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Individualizing HCI in E-learning Through Assessment Approach*

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In e-learning systems, learners can have the same goal, but not necessarily the same predisposition, or the same knowledge. Therefore, an optimal pedagogical path for one does not necessarily fit the other. Thus, providing an interactive environment tailored to the learner's needs is one of the most important goals of e-learning environments. In our proposal, we make the adaptation of learning our main objective. Our theoretical framework stems from the fact that HCI is a combination of cognitive, behavioral and computer sciences. On the cognitive and behavioural scope, we have opted for adaptive formative assessment so as to identify the learner's competence level and, thereon, to guide the learner to reach the educationally drawn output profile. The aforementioned assessment highlights the learner's real time competence. The latter and the learner's prior knowledge are pivotal elements in adapting the learning process. On the computing scope, this process is carried out via an e-learning system in which the proposed assessment is implemented through Services Oriented Architecture (SOA).

In this paper, it would be prominent to individualize the learning path by adopting formative assessment by proposing an adaptive test which offers a selection of optimal items in a sequence taking into account the profile and the progress of the learner. To implement the proposed system, first, we modelled learner and items according to competency based approach (CBA). Then, modelled the formative assessment in an adaptive approach using the Item response theory (IRT), this will provide a series of consecutively selected items. The answer to an item determines the selection of the next one taking into account the previous responses and performances recorded in the learner model.

Keywords: e-learning; human computer interaction; adaptive formative assessment; item response theory; services oriented architecture

1. Introduction

Human-Computer Interaction (HCI) is "a discipline concerned with the design, evaluation, and implementation of computing systems for human use and with the study of major phenomena surrounding them" [1]. The objective is to develop an interactive system that improves the quality of interactions between users and computers by reducing the gap between the functionality and usability. HCI is seen as an intersection between computer science and behavioural sciences. It is an interdisciplinary field that interrelates with many disciplines such as computer science, cognitive psychology, engineering and artificial intelligence. Hence, it incorporates the social as well as cognitive aspects of computing. The main objective of this interaction is to ensure operability, discoverability, simplicity, and learnability as well as safety, utility, effectiveness, efficiency, accessibility and usability [2].

The e-learning system is a mediating tool among the learner, competency and other learning actors. This mediation is the subject of several studies [3–8] attempting to personalize it by taking into account the learner's characteristics. The adaptation of learning is implemented through the adaptive learning systems. The latter adapt the learning environment in accordance with the learner's profile.

Our theoretical framework stems from the fact that HCI is a combination of cognitive, behavioural and computer sciences. On the cognitive and behavioural scope, we have opted for adaptive formative assessment [9] so as to identify the learner's competence level and, thereon, to guide the learner to reach the educationally drawn output profile. The aforementioned assessment highlights the learner's real time competence. The latter and the learner's prior knowledge are pivotal elements in adapting the learning process. On the computing scope, this process is carried out via an e-learning system in which the proposed assessment is implemented through services oriented architecture (SOA).

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The next section deals with the existing adaptive learning systems to identify our contribution. The third section presents two concepts personalization and individualization of HCI in e-learning. The fourth section concerns the learner modelling in a CBA. The fifth section presents the adaptive formative assessment to individualize HCI in learning system. To achieve this individualization a customized test will be implemented using IRT. The proposed system and its implementation will be presented in section 6, and we end up with a conclusion and research perspectives

2. Analysis of existing proposals

There are many proposals tackling the adaptation problem in the literature [3–8]. This section discusses some of the most relevant in highlighting the contribution of our proposed system (Table 1). In this comparative study, we use four criteria categories [11] including:

(a) *Learner Model*: this criterion allows highlighting how different systems use the learner model. This is possible by reviewing the content stored in the model, the technology used for its implementation, as well as how the content will be refreshed.

(b) *Resource model*: this criterion of classification systems allow an analysis of the resources structure implemented in the systems. This is possible by reviewing approaches in modelling this type of data and the existing resources (skills, knowledge). This classification can be spread to the standards used in the resource model.

(c) *Learning Model*: addresses the educational aspect, it can be; oriented activities or resource-oriented. Therefore, the learning unit can be split into fragments whose sequence will be decided at the time of a learning scenario.

(d) *Adaptation Model*: in this aspect, we identify the mechanisms of adaptation implemented in each system, highlighting the subject of this adaptation (navigation, presentation and content) and its scope (learning path, test, and learning activities) and how it is technically implemented.

3. Personalization and individualization of HCI in e-learning

In abroad manner, personalization aims to adapt contents and services offered to the user to promote the quality of his interactions with the system [12]. In the education field, personalization targets the

Table 1. Comparative study of adaptive learning systems

components	SYSTEMS	AHA	ALFANET	ANATOM TUTOR	ELM ART	Inspire	Metadyne	our proposed system
Learner Model	contents	profile, level of knowledge	level of knowledge	Profile	prerequisite, level of knowledge	profile, level of knowledge	objectives, level of knowledge, profile	Profile, competency's level,objectives
	technology	concepts based	IMS-LIP					IMS LIP + HR-XML
	refresh	dynamically by the system	static	dynamically by the system	static	dynamic	dynamic	dynamically by the system
resources Model		domain model	IMS-QTI , IEEE-LOM	domain model	domain model	metadata	domain model	Competency definition, domain taxonomy IMS-QTI, IEE-LOM, IMS RDCEO
Learning Model		oriented content using fragments	oriented activities	oriented activities	oriented activities	oriented activities	resources oriented	Based competency Approach oriented activities using IMS-LD
Adaptation	Type	Presentation and navigation	Contents, Presentation	navigation, presentation	navigation	navigation	navigation , presentation	contents, Presentation, navigation
	Technical aspect	Link annotation, link hiding using user model values	Feedback to author+ learning paths for user profiles	predefined sequence and stereotype knowledge	rules of methods' selection	rules of methods' selection	rules of learning unit selection	individualization of diagnosis via formative adaptive evaluation
	scope	contents	learning paths	test activities	contents	Learning paths	contents	learning and test avtivities

provision of learners with a training course perfectly suited to their level and needs [13].

However, the individualization concept in learning involves a set of procedures and educational theories to organize training. In this organization, first, we must build a learning path taking into account an individual request, expressed or implied. Then precede this path via planned and regulatory activities to achieve the expected purpose or skill. The regulatory activities will take into account the learner experiences, his level and expectations.

The individualization goal is to adjust the learning path focusing on the design of learning sequences. Its implementation, in an educational adaptive system, is the same for all learners who are not doing necessarily the same thing, but they use the same standard tools. Individualizing is providing each learner with the feeling that the training is designed specifically to meet their expectations taking into account their capacities. In e-learning environments, this is possible when implementing methods and techniques to provide customized activities and educational content. The mechanisms vary from system to another and can be summarized mainly in adaptive hypermedia systems, semantic web or theories from the education field. However, most research work focuses on the production of educational resources and referrals without giving importance to their operation.

Because learners are a component of the HC system, it is important to understand how they process information. In our proposal, the adaptation is based on the learner identification, his ability, prior knowledge and current performance for the acquisition of competency. Thus, we stipulate that two ingredients are essential, namely learner modelling and a relevant diagnosis vis-a-vis the current activity. In this perspective, we modelled [13] formative assessment to offer to the learning system a relevant diagnosis to regulate the learning process taking into account the characteristics and progression of each learner. Consequently, the learners borrow different learning paths and dynamically composed.

The dynamic composition of the learning paths is assembling a set of activities (including assessment) combining learning objects and services. The purpose is to draw for each student, the optimal path to acquire a competency (Fig. 1) responding to the specific needs and the output profile desired by the educational system.

The production of learning objects is time-consuming and costly and can be made profitable when reused as long as possible. For this, it is necessary to specify the structure and index them [15]. The referencing of learning objects is a necessity if we want to integrate them in a course while maintaining its coherence and relevance. It is very useful for designers of educational content to adapt the choice of educational resources based on the specified requirements [16]. In this connection, they must add semantic information which should be structured, usable and descriptive of the resource and its use. The latter is metadata that Bernes-Lee, T [17] defined as ″data about data″ and considers that ″Metadata is machine understandable information about web resources or other things’’. To enable operability and reuse, a standard must exist so that the educational content developers and users use the same repository. This repository can take various forms: Metadata standard (IEEE LOM (Learning Object Metadata) [18], DC (Dublin Core), taxonomies, ontologies formalized in various languages (XML, RDF, OWL).

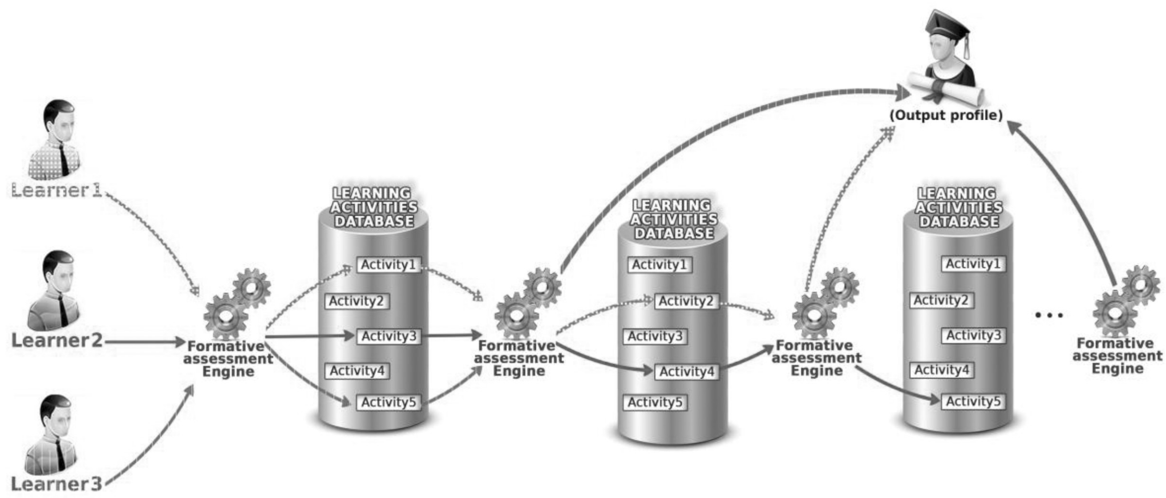

Fig. 1. The dynamic composition of learning paths using the proposed system.

4. Learner modelling

In HCI, the learner is central and the learning environment must take into account his needs and expectations for the acquisition of a competency. Learner modelling is a representation of the state of competencies. It focuses on learner characteristics and activities. It should represent information characterizing the learner at the static level (profile) as well as at the dynamic level (progression). In our contribution, the learner model is solicited in different stages of the proposed system. It will help to highlight the root causes of the competency gap. This is possible by providing the items suited for a relevant diagnosis. The learner model can be implemented using standard templates.

To ensure the provision of competence-based learning services and facilitate the interaction with the learner, it is necessary to record his individual competencies in a persistent and standard way. Thus, the learner can find learning activities that meet his needs to achieve the desired competencies. In our proposed system, we adopt the IMS-LIP specifications, which are “based on a data model that describes those characteristics of a learner needed for recording and managing learning-related history, goals and accomplishments” [19]. That model defines an XML structure (Fig. 2) for data exchange between different learning systems involved in the learning process. The IMS-LIP model offers the opportunity to refer to a competency described in an external source using the tag <exrefrecord>. This competency description must allow performance measurement. Thus, we expand the definition with the HR-XML model.

5. Adaptive formative assessment to individualize HCI in learning system

5.1 FORMATIVE assessment

In the learning process, the evaluation role must not be limited to certification, but should be conceived in a formative approach to guide the teaching/learning process [21]. Formative assessment helps the student to learn; it participates in the regulation of the learning process [22]. It is also made up of a cycle that is built on three layers and that we enriched with a pre-regulation layer [23]:

(1) *Observation*: Establish the position in relation to a repository, instead of confining the learner to a scale and comparing him/her to other learners.
(2) *Intervention*: identifies symptoms to address the root causes of problems. It involves analyzing metacognitive knowledge [24].
(3) *Pre-regulation*: it is the step we proposed [25]; it offers optimal items to the learner. The purpose is to have a pertinent diagnostic allowing the regulation of the path learning for each learner.
(4) *Regulation*: Describe the mechanisms that provide guidance, control and the adjustment of cognitive activities.

For assessment implementation in a competency-based learning system, there is a need to provide reusable definitions of competency, across the different systems [26]. Several models are proposed to describe a competence formally, such as the IEEE Reusable Competency Definition (IEEE RCD) [27] and the IMS Reusable Definition of Competence or Educational Objective (IMS RDCEO) [28] specifi-

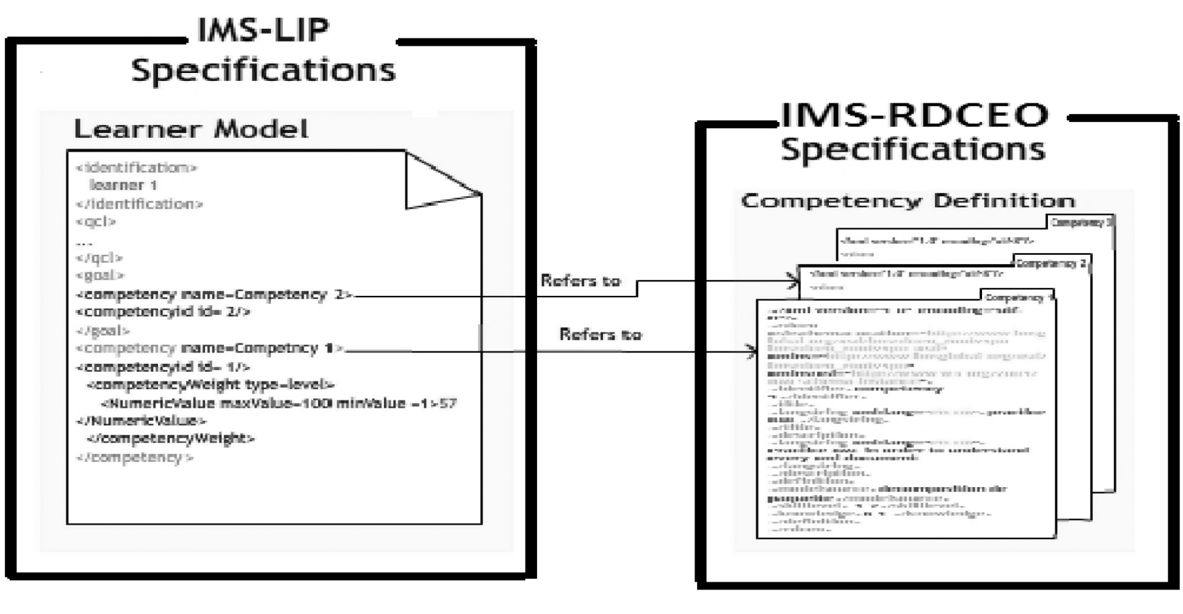

Fig. 2. Learner model [20].

cation. In our system [29], the competency has been defined in accordance with the IMS RDCEO specifications enriched by the HR-XML standard according to the recommendation of the European commission of normalization [26].

As far as the questions are concerned, items will be administered to assess learners, this uses an item database structured in a formal and standard way. In our proposed system, we opt for the standard Question & Test Interoperability specifications (IMS-QTI) [30], which allows representing the items data structure. Each of the items corresponds to a competency which allows representing the data structure of a question (item) and a test (assessment) and their corresponding results. This representation is done through an XML file (Fig. 3) providing interoperability

5.2 Adaptive assessment

In the majority of existing e-learning platforms, the questions given to learners and the sequence in which they are presented in an evaluation activity are the same. This raises various problems regarding the estimation of the skill level [31]. In such situations, the goal is to confine the learner to be on a scale and compare him/her to the other learners without taking into account his skill level. Indeed, the questions do not take into account the level of the learner and are administered randomly in a predefined order. Using this format of examination in a formative approach will not be of any use. Thus, we will opt for an adaptive test which is to provide each learner with questions tailored to his mastery of the subject, his profile and his answers to previous questions [31]. The questions will be presented in an evaluation activity in different sequence (Fig. 4). The items are designed according to IMS QTI specifications and the evaluation is given item by item. The item is chosen in the pre-regulation stage. The bank of items will be used until the end of the assessment. Once the assessment is completed, the final competency gap will be used in the last process to choose the next learning activity

In a computing environment, the implementation of an adaptive test requires, first, that we calculate the level of a given skill. Then, we use the learner's model to decide the next question. Finally, we adopt mechanisms to select the items (questions). In our proposal, to select items that will be administered to the learners, and to calculate the level of a given kill,

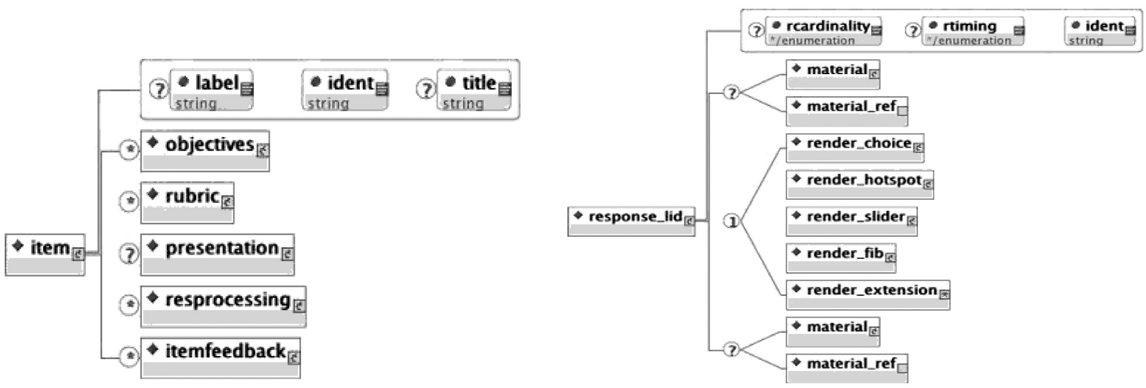

Fig. 3. Presentation of some elements of the question, according to IMS QTI.

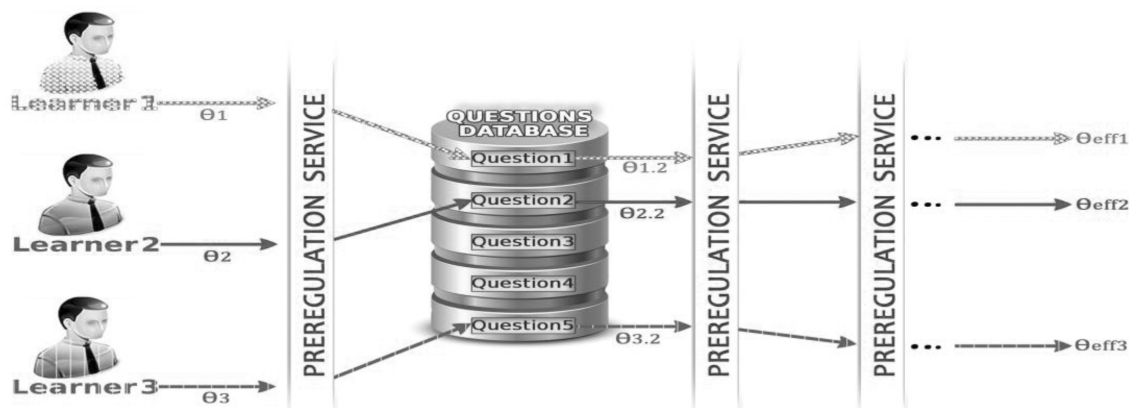

Fig. 4. The personalization of evaluative path for each learner.

we adopt a statistical probabilistic model named, the Item Response Theory (IRT) [32].

5.3 The Item response theory (IRT)

5.3.1 Rash model

Item Response Theory (IRT) was introduced to construct a formal approach to adaptive testing [33]. IRT is generally regarded as an improvement over classical test theory (CTT). For tasks that can be accomplished using CTT, IRT generally brings greater flexibility and provides more sophisticated information. This theory aims firstly at estimating as accurately as possible the learner's skill based on his/her responses to items, and secondly, the evaluation of psychometric properties of items [34].

The model is based on a probabilistic mathematical representation described through a function linking the learner's ability with the probability of a successful item. This function is called, the Item Characteristic Curve (ICC), which is the foundation of the IRT. ICC represents for each item the probability P(θ) that an examinee with ability θ will give a correct answer to that item (Fig. 5). The curve pattern depends on the item parameter values

Based on the number of parameters, there are four common models for ICC; one-parameter logistic model (1PL) or Rasch model, two-parameter logistic model (2PL), three-parameter (3PL) and four-parameter (4PL). In our prototype, we have opted for the Rasch model. This choice has been made to simplify the implementation. The Rasch model represents the structure, which data should demonstrate, in order to obtain measurements; i.e. it provides a criterion for successful measurement. In the (1PL) model (Fig. 6), each item *i* is characterized by only one parameter, the item difficulty *bi*; this parameter shows a high correlation with the proportion of correct responses observed on an item. The model is known as Rash Model [35] and uses this parameter as follows:

$$P_i(\theta) = \frac{1}{1 + e^{(-D(\theta - b_i))}} \quad (1)$$

Where:

D is a constant and equals 1.7

θ is the ability scale.

Several assumptions are taken into account to make interpretations based on the IRT. The first is the heterogeneity of the variance: a latent trait unidimensionality, local independence from one item to another; the probability of getting a good response to an item is independent of the probability of getting a good response to other test items, invariance of the level of difficulty compared to

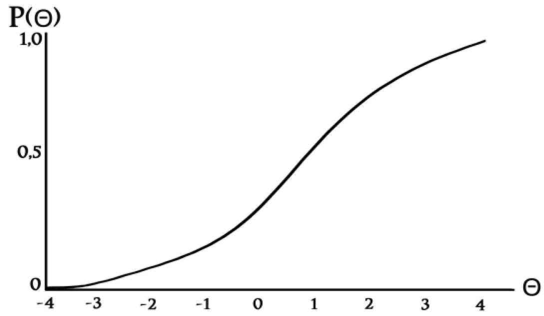

Fig. 5. Sample item characteristic curve.

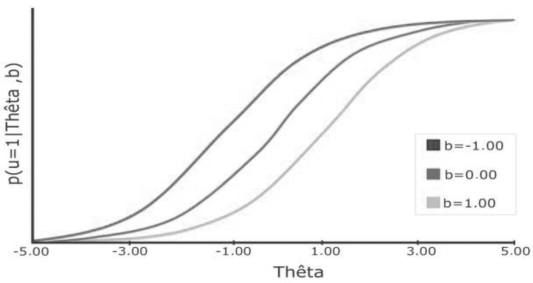

Fig. 6. Three-item ICC with different b values.

subjects and an invariance of the skill level compared to the items.

5.3.2 Constructing tests: Selecting the optimal item

Item information function (IIF) in IRT plays a central role in selecting optimal items to construct tests for examinees. Each item in a test provides information about the ability of the examinee. However, the quantity, quality and relevance of this information depend on how well the item difficulty corresponds to the learner's skill level. The amount of information, provided through a single item, can be calculated for each item in terms of skill level according to the item information function:

$$\mathrm{Ii}(\theta) = \mathrm{Pi}(\theta)\mathrm{Qi}(\theta) \quad (2)$$

Where:

i is the item sequence number
P (θ) is the first derivative of Pi (θ)
Qi(θ)=1–Pi(θ)

A test is composed of a set of items. Thus, for a given skill level, the test information is the sum of the item information at that level. Consequently, the test information function (TIF) is defined as:

$$I(\theta) = \sum_{I=1}^{N} I_i(\theta) \quad (3)$$

Where:

$I_i(\theta)$ is the amount of information for item i at ability level Θ.

N is the number of items in the test.

6. The proposed system

6.1 System activities as a business process

A business process is a collection of interrelated tasks, which are designed to deliver a particular result. Today, e-learning systems are in need of integrating new pedagogical approaches that tend to offer better results and quality of learning. In order to implement such capabilities, the system logic will be considered as a business process. We opt for an SOA where we define the services and their interactions using an orchestration plan. For the stated reasons, we had to adopt modelling methods in order to organize and combine these processes. There are several different ways to model a business process. Each way has its own rules and syntax. This makes it difficult to work with models written in different languages. This is why a standard to represent business processes is critical at the modelling level as well as at the execution level. For our project implementation, we opted to use the BPMN [35] standard for business process modelling and BPEL [36] language at the execution level. So we elaborated the diagram (Fig. 7) to model the workflow of the proposed system

6.2 Orchestration

An important advantage of SOA is the Business process modelling. Business processes are modelled by the orchestration, which means that each service would not need to know about the other participating services in order to create a business process. Orchestration allows for each service to be independent and ensures that none of the participating services communicates with the other services.

The orchestration handles calling services for execution in the frame of a predefined business process.

Service orchestration describes the matter in which services will interact with each other in

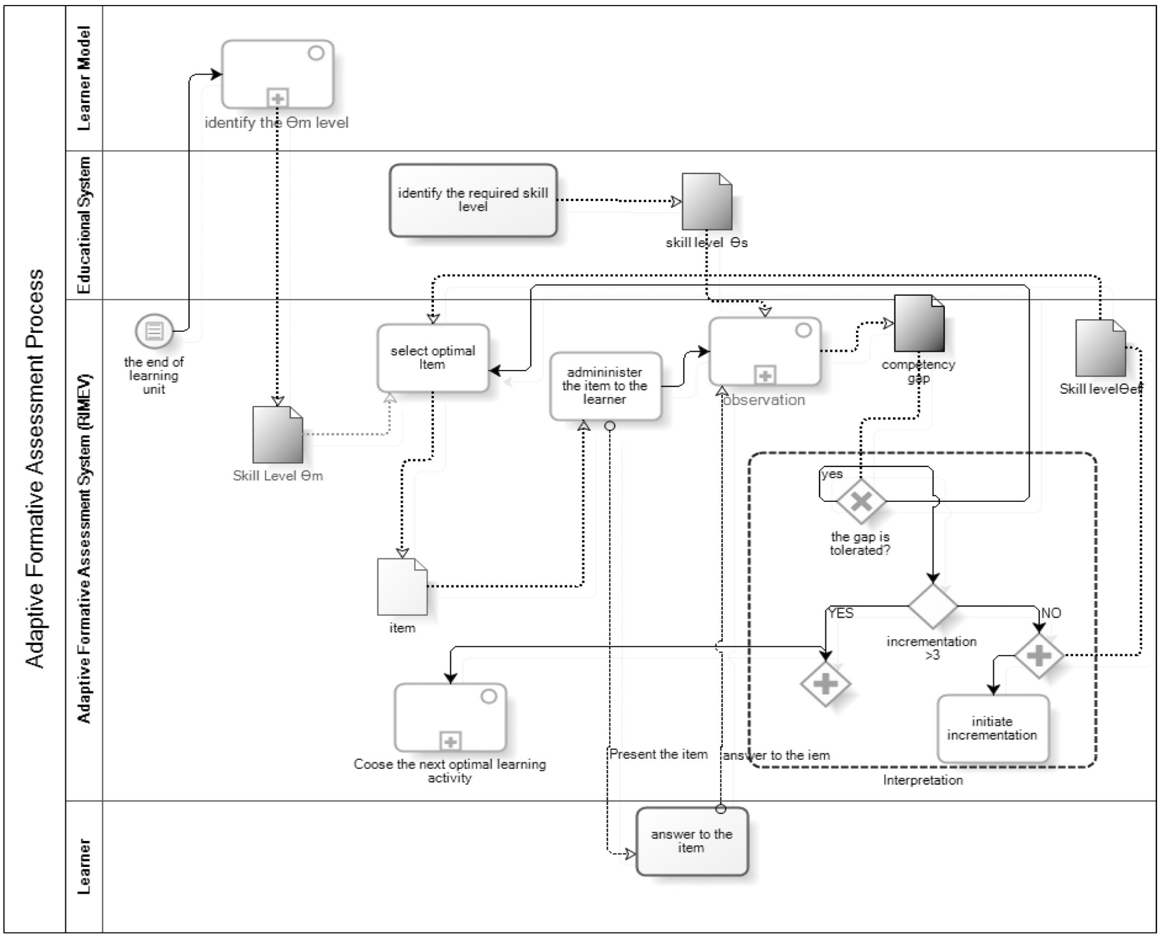

Fig. 7. Business Process Diagram illustrating the orchestration plan for the system proposed.

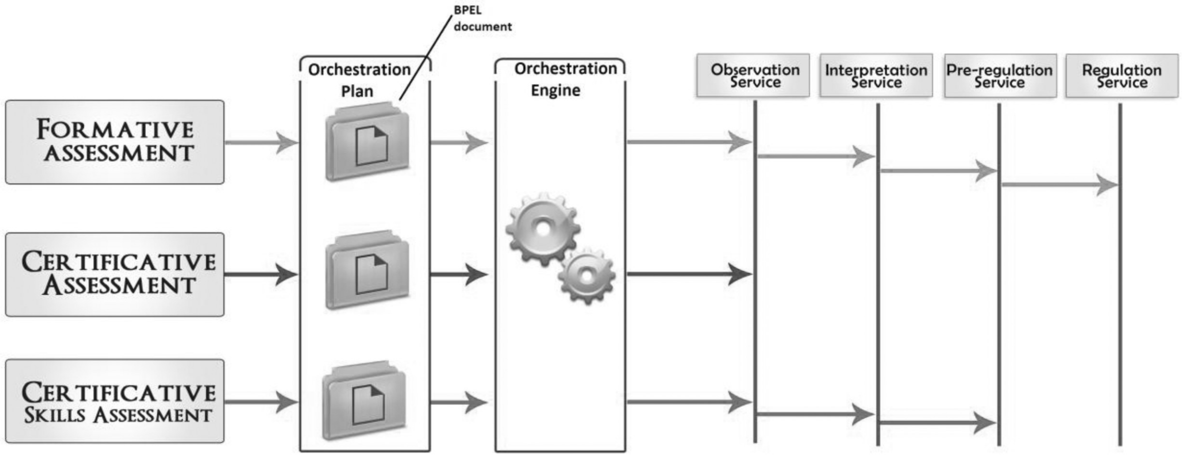

Fig. 8. Services reutilisation according to an orchestration plan.

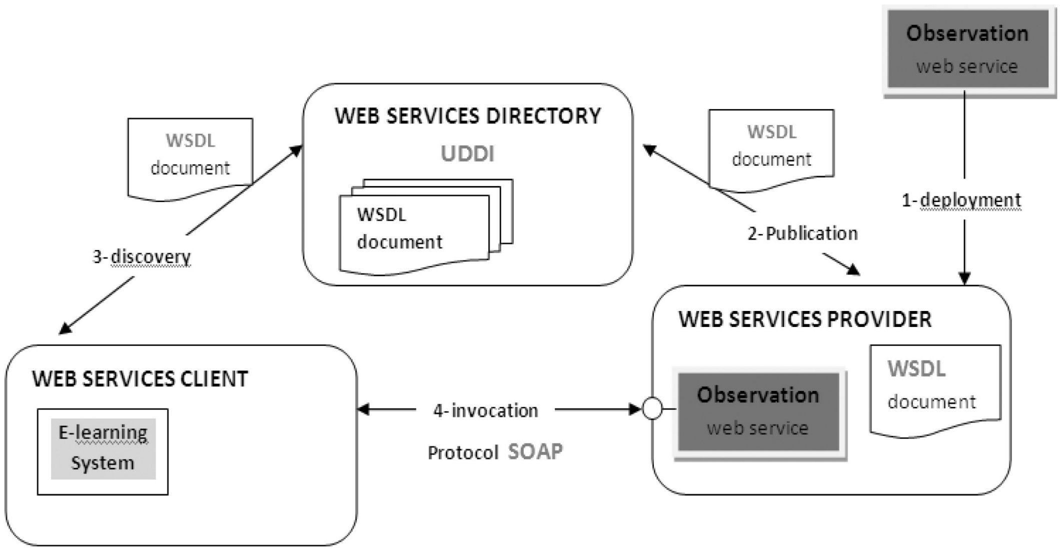

Fig. 9. Observation Web service.

order to create a business process. It includes the order of execution of the messages and the business process. In the orchestration, the orchestrator is responsible for the composition and controls the interactions between services. This orchestrator coordinates in a centralized manner different operations of partner services. Business process description adds a view of the process and constitutes an excellent formalization and analytical tool to build systems. For such reasons, it is an essential component in information systems. The orchestration allows the reuse of services; it defines a plan to coordinate services according to the context, training, certification or skills assessment test (Fig. 8)

6.3 Implementation

In Service oriented architecture the goal is to provide "an open Platform" for the development, deployment, interaction and management of distributed e-services [37]. The model of web services [38], is defined as an architecture calling upon a set of standardized protocols (Fig. 9). The orchestration of services is carried out by IMS LD specifications.

7. Conclusion

To provide an interactive environment tailored to the learner's needs is one of the most important goals of e-learning environments. Interactivity and adaptation do not rely solely on technical artefacts, but are the result of a combination involving educational theory, and technological advances in the field of ICT. Several studies have addressed the individualization from different angles. Ours is different, both in the approach and tools; it offers a system that individualizes the evaluation process offering a personalized diagnosis to decide upon the remediation activity. In the implementation of the proposed system, interoperability and reuse justify the choice of components and the environment interacting with the system. As far as the technical architecture is concerned, we adhere to our research team's global vision. In this vision, the e-learning platform should be composed of a set of reusable, interoperable and interacting services.

The proposed service is the composition of the four services. This service is implemented as an activity in a learning unit. Thus, several standards are possible. In our proposal, we opted for the standard IMS Learning Design. Several perspectives are considered, and can be summarized in:

(1) The deployment and testing in a learning unit.
(2) The collecting and analysis of formative assessment activity traces.

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