



# Towards Automated Specifications of Scenarios in Enhanced Learning Technology

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## ABSTRACT

*Recent standardization efforts in e-learning technology have resulted in a number of specifications, however, the automation process that is considered essential in a learning management system (LMS) is a less explored one. As learning technology becomes more widespread and more heterogeneous, there is a growing need to specify processes that cross the boundaries of a single LMS or learning resource repository. This article proposes to obtain a specification orientated to automation that takes on board the heterogeneity of systems and formats and provides a language for specifying complex and generic interactions. Having this goal in mind, a technique based on three steps is suggested. The semantic conformance profiles, the business process management (BPM) diagram, and its translation into the business process execution language (BPEL) seem to be suitable for achieving it.*

*Keywords:* automated specification processes; learning technology scenarios; learning management systems

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## INTRODUCTION

The IMS digital repositories interoperability (DRI) specification (IMS Global Consortium, 2003) suggests recommendations for the interoperation of the most common repository functions. This specification acknowledges that a wide range of content formats, implemented systems, technologies, and established practices already exist; it is tied to IMS specifications on the contents, but it does not assume the hetero-

geneity of the systems and formats, and does not provide a language for specifying complex, generic interactions.

In order to achieve interoperability among systems and formats, the eduSource Canada project has designed and implemented a standard communication protocol, ECL (Eap, Hatala, & Richards, 2004). The ECL protocol is flexible with respect to metadata schemas and repository contents, and it allows new

and existing repositories to communicate and share resources across a network. It conforms to IMS DRI specifications and implements its main functions, and, furthermore, it extends the IMS protocol with some definitions based on the OAI harvesting protocol. Also conforming to IMS DRI specification, the PAWSEL project proposes an architecture that intends to facilitate the heterogeneous conversational patterns among participants of the scenario (Macarro et al., 2006). The intermediary level provides the orchestration skills for the rest of the components through service interfaces and the relation among learning services. Their users and intermediaries are understood as scenarios. The SleD2 project presents another architecture that facilitates the integration of learning services instead of Web services. The CooperCore engines such as the IMS LD service are integrated into a workflow engine and satisfy the automation of scenarios but are limited to the delivery of activities (Vogten, Martens, Nadolski, Tattersall, Van Rosmalen, & Koper, 2006)

The term *scenario* in the e-learning area, and the reutilization of learning objects (LOs) as a scenario-based approach were introduced in an attempt to present the learning-objects metadata as required infrastructure to support some LMS (learning management system) functions (Sicilia & Lytras, 2005). Also, in relation to scenarios, it has been proposed to use the semantic conformance profile (SCP) toward the automation processes (Sicilia, Pagés, García, Sánchez-Alonso, & Rius, 2004). Taking into account this previous work (Macarro et al., 2006; Sicilia & Lytras; Sicilia et al.), and acknowledging the need for having a language for processes specification to describe the fundamental processes in the LMS and all the interactions among the participants, we propose BPMN (business process modeling notation) as the most suitable one. Subsequently, we state the main advantages that BPMN brings about to e-learning.

- **It supports the exchange formats between applications:** The serialization of

BPMN is done for XML (extensible markup language) exchange. A comparative study (Mendeling, Neumann, & Nüttgens, 2004) of about 15 different XML-based specifications for BPM (business process management) concludes that BPMN and BPEL (business process execution language) are the languages that satisfy the majority of the items that assure the exchange formats and the interoperability.

- **It reduces heterogeneity among LMS:** BPMN is accepted by the business community to describe the processes' workflows. It can also be used in an e-learning context as a specification language in order to reduce the heterogeneity among the specification techniques and bring interoperability between different systems (Object Management Group [OMG], 2006). The justification can be found in Helic, Hrastmik, and Maurer (2005).
- **It provides elements to specify complex and generic interactions:** To achieve dynamic and adaptive LMSs, their processes have to be specified in a language that will be able to (a) describe in a standard graphical and understandable notation, (b) define abstract modeling elements by means of a metamodeling notation, and (c) offer different techniques of modeling processes for one participant or more that are connected through the flow messages (OMG, 2006).
- **It provides support to the generation of executable specifications:** BPMN has an internal model that enables the generation of BPEL executable specifications with automated support. It contributes to reduce the number of errors introduced during the translation phase, decreasing costs of the development and increasing productivity. In a general sense, it can be considered in a normative way as a bridge for the gap between business process design and process implementation (OMG, 2006; Stephen, 2004).

This article proposes to address the specification of learning technology processes. Taking a concrete scenario that is not present as a user case in the IMS DRI recommendations, we will describe the steps to obtain their executable specifications. The rest of the article is organised as follows. The second section refers to the specification of learning processes in BPMN and its mapping to BPEL, and an example presents the advantages of using it. The third section presents the integration of the BPMN processes with IMS DRI recommendations and other learning technology specifications. Finally, the fourth section presents conclusions.

## **SPECIFYING LEARNING TECHNOLOGY PROCESSES WITH BPMN**

In order to obtain the executable specification of processes that implement a scenario, three steps are proposed: (a) the definition of the SCP of the scenario, (b) the construction of the BPM diagram corresponding to the previous SCP, and (c) the BPEL specifications obtained from the BPM diagram. We want to note that the steps we propose are a particular case of the methodology to develop e-learning scenarios proposed by Hamburg, Busse, and Marin (2005).

The scenario type of acquisition of a learning object will be taken as an example. This scenario describes the automated or semiautomated purchase of a reusable learning object to carry out a given learning objective inside the LMS (Sicilia et al., 2004).

### **The Semantic Conformance Profile**

In order to do a first analysis of the scenario in a consistent way orientated toward the automation, we generate the SCP (Sicilia et al., 2004). The description of the scenario must be clear so that it can be used to create its semantic conformance profile. This means that it is necessary to define the scenario in terms of its precondition (the initial conditions that have to be satisfied in order to execute the process), the restrictions (conditions to be checked throughout the process), and the postcondition (the objec-

tive of the scenario or the condition that is true or apparent when the process is finished). The preconditions and postconditions are more or less easy to determine because they are the starting and ending points of the scenario. However, the restrictions are more difficult to establish because they imply analyzing the different states through which the scenario passes and the conditions to be taken into account in order to reach the final goal. In Table 1, the preconditions, the restrictions, and the postconditions of the LO acquisition scenario are shown.

As anyone can see, the scenario proposed is simplified to the utmost. Table 1 shows only one repository and only one vendor system. It would be more usual to search the LOs in a federated way, so the search to find some LO satisfying some pedagogical characteristics was done in several repositories. Also, only one system vendor is considered and it would be more realistic to have many vendor systems providing the LO selected to purchase according to the LMS preferences.

### **BPM Diagram Process**

The second step is the construction of the BPM diagram. To achieve it, a deeper analysis of the SCP, defined in the previous phase, is needed. The BPM diagram requires identifying the participants or actors involved in the scenario, the determination of the interactions between all the participants, the tasks to be performed, and their execution order. All this kind of information about the scenario is easily expressed using the BPM diagrams as shown in the first section.

The BPM diagrams use a notation widely accepted by the business process community to specify workflows and exchange messages among participants in business scenarios. Therefore, they allow representing collaborative processes in a notation easy to be understood by all kinds of users, from the most specialised in the analysis to the final users.

Before presenting a BPM diagram as an example, it is interesting to know which are the essential elements used to represent the flow of activities and the exchange message

Table 1. SCP of the LO acquisition scenario

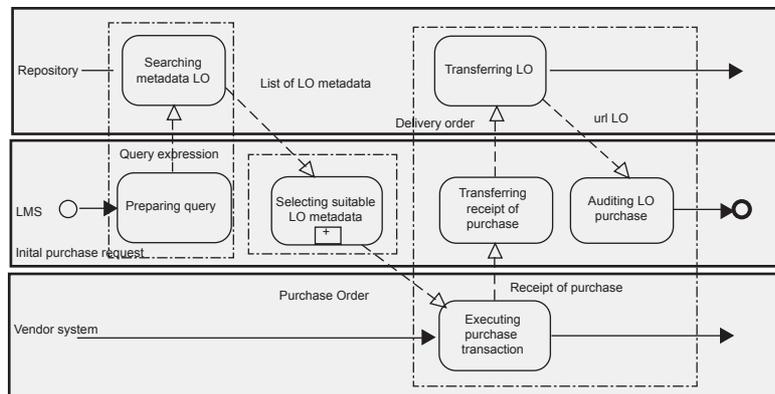
|                             |  |
|-----------------------------|--|
| PRE (Required elements)     | Pedagogical characteristics of the LO required.<br>Buying conditions.<br>Payment information.  |
| Restrictions (Idioms)       | The repository allocating the metadata LO of interest is available.<br>The pedagogical characteristics must be expressed in terms of the repository language.<br>There are some LO satisfying the requirements.<br>The purchase conditions are accepted.<br>The copyrights are met.<br>The legal conditions are satisfied.<br>The vendor system identifier must be part of the LO Metadata.<br>The vendor system is available to establish communication with the LMS.<br>The vendor system must carry out the economic transaction.<br>The purchase receipt is available.<br>The transfer of the url of the LO is done correctly.<br>The purchase process is audited. |
| POST (Run-time commitments) | Vendor system running<br>Availability of the learning object from the LMS.   |

between actors and activities. Activities are represented as rectangles with rounded corners. The control flow of the collaborative processes is indicated by arrows with a discontinuous line from one activity to another. The message exchanges are also represented as arrows but with discontinuous lines. Every participant or actor taking part in the scenario is represented in a pool diagram and inside of it there are the activities each participant carries out. The arrows within the pools represent the interactions between two participants.

Figure 1 shows the BPM diagram for the LO acquisition scenario. Three pools are represented in the diagram, one for each actor identified: (a) the repository allocating the learning objects, (b) the LMS as the buyer of the reusable learning object, and (c) the vendor system as the supplier. The scenario begins with the LO purchase request as the initial event. It

is represented by the empty circle. The scenario ends when the postcondition holds; it is when the LO has been bought and it is available to be used by the LMS for the learning needs. It is denoted with a dark circle. Between the initial and the final events, in order to achieve the goal of the scenario, the sequence of activities to carry out has been designed. The best way to do this consists of dividing the problem into smaller problems that are easier to solve. Thus, the LO acquisition scenario could be seen as composed of three subprocesses to execute sequentially: (a) the search for the LO, (b) the selection of the most suitable LO, and (c) the purchase of the LO. These subprocesses at the same time can split between a set of activities to refer to the most basic processes with a concrete functionality. Let us see the sequence of activities needed to implement the scenario in a usual case.

Figure 1. BPMN diagram of LO acquisition scenario



The scenario begins when the LMS receives the initial purchase request. This request includes the pedagogical characteristics of the learning object to be bought, the buying conditions, and the payment information. In order to search the set of LO according to the pedagogical requirements, the LMS has to prepare a query to ask the repository for the LO satisfying the requirements to be able to translate the received request into a query expressed in terms of a language that can be understood by the repository. Once the query is formulated, it is sent to the repository for searching the LO metadata. As a result of the search, the repository returns a list of LO metadata satisfying all the pedagogical characteristics required. Later, this list is transferred to the LMS and the system begins checking other issues in order to select the most suitable LO metadata: the price, the satisfaction of legal aspects, and the copyright are met among others. This checking activity is complex and it can be decomposed into simpler processes. In order to represent this collapsed process, BPMN proposes to use a small square with a plus sign inside. After the selection of the most suitable LO, the communication with the vendor system must be established. When the vendor system is available to communicate with the LMS, the purchase order is sent and the economic transaction begins. If the transaction has been successful, the vendor system sends

to the LMS the purchase receipt and this sends the delivery order to the repository. Then, the repository delivers the URL of the LO to the LMS, so that it has access to the learning resource. Finally, the purchase is audited by the LMS and the scenario is finished as the goal has been achieved.

The goal of the scenario (the postcondition) is achieved when all the subprocesses composing it finish, meaning that all the activities composing a subprocess must have finished too. Notice that in Figure 1, there is only one possible sequence of activities in order to hold the postcondition; there may exist others to implement the LO acquisition scenario. From the BPM diagram, it is easy to realise that the LMS acts as the backbone of the scenario. It interacts with all the other participants and connects them using peer-to-peer interactions.

## BPEL Specifications

The third step consists of mapping from BPMN to BPEL in order to obtain executable specifications of the scenario.

BPEL4WS (business process execution for Web services), or BPEL for short, is a language focused on the orchestration of SOAP Web services and based on XML, so it facilitates the exchange formats and brings about interoperability. BPEL is based on the idea of peer-to-peer

processes, purpose-based interactions between BPEL orchestrator processes and individual Web services. These characteristics seem suitable for the kind of scenarios of interest in the LMS context and their boundaries.

Once we have the BPM diagram of the scenario, it is time to decide which processes are going to be needed and how they are going to be specified. Some of these processes will be implemented as BPEL processes and others as Web services. In order to do it, the BPMN specifications (OMG, 2006) help to recognise three basic submodels (the private, the abstract, and the collaboration) and propose a mapping to BPEL if possible.

Private processes are those internal to the organisation, and they are usually called workflow or BPM processes. All their tasks are contained in one pool and cannot cross the boundaries of the pool. The BPMN specifications (OMG, 2006) that propose this type of process may be mapped to one or more BPEL documents. In the LO acquisition scenario there, are no private processes because the context is out of the scope of the organisation. This kind of processes of this scenario is very simple in contrast to organisational processes.

Abstract processes are used to represent the interactions between a private process and another process or participant. Thus, the abstract process shows the world the sequence of messages required to interact with that business process. BPMN specifications (OMG, 2006) suggest that every single abstract process should be mapped to a single BPEL abstract process, usually implemented by means of Web services. Figure 2 shows how the LMS interacts with the repository for searching the LO metadata and for delivering the LO. The LMS also interacts with the vendor system in order to do the purchase transaction. Therefore, it seems that three Web services could be useful in our case. Although the search and delivery of the LO are carried out by the repository, we have decided to implement only one Web service with both operations. We have also taken into account that the LO purchase is an economic transaction commonly used in the e-learning context, so it seems reasonable for it to be implemented as another Web service.

The last submodel identified by the BPM specifications (OMG, 2006) is collaboration. It depicts the interactions between two or more business entities and can be seen as two or more abstract processes communicating with each other. These interactions are defined as a

Figure 2. Abstract processes in the LO acquisition scenario

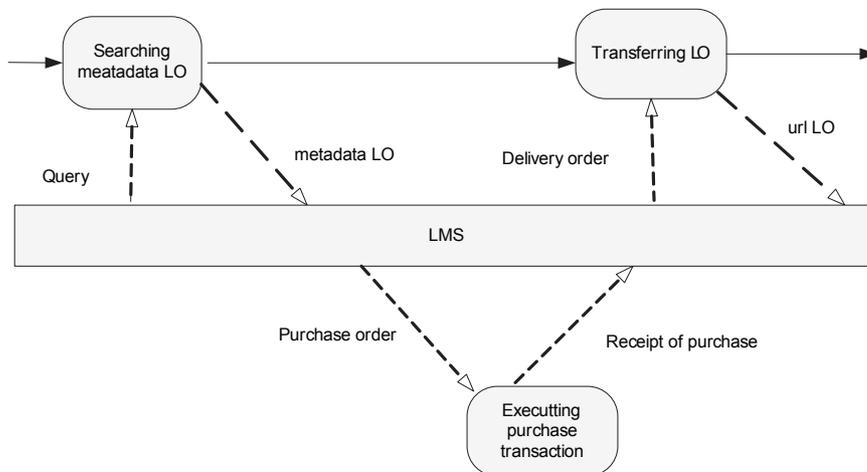
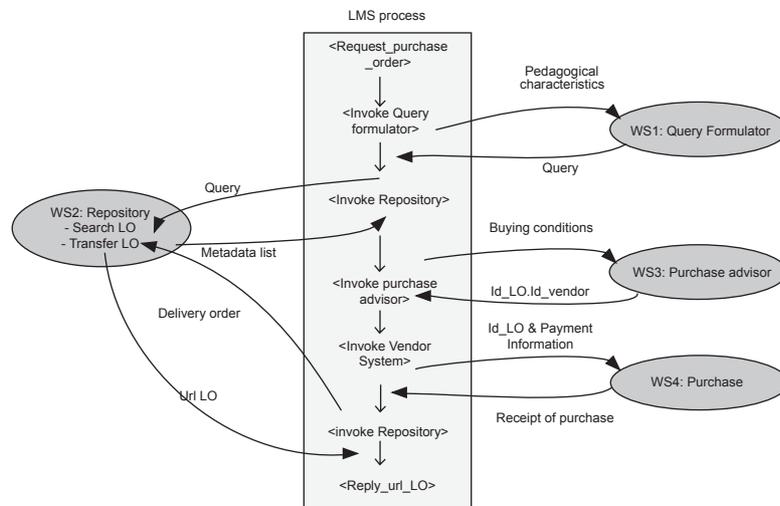


Figure 3. LO acquisition scenario processes



sequence of activities representing the message exchange patterns among the entities involved. For these cases, the specifications should be mapped to collaboration models such as ebXML, BPSS, Rosetta-Net, and so forth. In the LO acquisition scenario, the interaction between the LMS and the vendor system could be an example. The economic transaction involves many exchange messages and usually is guided by an established protocol in order to carry out the purchase. But as the study of collaborative processes is not the purpose of this article, the LO purchase has been considered like a unique interaction and has been modeled as an abstract process using a Web service.

Figure 3 presents a schema of the implementation of the LO acquisition scenario. The LMS is the orchestrator process of the scenario and, hence, it is designed as a BPEL process, which is activated by the purchase LO request as the initial event. It is adequate for implementing the LMS as a BPEL process because it consists of a sequence of invoke and receive operations and, as it has been mentioned in the previously, BPEL is suitable for programming peer-to-peer interactions between participants. Therefore, the interactions between the LMS and the repository or the LMS and the vendor

system have been treated as Web services as well as the BPMN specifications suggest. Another point to consider, in order to implement the LMS as a BPEL process, is that preparing a query and selecting the suitable LO metadata may need complex processing. The first activity must build a query to search the LO metadata, matching the pedagogical characteristics of the user; this implies some kind of translation of expression to a format understandable by the repository. The second one is supposed to select the most suitable LO metadata record from a list of possible LOs. This is a collapsed activity that has to carry out several checks about the price and other buying conditions, some legal conditions, and the copyright, among others. In both cases, the complexity of these activities and the possibility to reuse them many times has encouraged us to use other Web services. So we used the query formulator Web service and the purchase advisor Web service.

Consequently, the specifications of the acquisition scenario are obtained through the specifications of four Web services and a BPEL central process. The Web services implement some external functions that can be reused in other processes. Also, they have a predefined interface in order to facilitate the use of this

function by means of other actors. The four Web services proposed have two different reasons to exist. Two of them (the repository and vendor system Web services) are used to model the interactions between the LMS and other actors according BPMN specifications (OMG, 2006). The other two Web services (the purchase advisor and purchase Web services) have been used in order to isolate complex code in reusable functions.

Figure 4 presents a fragment of the BPEL process implementing the LMS in the LO acquisition scenario. We can see how the initial purchase request is received by the LMS process. This event sends the required data to carry out the LO purchase. Hence, the pedagogical characteristics are taken from the initial request and a variable called *client\_info* is prepared. This variable contains the infor-

mation needed to invoke the query formulator Web service. This Web service is invoked to obtain the query expression for searching the LO metadata in the repository. The query is formulated by the Web service and, considering the format, is accepted by the repository. Once the query expression is returned to the LMS process, the LMS *search\_query* variable is informed to be used in the invocation of the repository Web service. This is invoked later by the *search\_LO\_metadata* operation and it returns a list of LO metadata satisfying the query. The LMS process continues as a sequence of other invoke and receive operations, which are omitted in the example.

Figure 4. BPEL specifications as part of LO acquisition scenario

```

<sequence>
  <receive name="Receive_Purchase_Request"
    createInstance="yes"
    partnerLink="LMS"
    operation="LO_purchase"
    portType="ns3:client"
    variable="client_info"/>

  <assign name="Assign_pedagChar">
    <copy>
      <from>
        $client_info.client_info/ns0:pedagogicalCharacteristics
      </from>
      <to>
        $pedagogical_characteristics.parameters/pedagogicalCharact
      </to>
    </copy>
  </assign>

  <invoke name="Invoke_queryFormulator"
    PartnerLink="queryFormulator"
    operation="translate"
    portType="ns2:queryFormulator"
    inputVariable="pedagogical_characteristics"
    outputVariable="resultant_query"/>

  <assign name="Assign_query">
    <copy>
      <from>$resultant_query.parameters/return</from>
      <to variable="search_query"/>
    </copy>
  </assign>

  <invoke name="Search_Repository"
    partnerLink="LO_Repository"
    operation="search_LO_Metadata"
    portType="ns2:LO_Repository"
    inputVariable="search_query"
    outputVariable="Resultant_Metadata_List"/>

  <...>

```

## INTEGRATING BPMN WITH EXISTING LEARNING TECHNOLOGY SPECIFICATIONS

In the e-learning area, the research has developed a number of specifications and standards in the recent years, usually related to learning objects and their reuse. Our proposal aims at the integration of these specifications and standards in the process of executable specification processes.

The IMS DRI specification (IMS Global Consortium, 2003) addresses the interoperation of the most common repository functions. It recommends implementing these functions through Web services in order to define a common interface to promote their reusability. One of the two generalised implementations of different repository functions proposed by IMS DRI suggests the use of xQuery and SOAP- (simple object access protocol) based recommendations to achieve the full implementation of the core functions and functional architecture. Our proposal would include these recommendations using this kind of technology and implementing the repository Web service, which includes the *search\_LO\_metadata* operation that could be implemented as the IMS DRI federator function if it is decided that the scenario should be generalised with a federated search of LO metadata into several repositories. On the other hand, the translator function of the IMS DRI could also be used inside the query formulator in order to achieve the query expression in a language understandable by the repository. In this sense, the IMS DRI specifications permit us to take into account the wide range of content formats, implemented systems, technologies, and established practices existing in the area of digital repositories.

Learning-object metadata (LOM; IEEE Learning Technology Standards Committee, 2002), the standard of metadata, could also be integrated easily. It could be used to annotate the learning objects. This annotation would be useful to make the search in the repositories more efficient. Furthermore, once the system

has acquired the learning object, it could be annotated depending on the needs of the LMS so other LMS functions or scenarios can take advantage of it.

Other specifications such as LD (IMS Global Consortium, 2001) or IMS QTI (IMS Global Consortium, 2006) could be integrated in order to design the learning object. The IMS LD could be useful if the LO is a learning resource and the IMS DRI if the LO is an evaluation test. Following the specifications to define the LO would help to do it correctly and would facilitate the interoperability of LO among the LMS and other systems.

Another important standard to integrate is SCORM (Advanced Distributed Learning [ADL], 2004). It is clear that the scenario consists of the contents or metadata exchange among processes, so SCORM specifications would be useful to pack and unpack contents in the first instance. Also, it could be used instead of LOM in order to create a metadata application profile.

## CONCLUSION

In order to automate or semiautomate some functions that usually occur in the LMS and between it and other systems or repositories, there is a need to specify learning processes in such a way that it gives some support to their implementation.

This article has presented a technique based on three steps to obtain executable specifications of learning processes. The semantic conformance profiles are proposed to be used to describe the scenario in a learning-object-oriented way geared to the automation. The BPMN has been selected as the best language to describe the scenarios and so the BPMN diagram is useful to consider all participants involved in the scenario, their interactions, their workflow of activities, and messages sent among them. One of the main advantages of BPMN to be highlighted is that it promotes the interoperability, accessibility, and reusability of Web-based learning content and between systems and tools, promoting the sharing and reusing of learning objects. Furthermore, it

is attractive for all kinds of users and is very easy to understand, so it reduces the confusion among all kinds of e-learning users (Stephen, 2004). Later, the recommendations of BPMN specifications guide us to transfer the BPMN diagram to a BPEL code. Finally, we considered the integration of the other specifications of the e-learning area.

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