A Context-Aware Framework to Provide Personalized Mobile Assessment.

Ahlem Harchay[1], Lilia Cheniti-Belcadhi[2], Rafik Braham[3]

[1] PRINCE Research Group ISITCom, University of Sousse, Tunisia,
ahleminf@yahoo.fr

[2] PRINCE Research Group ISITCom, University of Sousse, Tunisia,
lilia.belcadhi@infcom.rnu.tn

[3] PRINCE Research Group ISITCom, University of Sousse, Tunisia

Abstract. In mobile learning environments, context-aware systems refer to applications that employ contextual information to provide appropriate services to the leaners or other applications to perform a specific task. An important challenge in such applications is context modeling, using ontologies to model context information and to reason about context at a semantic level. Semantic Web technologies have been applied in recent years with different purposes in education. But their applications for generating useful personalized mobile assessment resources have not been researched enough so far.In this paper, we introduce a context-aware approach that makes use of Semantic Web technologies to support personalized assessment in mobile environments. We propose a Service-based framework for bringing assessment techniques to a mobile environment. We provide a formal description for our mobile assessment framework and detail the functionalities of its various layers. We have carried out also an experiment with computer science students to determine the degree of their satisfaction.

Keywords: Personalized assessment, Semantic Web, Ontologies, Mobile environments, Web Services.

1 Introduction

Recent years have seen an important increase in the use of mobiles devices promoted by the continuous development of Web-based learning. Assessment is one of learning activities that can be completed electronically and via mobile devices. Mobile assessment is defined as an assessment activity that involves mobile technologies and other mobile applications [1]. Web-based assessment presents today many challenges. The design of a mobile assessment system should take effective personalization

approaches to provide learner orientation efficiently. Moreover, this task becomes exhausting if the learner has a large amount of questions. Nevertheless, providing learners with personalized mobile assessment tests may be considered as an important issue given the need for learners in a mobile environment. Therefore, it requires the development of new methodologies for supporting such process.

On the other hand, context-aware mobile learning is an important requirement for next generation intelligent e-learning systems. The goal of many research works in this field is to develop mobile environments capable of providing useful learning and assessing resources on demand, anywhere, in a learner-driven context and on a learner's schedule. Context-aware mobile learning is considered as an important requirement for effective design of e-Learning systems. It is particularly important in m-Learning because the application of mobile learning context is highly dynamic [2]. Context-aware application in mobile environment can adapt operation to the current context and be more effective. Works have gone into developing infrastructures that enable applications to be context aware (see for example [4] and [5]).

In this research work, we focus on describing our vision of a generic personalized mobile assessment framework enabling assessment personalization in a mobile environment. In this framework, ontologies are used to model context. Alternatively, a Web Services-based framework illustrating the main functionalities of the personalized mobile assessment is investigated. The architecture integrates independent mobile assessment and personalization services without the need of centralized control.

The remainder of this paper is structured as follows. Section 2 gives an overview of our proposed framework. Section 3 describes our proposal in the assessment context layer. The assessment resources layer is presented in section 4. Section 5 describes the semantic layer and reveals the validity of our framework by illustrations of use. Section 6 presents the experiments that we have carried out. Section 7 discusses some related works and Section 8 summarizes the main results and gives some directions for ongoing and future work.

2 PMAF: A Personalized Mobile Assessment Framework

The need for managing context information impels the incorporation of facilities to deal with learner's needs in mobile assessment situations [6]. Learners are different in their abilities, needs, and profiles. These variances should be taken into consideration when designing an intelligent assessment process. In mobile environments, self-assessment is an effective strategy to help learners perform self-regulated learning.

To achieve this objective, we propose a framework that supports the development, description and publication of personalized mobile assessment resources. Our goal is to offer relevant and suitable information depending on the user's particular context. Thereby, personalized mobile assessment utilizes mobile Web-based services framework to deliver assessment resources. It allows to generate automatically assessment questions and to receive corresponding responses. The framework implements a pragmatic use of Web Services and semantic Web technologies. Indeed,

Web services provide access to various data repositories, compose and invoke other Web services. Ontologies are also used to search and to select appropriates assessments resources relevant to learner's profile and skills.

Figure 1 illustrates an overview of our framework main layers. Each one describes our proposal to a given stage of the personalized mobile assessment tests generation.
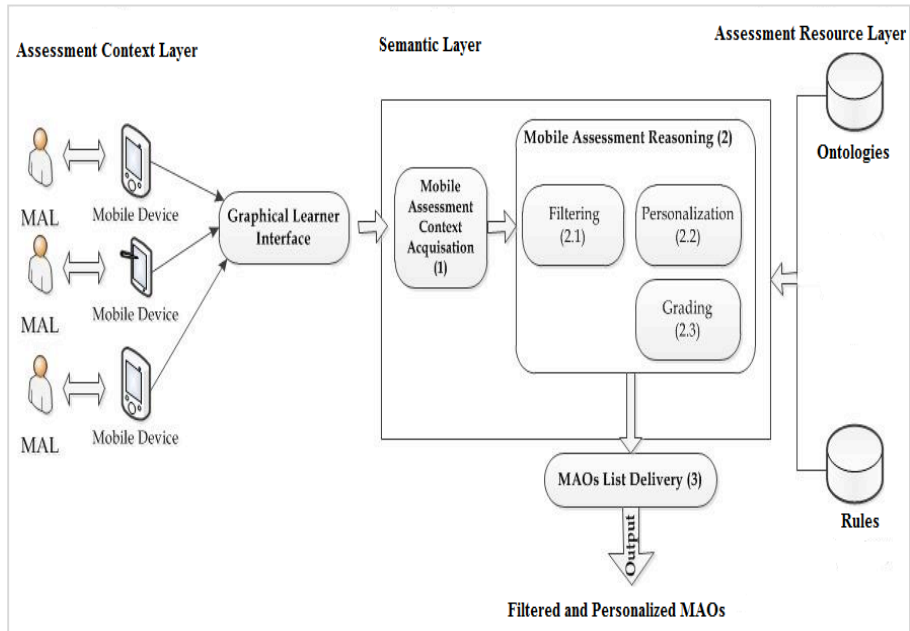

Fig. 1.. Personalized Mobile Assessment Framework main Layers.

The proposed framework consists of three layers:
- *Assessment Context Layer*: interacts with learners via portals.
- *Semantic Layer*: contains a core system and has three sub-Layers: (1) Mobile Assessment Context acquisition, (2) Mobile Assessment Reasoning, and (3) Mobile Assessment List Delivery.
- *Assessment Resources Layer*: contains reasoning rules and modeling ontologies.

The following sections will concentrate on a detailed description of each layer.

3 Assessment Context Layer

Assessment Context Layer is the main gate of the system with learners. It is responsible for preparing dynamic output and calling the suitable web page to display

data. This layer creates the interface description on a request received from the learner based on the available assessment context dimensions.

For more details, we present a use case scenario to motivate our work and to illustrate information captured by the Assessment Context Layer.

Consider the following situation: a student is on **the bus** on her way to the campus and decides to take advantage from this idle time and uses her **iPhone** to connect to PMAF. The learner interacts with a learner interface where he/she specifies the assessment activity topic (**Object Oriented Programing**), the related keywords (**class, object, and heritage**), the local type (**public noisy**), and the given time to solve questions **(30 minutes).**

Assessment Context layer manages information data related to the learner profile (prerequisites and competence), the used device and the accessed GLI (Graphical Learner Interface). Figure 2 shows the learner interface allowing to access to the PMAF. The learner interface allows specifying required data to generate personalized mobile assessment tests. The Responsive Web Design is used as a Web design approach allowing web applications to provide an optimal viewing experience across a wide range of devices.
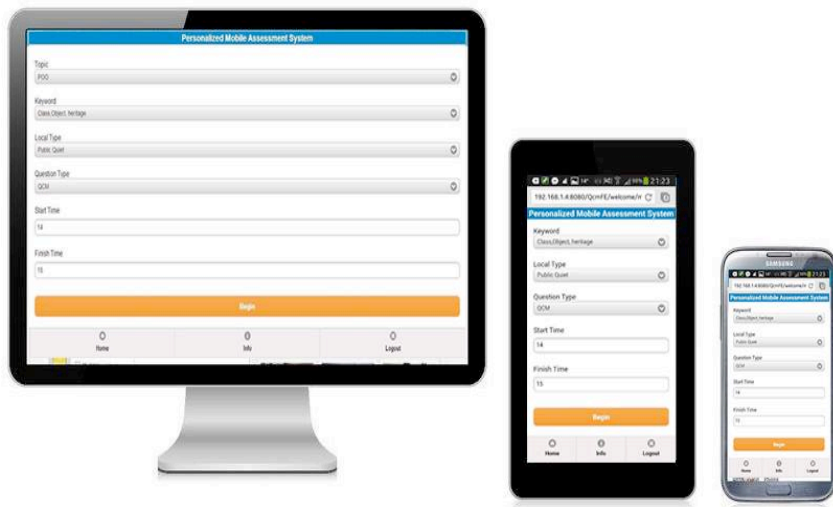

Fig. 2.. Graphical Learner Interface shown in several devices types.

4 Assessment Resource Layer

The Assessment Resource layer contains used ontologies and logical rules. This layer communicates with the Semantic Layer to deliver personalized mobile assessment tests.

Based on the above use case scenario, we need to describe learner's Mobile Assessment Situation [6]. Therefore, to implement the semantics of PMAF, we propose a set of ontologies [8]:

- Mobile Assessment Object (MAO) ontology: it represents the metadata ontology. It provides the common structure of metadata to index the content of a mobile assessment object. The MAO ontology is inspired from IMS/QTI specification to model a MAO. It refers to the ALCoM-Core ontology to model MAO content [11].
- Mobile Assessment Learner (MAL) ontology: it is used to model a learner in a mobile environment. It is based on the use of IMS/LIP specification. It deploys also FOAF and SIOC ontologies in order to model learners' social dimension.
- Mobile Assessment Context (MAC) ontology: it provides contextual information that allows a learner to be described in a Mobile Assessment Situation.
- Mobile Assessment Portfolio (MAP) ontology: it contains information allowing to characterize assessment activities history and to save learners' interactions.
- Mobile Assessment Domain (MAD) ontology: it represents domain knowledge in which assessment activities will be applied.

Such ontologies include the knowledge that the learner has to acquire in a particular domain and provide the semantic context for the generation of mobile assessment.

In the following, we give details concerning the MAC ontology as it regroups MAO and MAL ontologies.

In literature, several definitions were attributed to the context notion. Our vision on context is oriented towards the definition given by Dey & al.: *Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves* [18].

We understand context as description of learner's current situation, which is characterized by their identity, their prerequisites, their levels, the device they are using to access information, where they are at the moment, the assessment items, and any information relevant to these aspects. The MAC ontology defines characteristics related to the deployment of mobile assessment activities. It provides contextual information that allows a learner to be described in a Mobile Assessment Situation.

A Mobile Assessment Situation is a set of contextual information defined in a specific period of time:

$$MAS = \{MAC, Initial\ time, Final\ time\}\ with:$$

- MAC = {*MAL, MAO, spatial dimension, temporal dimension, mobile device*}.
- Initial time: start time of MAS.
- Final time: finish time of MAS.

As shown in Figure 3, MAC ontology is characterized by five essentials dimensions:

- *The temporal dimension*: to specify the start and the finish time of an assessment activity.
- *The spatial dimension*: to identify the assessment activity location.
- *The mobile device*: to detail the used device. The W3C's CC/PP (Composite Capability/Preference Profiles) specification [12] is used to model the device.
- *The Mobile Assessment Learner*.
- *The Mobile Assessment Objects*.

The Protégé tool is used to build the all ontologies used to implement the semantic of the framework. Figure 3 shows the Mobile Assessment Context ontology.
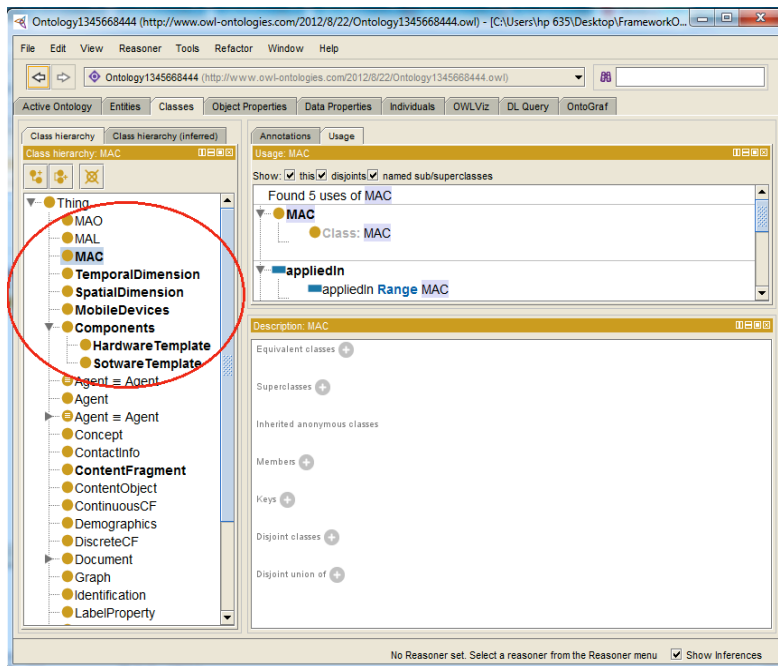

Fig. 3.. Mobile Assessment Context ontology editing with Protégé.

The mobile assessment context ontology can be described as follows:

MAC = {MAO, MAL, Temporal Dimension, Spatial Dimension, Mobile Devices}

MAO = {identifier, MAO_Level, MAO_state, MAO_prerequisites, MAO_objectives, MAO_interaction, accordedTime, body, score, correctResponse, feedback}

MAO_Level = {Hard|Medium|easy}

MAO_state = {NotVisited|SolvedCorrect|SolvedIncorrect|VisitedNotSolved}
MAO_interaction = {MCQ|MRQ|T/F|fill in blanks}
body= {MAO_test, MAO_context, MAO_content}
MAO_content = {audio|video|image|text}
MAL = {identification, LearnerAccount, MAL_prerequestes, MAL_Level}
identification = {name, forname, address, contactInfo, demographics, agent}
contactInfo = {email, mobile, telephone, web page}
demographics = {gender, birthdate, place of birth, uid}
agent = {agentid, agentDomain}
MAL_prerequestes = {Beginner|Intermediate|Advanced}
TemporalDimension = {begin(yyyy:mm:dd;hh:mm), end(yyyy:mm:dd;hh:mm)}
SpatialDimension = {LocalType, Local_description}
LocalType={Private|PublicNoisy|PublicQuiet}
MobileDevices = {components (hardware, software)}

The Assessment Resource Layer regroups a set of logical rules. The definition of logical rules permits reasoning over distributed information. Rules which are defined in first-order-logic can be applied to achieve assessment personalization in mobile learning environments. The use of first-order-logic (FOL) is driven by the promise of convenience in transcribing rules from the natural language to logical language [9]. Context reasoning is done here to generate the most suitable assessment object. A Personalized Component (PC) is used as a finite set of FOL sentences describing the personalization of the assessment functionality [10]. The PC is composed of constants and rules. We hence define the constant **Selected** specifying if a MAO is selected. This constant and its negation (**NotSelected**) appear in rules. In the following, we present some FOL rules:

- A MAO is recommended to be selected if all its prerequisites are acquired by the learner:

$\forall$ concepts C, $\forall$MAO O, $\forall$ MAL L (MAO_prerequisites (O, C) $\cap$ MAL_prerequisites (L, C) $\rightarrow$ PC (O, L, Selected))).

- A MAO having the state **NotVisited, VisitedNotSolved** or **SolvedIncorrect** can be selected:

$\forall$ MAO O, $\forall$ MAL L (MAP_state (O, L, NotVisited) $\cup$ MAP_state (O, L, VisitedNotSolved) $\cup$ MAP_state (O, L, SolvedIncorrect)) $\rightarrow$ PC (O, L, Selected)).

- A MAO having the state **SolvedCorrect** cannot be selected:

$\forall$ MAO O, $\forall$ MAL L (MAP_state (O, L, SolvedCorrect)) $\rightarrow$ PC (O, L, Not Selected)).

- A MAO is selected if at least one of its objectives is a keyword specified by the learner:

```
(  concepts C, ∀ MAO O, ∀ MAL L (MAO_objective (O, C) ∩
keywords (C)) → PC (O, L, Selected)).
```

- A MAO is selected for assessing if its type is compatible with the used device. We assume that MAOs have types: MCQ, MRQ, True/False, and fill in blanks. Fill in blanks questions can only be displayed in laptops:

```
(∀ MAO O, ∀ Interaction I (Interaction (O, Type) ∩
Compatibility (O, Device)) → PC (O, MAL, Selected)).
```

- MAO's generation depends on the location type. In fact, if the location type is private or public noisy then all MAOs content type can be generate. If the location type is public quiet then only MAOs that don't contain audio content can be displayed:

```
(  MAO O,  Local L (ContentType (O, "audio") ∩ Local (L,
"PublicQuiet")) →  -PC (MAO, MAL, Selected)).
(  MAO O,   Local L (ContentType (O, "Text") ∩ Local (L,
"PublicQuiet")) → PC(MAO, MAL, Selected)).
```

Using rules to deduce contexts can lead to ambiguity when different rules are activated simultaneously. We then need to resolve conflicts between deduced contexts. To effectively exploit mobile assessment objects, selection criteria must be established. The MAOs generation is done by using an algorithm for assessment resources retrieval [10].

5 Semantic Layer

Semantic Layer holds services composing the core of the PMAF. It interacts with the Assessment Context Layer and the Assessment Resources Layer to deliver a personalized mobile assessment test. The Semantic Layer is composed of three sub layers: (1) Mobile Assessment Context Acquisition, (2) Mobile Assessment Reasoning, and (3) MAOs List Delivery.

5.1 Mobile Assessment Context Acquisition

It represents the first level of our personalization engine allowing to detect context dimensions: used device, local type, assessment activity accorded time, and so on. Context dimension are retrieved from the GLI. Furthermore, the system must retrieve the type of used operating system in order to specify used device (mobile phone, PDA, laptop). So on, context acquisition's dimensions may be done in two ways:
-   Explicit Acquisition: executed due to the learner's interaction with the system.
-   Implicit Acquisition: represented as an automatic detection of context dimensions.

5.2 Mobile Assessment Reasoning

This layer represents the reasoning information provided by learner or other sensors. It is based essentially on the use of a personalized assessment resources retrieval algorithm. The key of the algorithm is the use of ontologies, logical rules, and an assessment resources matching method [10]. A set of meta-reasoning rules are applied to extract the most appropriate assessment resources. The algorithm is followed in three distinct steps:

- *Filtering*: this first step is based on the use of a set of rules that excludes a number of assessment resources and deducts them from the global assessment resource set. It consists of filtering the initial assessment resource list by excluding resources that do not fit in the mobile assessment context.
- *Personalization*: the second step depends mainly on the learner profile and the assessment portfolio. It consists to personalize assessment resources according the learner profile and MAO resources states. The result is the generation of a list of questions personalized and adapted to the mobile assessment context.
- *Grading*: the result of the first and second steps of the retrieval algorithm is a list of MAOs filtered and personalized to the learner profile and the assessment context. This list is not presented in an order that meets maximum assessment activity objectives. The optimization process step is to allocate weights to some parameters. Weights help to determine the mobile assessment object must be submitted first.

The Semantic Layer is where the codes step arises. The main program for assessment resource generation is written in Java to take advantage of its object oriented technology and to allow integration of its output into dynamic web sites using Java Server Pages technology. Apache Tomcat was chosen as a web Servlet container and web server to run JSP script. The PMAF is based on mobile web applications employing the Model View Controller architecture: for the model, RDF files are used where different kinds of context information can be managed; for the view, JSP is used; and for the controller, Java and Web services are employed.

Indeed, the proposed system is a collection of stateless Web Services in order to obtain advantages of ensuring interoperability and data exchange. The PMAF is based on the use of REST (REpresentational State Transfer) Web Services architecture. It is a stateless client-server architecture in which the web services are viewed as resources and can be identified by their URIs. Web Services are available to search for lightweight MAO from RDF document.

Concretely, a mobile assessment system that performs a personalization assessment task needs to represent different types of information traduced in logical rules. To select the most appropriate assessment resource, the system uses a set of logical rules. To realize this, it is necessary to choose a Semantic Web query language, which enables to query RDF resources. SPARQL is designed to query data conforming to the RDF data model. Queries must be consistent with different logical rules already established. To validate SPARQL queries, the Java API for RDF Jena is integrated. Jena is used to create and manipulate RDF graphs and to construct Semantic Web

applications. Based on the use case scenario detailed in Section 3, contextual data would contain information about: assessment activity topic (following query line 4), assessment activity accorded time (following query line 5-6), assessment activity objectives (following query line 7-8), assessment activity local type (following query line 9-10), the delivery media which in this specific case is an iPhone. Based on this current in-use, we can query the Mobile Assessment Object ontology to generate a personalized mobile assessment test accorded to the learner context. The following excerpt shows an instance of such a query in the SPARQL query language:

```
1. PREFIX obj:<http://www.owl-ontologies.com/MAOOntology.owl#>
2.SELECT ?identifier ?interaction_type ?accorded_Time ?MAO_state ?learner_Level ?MAO_Level (GROUP_CONCAT(DISTINCT ?objectives;   separator=';  ') AS ?objectives) (GROUP_CONCAT(DISTINCT ?MAO_prerequestes;   separator=';  ') AS ?MAO_prerequestes) ?Text_question ?Context_question ?Proposition_question
3.WHERE {
4. ?x obj:Topic " Object Oriented Programing ".
5.?x obj:accorded_Time ?accorded_Time.
6.Filter (?accorded_Time <=30).
7.?x obj:objectives ?objectives.
8.Filter (?objectives IN ("class", "object", "heritage" ))
9.?x obj:local_dependancy ?local_dependancy.
10.Filter (?local_dependancy IN ("Public noisy")).
11.?x obj:MAO_state ?MAO_state.
12.Filter (?MAO_state NOT IN ("VisitedSolvedCorrect")).
13.?x obj:MAO_state ?MAO_state.
14.?x obj:has_level ?MAO_level.
15.?MAO_level obj:learner_Level ?learner_Level.
16.?MAO_level obj:MAO_Level ?MAO_Level.
17.?x obj:MAO_prerequestes ?MAO_prerequestes.
18.?x obj:interaction_type ?interaction_type.
19.?x obj:device_dependancy ?device_dependancy.
20.?x obj:has_Body ?MAO_Body.
21.?MAO_Body  obj:Text_question ?Text_question.
22.?MAO_Body  obj:Context_question ?Context_question.
23.?MAO_Body  obj:Proposition_question ?Proposition_question.
24.?x obj:identifier ?identifier .}
26.GROUP  BY  ?identifier  ?interaction_type  ?accorded_Time  ?MAO_state ?learner_Level      ?MAO_Level      ?Text_question      ?Context_question ?Proposition_question ?Response_Value
```

The PMAF collects context information. It queries the MAO ontology, the MAL ontology, the MAP ontology and the MAD ontology. Then, it executes the Personalized Assessment Resources Retrieval algorithm.

5.3 Mobile Assessment List Delivery

MAOs List Delivery is the last step allowing assessment resources generation. It is also responsible for displaying the required resources. The personalized mobile assessment test related to learner demands and according to his/her mobile assessment context as described in the above scenario is shown in Figure 4.

Fig. 4.. Personalized Mobile Assessment Test Generation

Interacting with the test, the leaner can evaluate his progress by showing a statistical result detailing the percentage of correct/false answers and the corresponding correct response (figure 5). The result is then saved in the mobile assessment portfolio.
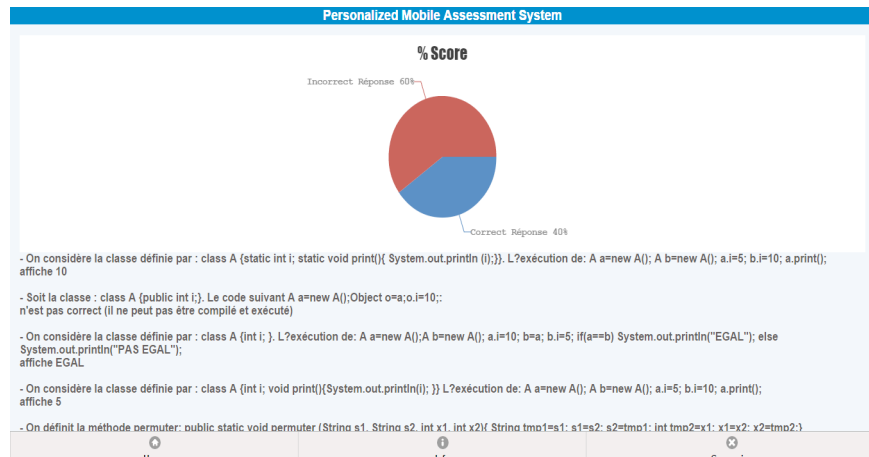

Fig. 5.. Learner's Mobile Assessment Test Interaction.

6 Personalized Mobile Assessment System Evaluation

PMAS evaluation is designed to test personalization and adaptation aspects. The system feasibility is also checked. We have carried out experiments with university students from 3rd year bachelor and master's students in Computer Science at the Higher Institute of Computer Science and Management of Kairouan. The objective is to evaluate student's results and satisfaction when they test the system on various devices type (PC, PDA and mobile phones), change location type (public quiet, public noisy), and use the system for many times to assess their prerequisites.

Evaluation was executed with 30 students in the same institute. Students were divided according to their prerequisite in OOP (Objects Oriented Programming) course in two groups: students whose level is intermediate and others whose level is beginner. The system is equipped with 80 questions. A system performance evaluation form was distributed to all students. The form consists of 16 questions based on 4 assumptions. The following table shows PMAS assumptions.

Table 1. Evaluation hypothesis

Hypothesis	Hypothesis description
H1: Evaluation of personalization aspect	H1 is composed of 4 questions testing student's level and student's portfolio.
H2: Evaluation of adaptation aspect	H2 is also composed of 4 questions. Students are invited to compare the generated test by changing: the location and device.
H3: Evaluation of usability	H3 consists of 4 questions. Students are invited to improve their opinions in terms of: navigation, generic use, etc.
H4: Evaluation of improvements and system guidance	H4 consists of 4 questions testing effectiveness and futures adaptations.

The histogram shown in Figure 6 presents the answered questions according to students' levels.

Most intermediate students have clearly perceived the personalization criteria. The majority of beginner students find the criteria less respected. Indeed, students must use the system for many times and respond correctly to some questions in order to appreciate personalization aspect. The analysis of H2 affirms that adaptation aspect is appreciates by both groups. A change of local type or of used device reveals differences between tests' generation. From H3 and H4, we can deduce that beginner students found more difficulties when they use the system. This result is mainly due to the difficulty of OOP courses content. Indeed, most beginner students believe that generated tests are more difficult than their level. Also, most students prefer to use the system with large screen devices. This is mainly due to the student's habits in using small screens generally for entrainment and not for learning and assessment.

In addition, students were motived to use the system and found that is an effective tool for self-assessment in a mobile environment. They suggested also to generalize the system to other courses.
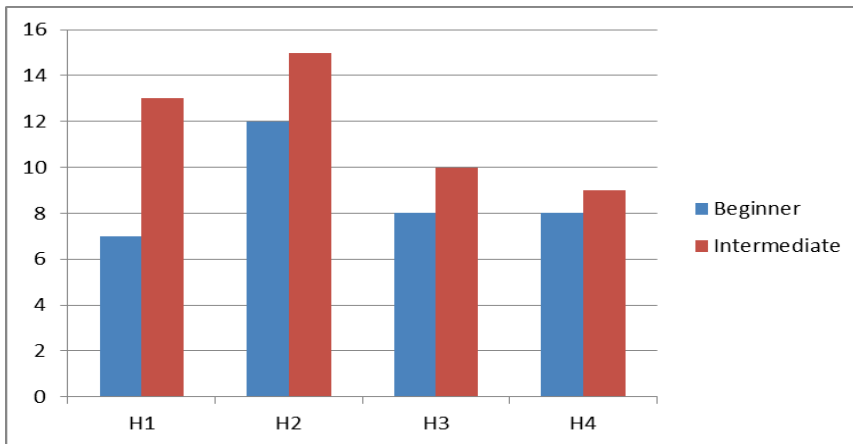
Fig. 6.. Histogram representing answered questions according to students' levels.

Preliminary results of our first experiment are encouraging. In particular they claim the respect of the two criteria of personalization and adaptation. In addition, they confirm that the system can be used by a large community of students as soon as the tool is hosted and generated for several knowledge domains.

6 Related Works and Discussions

In this work, an approach for supporting personalized assessment in mobile learning environment combining Semantic Web technologies is presented. We explain how assessment has been addressed in mobile environment in recent years. Alternatively, the use of Semantic Web technologies in mobile learning environment will be discussed.

The provision of assessment system in mobile environment has been an active area of research in last decade. The findings of recent studies show that using mobile learning environments have positive impacts on developing assessing methodologies. Chen [13] proposed a Mobile Assessment Participation System using PDAs as platform. The system facilitated the effectiveness of self and peer-assessment in classrooms. Hwang and Chang [15] explored a mobile learning system using formative assessment based mobile learning. The system uses a mechanism for conducting a local cultural learning activity with wireless networks and PDAs. Furthermore, an in-field activity on an indigenous culture course of an elementary school with a formative assessment-based learning strategy was conducted [16].

Generally speaking, the above detailed research works and others require improvements. The consideration of context dimension in a mobile environment is required. Therefore, they are not suitable for personalized mobile assessment test generation. In addition, such systems require specific web services-based architecture. For this reason, they cannot be easily reused in different domains and for different assessment contexts. The framework that we propose encapsulates context dimension

reuse and provides personalization of assessment in mobile learning environments enabling automatic generation of mobile assessment objects. We use ontologies to model assessment objects, learners profiles, assessment context and the semantic annotations to classify the learner interaction with his/her mobile context.

Recently, Semantic Web technologies have been increasingly used as a tool for generating, organizing and personalizing eLearning content, including e-assessment [17]. The use of ontologies for context modeling in many research works explores the relationship between Semantic Web technologies and context modeling. EasyMeeting and Cobra prototypes [3] demonstrated the feasibility of using OWL ontologies to let distributed agents share knowledge and reason about contextual information. Semantic web technologies especially ontologies were also used as an efficient modeling approach to propose an exhaustive learner model called "learner context" [14]. In this work, the context was defined as a set of evaluative elements appropriate to the interaction between learner and learning application. An attempt to solve some imposed mobile environment' problems is made in [7] by proposing an ontology-based framework for context-aware mobile learning. The system consisted mainly of a rule-based ontology and a search agent.

Nonetheless, the use of semantic web technologies to personalize assessment in mobile learning environment is still rarely studied. The role of ontologies in designing assessment resources has been less evoked. Only recently, techniques for ontology-based assessment design strategies start to emerge [6], [8]. In this paper, an attempt was made to deal with some of the imposed challenges. In fact, most educational systems incorporate solutions for assessment based on unified questions delivered to learners independent of their profiles and competences. Nevertheless, there is clear need for approaches considering the use of personalization approaches in mobile environments for assessment resource generation.

7 Conclusion and Future Work

This paper proposes a Web Services-based framework to personalize assessment activities in mobile learning environments. The assessment-based approach is built on top of ontologies, semantic annotations, and a personalized assessment algorithm allowing assessment resources filtering and personalization. The algorithm operates based on constraints and rules for automatic assessment resources generation. The first order logic language is also employed to make context reasoning. To interrogate and reason over ontologies, SPARQL language is employed as an RDF query language able to retrieve and manipulate data stored in RDF documents. The mobile assessment resources generation is based on the use of Restful web services. The results obtained in a real course (object oriented programming course) are promising, since the system is capable of generating personalized assessment resources in mobile learning environment. The qualitative and quantitative evaluation of the system is done with university students from 3rd bachelor and master's student in computer science.

In the future we plan to do more experiments with students with different backgrounds (such as medicine, chemistry or physics students). Finally, we hope to

add more different types of items into the system, such as matching or ordering questions and others types.

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