3 describes the levels and meta-model of the CAAML language, while the steps of the proposed pervasive learning design process are summarized in section 4. Section 5 presents the supporting tool ContAct-Me (CONText and ACTivity Adaptive Modeler for Malleable Learning Environments) while the evaluation of our work is described in section 6. Section 7 concludes the paper and suggests future research directions.

2 A Case Study

In order to illustrate how pervasive learning can be applied in a realistic scenario, we will start by introducing a case study.

A French high school decides to raise the awareness of pupils on the effects of pollution on the environment by organizing a trial as a follow-up to the pupils’ educational curriculum in the field of “Education about the environment”. This trial enables pupils to learn through factual cases and to experience various scenarios using pervasive and mobile technologies.

The physical settings of this trial, the where activities take place, are the school’s laboratory and an ecological zone in a nearby industrial area.

In order to boost intra-group competition, students were divided in three groups under the supervision of their coach and each group consisted of six pupils. Additionally, each group was divided in two subgroups of three students each, where one subgroup was working indoors in the laboratory of the school while the other group was outdoors in the field. The ultimate goal behind this clustering was to reinforce teamwork and collaboration within the individual subgroups. Only one group was conducting this activity at a time, which makes it a collaborative and challenging game that takes place in different locations and in four stages as follows:

- Plant sample picking and identification.
- Water treatment (the measure of pH and conductivity rates and the collection of water samples in appropriate containers).
- Soil analysis (soil sample gathering and identification).
- Plant characteristics analysis (verification of presence of toxic gases such as CO and CO₂) and plant preservation in the laboratory.

The outdoor subgroup was equipped with an iPhone with a GPRS connection. The indoor subgroup was equipped with a laptop computer and a Wi-Fi connection.

At the beginning of each of the first three stages, the outdoor subgroup had to identify and take a photo of a QR-code stuck to a tree. Instantly, a text adapted to the pupils’ level and pictures that visualize and describe the activities to accomplish in the current stage were displayed on the iPhone. To accomplish these activities, indoor and outdoor subgroups had to collaborate together. For example, in the first stage, the outdoor subgroup could take a photo of a plant and send it to the indoor group for identification through internet research.

After a pre-defined time of each stage, the subgroup would receive a stage-adapted quiz via an automatic text message. Pupils needed to write an answer using their iPhone and submit it. If the answer was correct, the system sent the instructions describing how to reach and identify the next QR-code of the next stage. If the answer submitted by the group was not correct, the system sent an alert to the coach informing him/her that pupils needed some support. The coach had to send them some hints.

Having completed the stages described above, the indoor subgroups received a list of activities for the fourth stage and were joined by their corresponding outdoor subgroups that were to hand over the picked plant samples.

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1 A QR-code is a specific matrix barcode (or two-dimensional code), readable by dedicated QR barcode readers and camera phones. The code consists of black modules arranged in a square pattern on a white background. The encoded information can be text, URL or other data.
The indoor team had to run experiments on those samples with a view to investigating the presence of toxic gases such as CO and CO\textsubscript{2}. They also had to preserve the samples under suitable temperature conditions. If the temperature were not appropriate, the system would interact with the smart object in which the plant sample was preserved in order to adjust it to the required experimental temperature.

At the end, each of the three groups had to draw their own conclusions and present the outcome of their study about the effects of pollution on the environment.

The following sections outline an approach that enables the development of this kind of pervasive e-Learning systems.

3 The CAAML Language

In a previous work, first we defined the notion of context as a set of evolutive elements appropriate to the interaction between learner and pervasive learning applications including the learner and the applications themselves. This set of contextual elements comprises the context of the interaction that can be divided into two classes: learner context and activity context [14]. Then, we proposed to widen the notion of adaptivity to take into account all possible interactions between context and learning activity, because they influence each other in learning processes [15]. This "bijective adaptation" or "co-adaptivity", which is a useful designation we have taken from the field of biology [16], aims to make things easier for the learner and create an adequate learning environment which helps him/her to concentrate better on his/her learning tasks.

The core of our proposed methodology consists of an Educational Modelling Language called CAAML (Context-aware Adaptive Activities Modeling Language). It is a visual modelling language that takes into account the concepts of context and co-adaptivity to provide a framework of elements that can design pervasive learning scenarios in a formal manner.

3.1 The CAAML Levels

CAAML is made up of four levels, where each level requires, extends and incorporates the previous one:

1. **Resources Creation Level** contains: Learning resources (document, course, file...), tools (smart object, sensors, mobile devices and their physical and software characteristics) and services (E-learning, M-learning and P-learning Services);

2. **Components Creation Level** includes the main components of the scenario: Contexts (static or dynamic) and their acquisition sources (sensors), roles, persons, outcomes and activities (Learning or coaching activities) and each activity must refer to its outcome and relevant contexts;

3. **Scenario Creation Level** contains the core of the CAAML Meta-Model: the Pervasive Learning scenario Description (Community, objectives, pre-requisites, outcome) and the coordination between the components like learners, coaches, activities, outcomes and contexts. This simply provides a series of context-aware learning activities to be performed by learners or coaches using Pervasive Learning Resources;

4. **Co-adaptivity Level** adds up better control and adaptation through the use of Co-adaptive rules allowing the adaptivity of activities to context and vice-versa. This level offers also the opportunity for more sophisticated learning designs through notifications (messaging), which allow for notification of new activities to be triggered automatically in response to events in the learning process. For instance, a coach may be notified by email that a pupil needs some support if his submitted answer is not correct. The coach should send him/her some hints.

3.2 The CAAML Meta-Model Structure

The CAAML meta-model describes a learning scenario as being a composition of several phases. Each phase includes role-parts (activities and their relevant contexts) as shown in Figure 1.

The context can be:

- Static: does not change during interaction (e.g., season, student’s name);
- Dynamic: changes during the interaction (e.g., noise level, temperature...). A dynamic contextual element can be directly acquired through "embedded environmental sensors" or "mobile device sensors".

The CAAML meta-model defines two classes of "co-adaptivity rules": rules for adaptivity of context to activity and rules for adaptivity for activity to context. A rule is based on a context to trigger the appropriate co-adaptivity actions. Rules have the basic format:

" Those new scenarios aim to ensure learners’ autonomy, motivation and challenge by experiencing various learning scenarios indoors and outdoors "

Our methodology is model-driven, iterative and incremental "
IF [expression] then [show, hide, change-context value or notify someone]

The expressions are mostly defined in the context of the interaction between application and learner. An action is performed according to the success (true) or failure (false) of the condition. The action is to show or hide activities, change context value or notify someone.

With notification it is possible to send a message to a role based on certain events:
- The completion of a certain activity;
- The completion of a certain phase;
- When an expression in a certain condition is true;
- When a certain context value has been changed.

The CAAML meta-model also defines components related to pervasive learning environments such as "smart objects", "sensors" and "mobile or pervasive services".

4 A Pervasive Learning Design Process

The proposed learning design process organizes the design of pervasive learning scenarios into three steps (specification, modelling and simulation) and each includes a variety of tasks that take place during the process.

4.1 Specification

The specification of new pervasive learning scenarios is done through a top-down approach containing three levels of abstraction and consisting of breaking down a scenario into its compositional phases. Each phase is then refined in yet greater detail, into many learning activities. And for each level (scenario, phase and activity), the pedagogical designer must extract the required structure, resources, components and co-adaptive rules. This specification is done first through a textual description and then through a UML activity diagram.

4.2 Modelling

This includes two major tasks: design and CAAML/IMS-LD models transformation:

Task 1: Design. The major steps of this task are:
1. Creation of a learning design (specifies the title, learning objectives, prerequisites and outcomes of learning scenario);
2. Creation of different levels of the CAAML language (resources, components, scenario structure and co-adaptivity rules);
3. Generation of an exploitable description of the CAAML model in XMI format.

Task 2: CAAML/IMS-LD models transformation. In order to ensure the interoperability of the designed activities across different learning platforms, this module transforms models represented in CAAML language into executable models represented in the IMS-LD standard [4].

4.3 Simulation

Through this module, the teacher should perform the following tasks:
Supporting Tool: ContAct-Me

ContAct-Me (CONText and ACTivity Adaptive Modeler for Malleable Learning Environments) is a pervasive learning design tool based jointly on the CAAML language and the proposed process. It is implemented through an MDD approach (Model-Driven Development). It aims to help pedagogical designers to model and simulate context-aware adaptive learning scenarios using friendly interfaces.

To implement ContAct-Me, we used:
- Domain-specific modelling Eclipse Tools (EMF and GMF) to develop the graphical modeller.
- The ATL transformation language to transform the CAAML generated models into IMS-LD models.

1. Generate an automatic mobile interface for each phase of the pervasive learning scenario based on the generated CAAML model or the IMS-LD model.
2. Model the execution environment of the simulation.
3. Place smart objects and sensors (defined in the CAAML model) in the appropriate zones of the pervasive learning environment.
4. Launch the simulation of the execution of the pervasive learning scenario in run time thanks to co-adaptivity rules defined in the CAAML model. The simulation shows interactions and co-adaptivity between the generated mobile interfaces and the context (the surrounding pervasive learning environment).

5 Supporting Tool: ContAct-Me

The core of our proposed methodology consists of an Educational Modelling Language called CAAML (Context-aware Adaptive Activities Modeling Language)
XSLT and XHTML-MP to generate mobile user interfaces.

- The context simulator DIASIM and the DiaSpec language to simulate the execution of the modelled malleable learning scenario: we integrated this simulator in ContAct-Me.

The architecture of ContAct-Me includes three interrelated modules (see Figure 2): the graphical modeller, the CAAML/IMS-LD models transformation module, and the simulator of pervasive learning scenarios module [16].

5.1 The Graphical Modeller
Through this module based on the CAAML meta-model, the teacher or the pedagogical designer can:
- Model different levels of the CAAML language (resources, components, scenario structure and co-adaptivity rules). Figure 3 shows a snapshot of the tool concerning the edition of a co-adaptivity rule related to the case-study.
- Generate a CAAML model in XMI format. Figure 4a shows an example concerning the resources section for the case-study.

5.2 The CAAML/IMS-LD Models Transformation Module
This module transforms models represented in CAAML language into executable models represented in IMS-LD. This is done such that IMS-LD complexity is hidden by the use of concepts related to context-awareness.

IMS Learning Design (IMS LD) is a specification for a meta-language which enables the modelling of learning processes. The specification is maintained by IMS Global Learning Consortium [4].

Regarding the technical details, in ContAct-Me the CAAML meta-model is represented in ECore, while the transformation from CAAML to IMS-LD is encoded in the ATL transformation language. Thus, the transformation module is composed of a set of ATL rules (see Figure 4b). Each rule defines the way an input element (that is a given type of entity of the input model) is transformed into a target element (that is a given type of entity of the output model).

5.3 The Pervasive Learning Scenarios Module Simulator
Based on the CAAML models generated by the graphical modeller, this module allows the teacher to perform the tasks (described in Section 4.3) of the simulation step.

Figure 5 shows a snapshot of a simulation scenario concerning the case-study. In order to enable such a simulation, we generated corresponding mobile interfaces for each phase of the pervasive scenario. Then we defined the parameters of the simulation, which enabled us to execute such a simulation.

“ContAct-Me (CONText and ACTivity Adaptive Modeler for Malleable Learning Environments) is a pervasive learning design system that we used as support tool”
In future works we will attempt to boost the game approach in learning as recommended by the teachers and designers that assessed the ContAct-Me system.

6 Evaluation
As pervasive learning is a very innovative field and most pedagogical designers and teachers are unaware of its key concepts and utilities, in order to assess the ContAct-Me system, we chose teachers with extensive experience in using e-Learning platforms and in creating learning activities in accordance with the IMS-LD standard through different authoring tools.

At the beginning, we briefed the pedagogical designers and teachers on pervasive learning and its basic concepts such sensors, smart objects, QR code, context and co-adaptivity... and described the proposed scenario. They were then allowed to explore different modules of the ContAct-Me system while being provided with assistance. The goal was to evaluate the system from the graphical, ergonomic and functional point of view.

(a)
```xml
<Resources>
  <Tool identifier="iphone" xsi:type="MobileDevice"/>
  <Tool identifier="Qr-code 1" xsi:type="SmartObject"/>
  <Tool identifier="Qr-code 2" xsi:type="SmartObject"/>
  <Tool identifier="Qr-code 3" xsi:type="SmartObject"/>
  <Tool identifier="Fridge" xsi:type="SmartObject"/>
  <Tool identifier="localisation_Sensor" xsi:type="Sensor"/>
  <LearningResource identifier="" xsi:type="LearningResource">
    <File href="Pollution course"></File>
  </LearningResource>
  <LearningResource identifier="quiz1" xsi:type="test">
    <description Quiz1"></LearningResource>
  </LearningResource>
  <LearningResource identifier="quiz2" xsi:type="test">
    <description Quiz2"></LearningResource>
  </LearningResource>
</Resources>
```

(b)
```java
rule Learner2Learner {
  from
    s: caaml!LearnerRole
  to
    t: ims!LearnerRole {
      identifier <- s.identifier,
      title <- s.title
    }
}
rule Coach2Staff {
  from
    s: caaml!CoachRole
  to
    t: ims!StaffType {
      identifier <- s.identifier,
      title <- s.title
    }
}
```

Figure 4: (a) Excerpt from the XML Encoding concerning Resources; (b) Some Rules of the CAAML/IMS-LD ATL Transformation.
By going through the graphical modeller, the teachers appreciated:

- The user-friendly graphical interfaces as well as the workflow of the different steps, from resource creation to CAAML model generation.
- The creation of context-aware activities.
- The structure of the scenario creation, based on phases allowing the creation of game-oriented learning scenarios.
- Their involvement in the specification of adaptivity in design time, unlike other authoring tools which are not based on context-aware activities.
- The possibility to export the CAAML model into IMS-LD format in a very smooth manner.

From the simulator standpoint, they appraised the model-driven automatic generation of mobile interfaces that corresponds to different phases without necessarily having the knowledge and skills of IT programmers. Furthermore, they enjoyed the output of the simulation run of their own designed works.

Along this experience, the teachers did not feel comfortable with the high number of new concepts that are not in common use and the necessity to get assisted to run the system.

7 Conclusion and Further Works

In this paper, we proposed a pervasive learning design methodology to support pedagogical designers and teachers, and to model, generate and simulate pervasive, context-aware and adaptive learning scenarios.

Our methodology is based on three components: the CAAML language, the design process, and the supporting tool ContAct-Me. The latter is based on an MDD (Model-Driven Development) and takes into account context and co-adaptivity rules.

In order to ensure the interoperability of the designed activities across different learning platforms, this tool transforms models represented in CAAML language into executable models represented in IMS-LD in such a way that the IMS-LD complexity is hidden by the use of concepts related to context awareness.

As the IMS-LD standard does not yet support mobility and its players do not allow the execution of mobile activities in real time, the community of researchers actively working on this standard should find effective solutions to accompany the great steps forward made in mobile and pervasive learning.

Finally, in future works we will attempt to boost the game approach in learning as recommended by the teachers and designers that assessed the ContAct-Me system.

References


