Adaptive Digital Resource Modeling as Service Provider and Consumer

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***Abstract*—The increase in the production of heterogeneous and multi-source digital data over last years raises several issues regarding their management and use. Hence, users can face some difficulties in selecting the adequate digital resources and combining them to reach their objectives in a given activity. In this paper, we focus on digital resources design and management in order to enhance their retrieval, interoperability, adaptation and collaboration within an adaptive system. In practical terms, our work consists in a new method for digital resource design and management capable of enhancing their usability. It relies on RESTful web service-based methodology and platform thinking approach. We have implemented our method in an interactive and adaptive PLE to assist researchers in using and managing their digital resources, called PRISE for PeRsonal Interactive research Smart Environment. We have also undertaken some experiments with PRISE platform in our laboratory. The result showed that modeling digital resources with RESTful and platform thinking concept enhances digital resource usability in terms of retrieving, interoperability, adaptation and collaboration.**

***Index Terms*—Digital resource modeling, usability, interoperability, adaptation, learning platform.**

I. Introduction

Recent research studies prove that the rapid growth in the production of digital data gives rise to new issues regarding their management [1], [2]. Information system users face several major challenges in organizing and assessing the relevance of information retrieved from diverse data sources regarding interoperability, adaptation, and discovery. They express the need for a consistent environment with reliable information, which can handle data source multiplicity and heterogeneity. These data should be easy to find, easy to adapt to users' system models, activity contexts and profiles. Let us consider users with different profiles who have access to multiple and heterogeneous data sources. The main problem that arises here is: Can heterogeneous data, from various data sources be integrated into and used in a given user specific environment? In other terms, how to make these data useful in any digital resource management environment?

Given that it is very difficult or even impossible for different users with different profiles and evolving in different contexts (system contexts) to have the same environment specification, we are aimed at providing a digital resource model that is easy to manage and integrate into user's environment. This means that each digital resource should be delivered and used according to user's characteristics and environment context. This is all the more true when it comes to digital learning environments such as LMS (Learning Management System), MOOC (Massive Open and Online Courses), PLE (Personal Learning Environment), RBLE (Resource-Based Learning Environment), which raise new challenges in digital resource modeling that should comply with them. For example, Personal Learning Environments are modern tools built upon the concept of how users (learners in this context) can organize their digital resources in a personal environment. But digital resources can become quickly complex and difficult to adapt to users' needs.

To answer these research questions, we introduce our approach, which relies on the experiences learned from software development area. Particularly, we consider API-based approach to build software as services instead of web frameworks, since today, *applications are built by consuming and producing APIs* [3].

Some research works [4]-[6] tries to propose architectures and mechanisms to create learning environments, which are adaptive to their users' requirements and profiles. In [7] the authors proposed a PLE that adapts itself to the needs and preferences of each user. In [8] the authors propose adaptive mechanisms that can adapt themselves to the context of each user model in adaptive educational systems. These studies are mainly focused on the learning tools and less interested on the digital resource integration across users' environments. Hence, literature studies on PLE are mainly on the personalized tools that allow a user organizing, choosing, sharing their data and personalizing his/her environment. Thus, PLE architecture contains three important parts: *The user model*, which is the main component of the system, *the digital resources model* and *the tools* that are used to manage or process the resources.

II. Resource-Based Platform Characteristics

Digital resources are an essential component of PLE. The authors in [9] proved that the potential of Resource-Based Learning Environments (RBLEs) for instruction and learning is considerable. Resources are generally distributed across different sites, such as libraries, classrooms, and learning environments. They claimed that in large measure, this situation evolved in response to pragmatic concerns such as the cost of duplication and assumptions related to resource usage (e.g., documents copyright).

However, widespread distribution without the benefit of a comprehensive retrieval system has complicated the location and the use of such resources for learning. Packaging has also a complicated resource use. For example, the packaging

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design for a specific context makes it difficult to use its content in other learning contexts. Consequently, it often limits the access and use of its contents for other contexts. They authors keep demonstrating that the process used to integrate multiple resources into a coherent learning environment has not been well established. Indeed, this paper tries to provide to a user a suitable digital resource model for multiple resources integration and usage enhancement.

TABLE I: COMPARISON OF DIGITAL LEARNING RESOURCE MODEL CHARACTERISTICS

Project	Resource model	Discovery	Interoperability	Adaptation	Collaboration	Execution Environment
IEEE-LOM	Accessibility-based	+	-	-	-	LMS, LO Repository
ADL-SCORM	Interoperability-based	-	+	+	-	LMS
OER	Reusable-based	-	+	+	-	LMS OER repository
EDUPUB	eBook resource-based	-	+	-	-	Reading system
Our Proposal	Service-oriented based	+	+	+	+	Platform-based environments

LOM: Learning Object Metadata; SCORM: Sharable Content Object Reference Model; OER: Open Educational Resources; EDUPUB:EDUcation PUBlishing; LMS: Learning Management System; LO: Learning Object; DR:Digital Resource

Table I summarizes existing digital resource models and the last line highlights our proposal characteristics developed in this paper. In Table I, we notice that the digital resource initiatives are incompatible with PLE and do not fulfill our most criterions. That means that digital resources are increasingly produced, but the operation of using them are not optimized. For example, MERLOT (Multimedia Education Resource for Learning and Online Teaching) contains about *62 584* learning materials [10], GLOBE (Global Learning Objects Brokering Exchange) contains about *1.2 million* of learning objects [11] and FUN (France Numeric University) contains about *33 807* pedagogical resources [12]. Most of these digital resource repositories are difficult to integrate into user's personal learning environment. For example, in [13], the authors identified the problem of SCORM (Sharable Content Object Reference Model) in its model, it is difficult to be used in LMS. Our goal is to propose a model that improves digital resource usability in terms of interoperability and collaboration in users' platforms.

An evaluation of FUN repository showed that respectively 23% of students and 28% of teachers involved in the questionnaire use the resource of FUN repository [14]. Thus, the problems identified are as follows:

1) Collaboration issues in user environment;
2) Adaptation problem to the user needs;
3) Production oriented based model not a usability-based model.

Therefore, these issues have raised new requirements in the multiple digital resources modeling. In [15], the authors stated that it requires new architectures and five domains of core functionality such as interoperability and integration, personalization, analytics, collaboration and accessibility for New Generation Digital Learning Environment (NGDLE).

The contributions of this research study are as follows: Defining a methodology of digital resource modeling that will provide the best user experience and enhance resource usability in terms of retrieving, interoperability, adaptation and collaboration.

III. BACKGROUND

A. Study Context

In our study, we define an interactive and adaptive system as a situation-based scenario system [16]. A "*situation*" is a component of the system where actors interact using local resources in a specific context to achieve one or more common objectives. The system contains three main components as shown in Fig. 1, the user model, the resource model and the process management model. In this system, the user is involved in a situation and he/she uses resources to achieve his/her objective. The management of these digital resources in a situation can help the user retrieve the appropriate resources and integrate and use it into his/her situation.

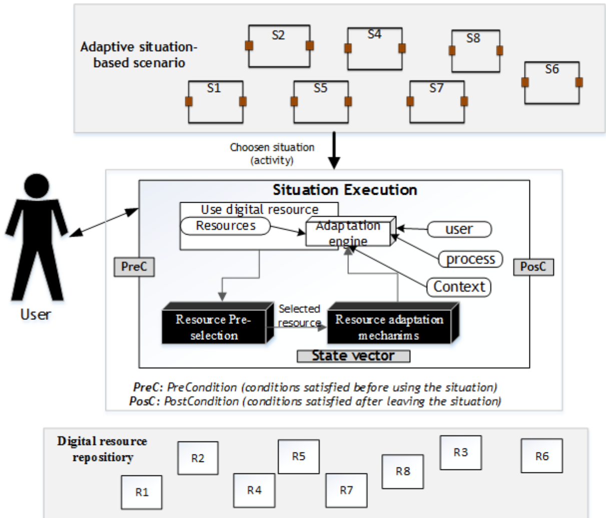


Fig. 1. Digital resource management architecture.

A situation is described with IMS-LD metadata [17] and allows the system to capture the context of user activity. The user model is a representation of information about an individual user that is essential for an adaptive system to provide the adaptation function,[8]. The resource model is the representation of information about each resource that is essential to help the user selecting it and integrating it into an activity. The process management represents the mechanism, which is associated to each user in a given situation to help him/her use the resource and manage his/her environment.

In this context our objective consists in helping each user in a situation to easily integrate and use a digital resource in his/her environment to achieve the situation goals. To achieve the aforementioned objective, we propose in this paper a new resource usability-driven method for digital resource modeling. That will enable a resource discoverability, interoperability, adaptation and collaboration in any environment. To do so, we adopt two approaches: 1) the design of digital resource as RESTful-based [18] services.

A digital resource is a component that provides services to its users through producing and consuming services; 2) integration of digital resources as Minimum Viable Product (MVP) according to Platform Thinking approach [19]. Digital resource has to be considered as the basic component of digital resource management-based environment. *A Minimum Viable Product is the smallest thing you can build that delivers customer value* [19].

B. Adaptive Digital Resource Core Architecture

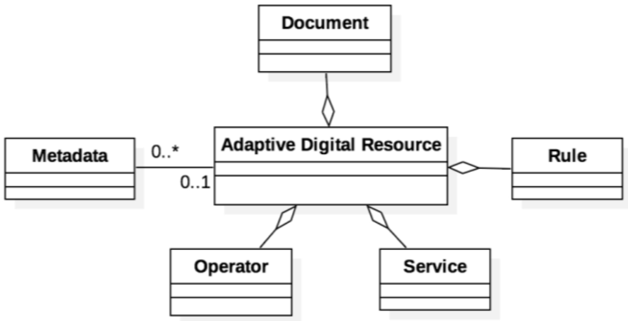


Fig. 2. Adaptive digital resource diagram class.

An adaptive digital resource (ADR) [20] is composed as shown in Fig. 2 by: metadata describing the resources, tools for manipulating the resources in the environment, rules to verify the resources's ownership to adapt it according to user characteristics. The "*service*" class is the new added class that gives an interface to third-party applications to consume the ADR exposed services.

Each digital resource in the environment includes:

1) Document: the set of files which composes a resource;
2) Metadata: to describe the resource's content (IEEE-LOM [21] application profile is used);
3) Operators: define the operations on resources and the operations between the elements contained in a resource. Operators for a resource are defined as: 1) Composition; 2) Aggregation; 3) Fusion; 4) Filtering.
4) Rules: define the rules to manipulate a resource;
5) Services: define access points for other applications.

The component used to adapt the execution and to control rules in each situation are: the user profile (described in [22]); the resource profile (the metadata of the resource IEEE-LOM model); the process profile; the contexts (by using IMS-LD model [17]).

IV. Method for Digital Resource Modeling and Integration

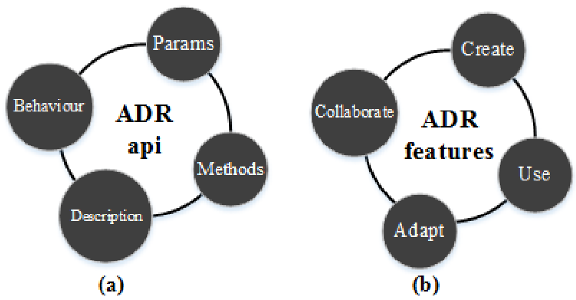


Fig. 3. Adaptive digital resource API architecture and features.

Our method consists in modeling an interoperable and collaborative digital resource ensuring discoverability functions and usability capacity, which is easy to integrate into users' platforms.

Interoperability means that the resource needs to be well described, context free, retrievable, usable, and technology independence. RESTful-based services are a good answer to implement these characteristics. Collaboration means that the digital resource needs to be produced, evaluated, shared and consumed by diverse stakeholders in the platform. Platform thinking approach can be used to implement these characteristics. The following section details our method to design digital resource which fulfills our characteristics (Table I).

A. ADR as RESTful-Based Service

REST stands for *REpresentational State Transfer* [23], which is an architectural style for networked hypermedia applications. It is primarily used to build Web services that are lightweight, maintainable, and scalable. A service based on REST is called a RESTful service. REST is not dependent on any protocol, but almost every RESTful service uses HTTP as its underlying application protocol.

More than a decade after its introduction, REST has become one of the most important technologies for Web applications. Its importance is likely to continue growing quickly as all technologies move towards an API orientation. Every major development language now includes frameworks for building RESTful Web services [24]. As such, it is easy for developers and architects to build RESTful services.

In RESTful service every system uses resources. These resources can be pictures, video files, web pages, business information, or anything that can be represented in a computer-based system. In our context, the resource is each ADR involved in the user environment. The purpose of a service is to provide a window to its clients so that they can access these resources. Service architects and developers need this service to be easy to implement, maintainable, extensible, and scalable. RESTful design promises these characteristics and even more. In general, RESTful services have many properties and features described in [24] and [25]. Within these properties and features our proposal uses:

1) **Representation:** The focus of a RESTful service is on resources and how to provide access to these resources. A resource can easily be thought of as an object as in OOP (Object-Oriented Programming). It consists in identifying the resources and determining how they are related to each other. As illustrated in Fig. 2 ADR is the representation of resource model in the platform. The new component added to this model is the service class, which describes the RESTful API service delivered by each digital resource. After identifying the resource, the next step is to define a way to represent these resources in our system. To do so, we make use of JSONLD (JavaScript Object Notation for Linked Data) [26] data format. JSON-LD is a subset of the key-value based JSON document format that provides a way of describing machine-readable information with semantic context. JSON is used as a base data format for search engines such as *Elastic Search* [27] and

NoSQL data store which is used by our platform architecture. JSON-LD is also designed to lower the barrier for data publishers who wish to provide "*Linked Data*" so that concepts and entities can be identified with certainty [28].

2) **Addressing resource**: REST requires each resource to have at least one URI. Each resource is identified by its *id*. According to **JSONLD** format the *id* is in URL format. This URL has following format: *"@id": http://prise.univ-lr.fr/resource/1821*. RESTful systems may have a uniform interface.
3) **Stateless and caching:** A RESTful service is stateless and does not maintain the application states for any client. A request cannot be dependent on a past request and a service treats each request independently. We use Trace-based system [29] to **implement** stateful services in our architecture, since we need a mechanism to maintain the resource context of use or to maintain user service contexts. Caching is the principle of storing the generated results and using the results stored instead of generating them repeatedly if the same request arrives later. This can be done on the client side or server side and it is a way of enhancing the service performance. The trace-based system is used for that purpose.
4) **Link between resources:** A resource representation can contain links to **other** resources. In a situation execution, users sometimes request for additional information (or other similar resources) or some resources require complementary information. In [30] we propose a method to connect digital resource based on similarity algorithm and software configuration approach.
5) **Documenting:** RESTful services do not necessarily require a document to help clients discovering them. Thanks to URIs, links, and a uniform interface, it is extremely simple to discover RESTful services at runtime. But documenting an API for customers can foster API's adoption [31]. We used swagger metadata to create an interactive REST API documentation that enables documentation to be synchronized with any changes made in our RESTful services. The documentation generally contains information about the API such as API version, title, description, license, etc.

Finally, The advantage of web service approach is to provide an environment that allows each service to be independent of the technology and gives methods to encapsulate and to adapt digital resource usability in user's environment. It enhances interoperability and discoverability. It gives to the user a capacity to:

1) Identify: what is the resource? And what is its configuration?
2) Control: how to configure the resource to be used in the situation context?
3) Adaptation: in the executive environment, how to adapt the resource to the user's context?
4) Interaction: what interaction feature may be used to interact with another resource?
5) Maintenance: how to maintain the resource state or save the last used configuration for reusability?

The Fig. 3(a) presents the main components of an API-based service in the system. Each API may contain a *description* metadata (for example using swagger metadata), a set of *methods* to be requested, a set of *arguments* exploited to adapt the results needed and a specific behavior when the service is called.

B. ADR Integration as Platform Thinking MVP

Platform thinking is one of the most innovative approaches that help developer maximize digital ecosystem design. *"A platform is a plug-and-play business model that allows multiple participants (producers and consumers) to connect to it, interact with each other and create and exchange value."* [32] The goal of a platform is to enable interactions between producers and consumers.

Interaction is a fundamental unit of analysis on a platform. Some platforms may have multiple participants connecting to them and many different types of interactions.

MVP [33] is the core interaction of Resource-based platform. ADR producers and consumers perform repeatedly set of actions to gain value out of the platform. These actions are illustrated in the Fig. 3(b). In this figure, ADR, stakeholders create, use, adapt and collaborate as a set of actions:

1) Create: In every interaction, there is, at least, one producer (as a role in the platform) who creates the resource;
2) Use: In every interaction, there is, at least, one consumer, who consumes the resource;
3) Adapt: To encourage usability the resource can be refined, re-used and personalized by the consumer;
4) Collaborate: To encourage good quality and quantity of resource creation, as well as to ensure that the right consumers are using the right resources. In collaboration actions, the consumers can share, comment, evaluate or review resources.

Indeed, our proposed adaptive resource model is assumed to be reusable in any situation context [20]. In order to integrate multiple resources into a coherent learning environment [34], it is necessary to adapt each resource to allow interaction within them. In [30] a method has been proposed to connect digital resource. To extend this proposal to the integration of these resources into the user platform, our method consists in:

1) Creating and configuring the resources, which are suitable to be used by a consumer in a situation. Each resource should meet the RESTful requirements for interoperability issues;
2) Enabling collaboration between users and the resources;
3) Updating and maintaining each resource in the system for reusability and personalization feature. This third step consists in maintaining the resource life cycle. Each resource is reconfigured and updated to take into account the usage experience.

Our method allows the integration of multiple digital resources in a situation-based scenario or in a situation. Interoperable, adaptive and collaborative digital resource helps users efficiently achieve the situation objectives. In our model, the configuration process consists in activating or deactivating the right “operator” or handling “rules” or “services” to make the interaction useful for the consumer request. The general architecture of our proposition is illustrated in Fig. 4. In the platform architecture, we adopted RESTful API micro-service topology [35] to allow the platform model to perform RESTful API-based communication with the internal components of the platform and also with third-party applications.

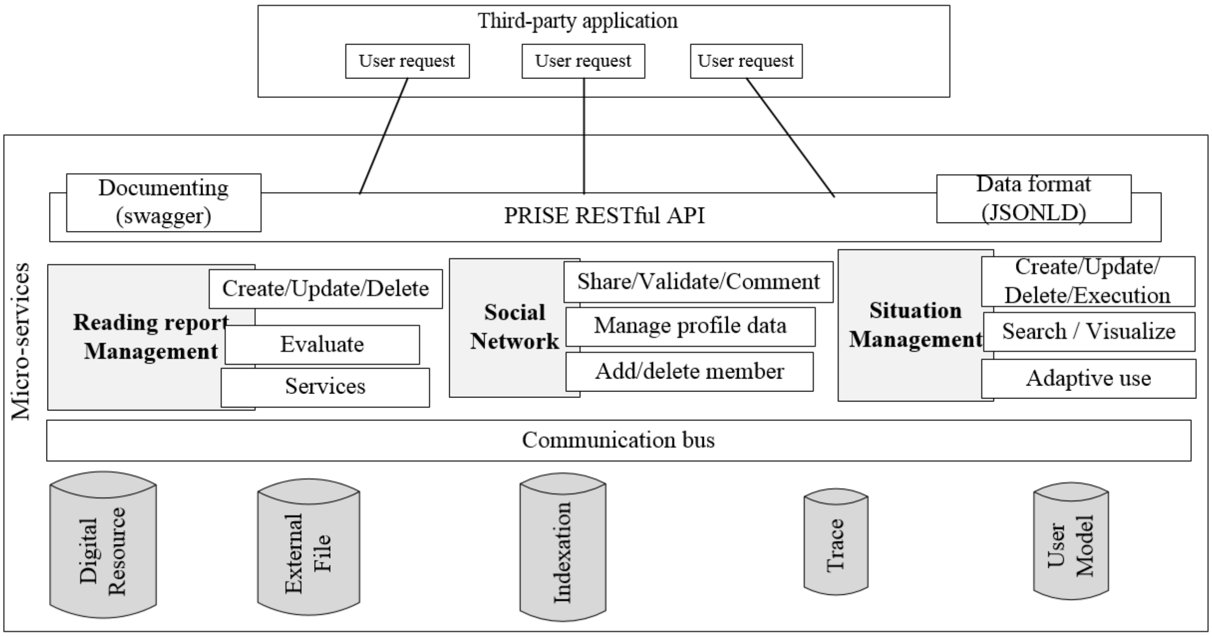


Fig. 4. PRISE API REST-based micro-services architecture.

V. Experimentation and Results

We have experimented our method in a platform called PRIS[1] for PeRsonal Interactive research Smart Environment that allows researchers to manage their digital resources. In PRISE, each digital resource is represented as a reading report. A reading report is an object that is created by users of PRISE to describe and save their digital resource in the platform. It contains the resource bibliography, the user summary and review and also the community comments. PRISE platform offers:

1) Digital resource management with standard operations of reading report such as create, read, update, delete (CRUD);
2) Social networks that include our model of researcher’s profile (IMS-LIP extension [17]);
3) Situation management that allows a user to perform an activity. The resource model and the platform model allow resources to be retrieved and integrated into the situation execution:
4) To enable collaboration among the users around the resources;
5) To automatically adapt resource presentation with user’s profile. For example, if the user prefers French and the resource supports both French and English versions, the system will deliver the French version to the user;
6) To automatically activate or deactivate the resource options according to arguments of the web service.

In this experimentation, we built digital resource web services with *DunglasApiBundle* [36]. *DunglasApiBundle* is an easy to use and powerful system to create hypermedia-driven REST APIs [37]. It is a component of the API platform framework and it can be used as a standalone bundle for the *Symfony* framework. It embraces JSON for Linked Data (JSON-LD) and Hydra Core vocabulary web standards [38].

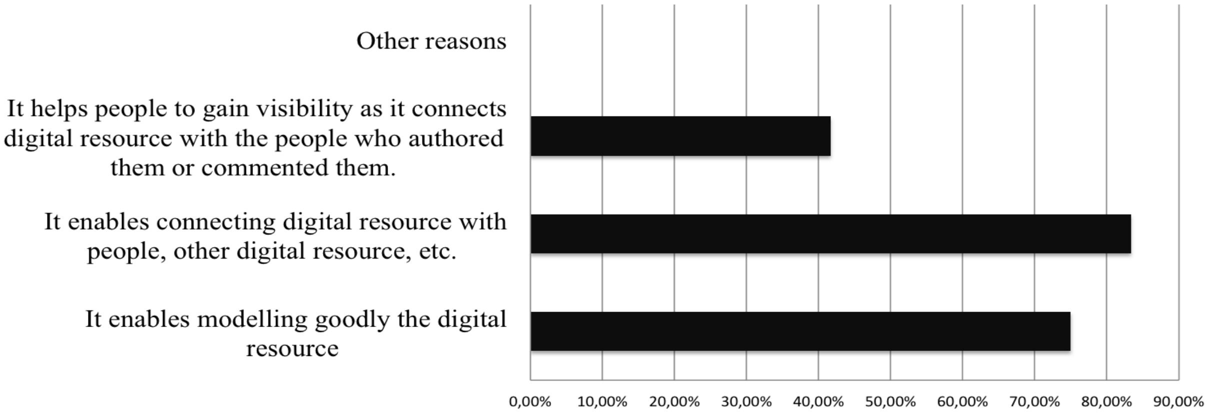
[1] http://prise.univ-lr.fr

In a reading report the user can perform one of the following requests:

1) GET readingReport: returns all information about the mentioned reading report readingReport. Consumers can also define what information they are seeking for, it could be the list of comments, the review information, the summary information or the bibliographic information;
2) POST readingReport: allows producers to post a readingReport or to update existing reading report information;
3) DELETE readingReport: allows producers to delete readingReport;
4) PUT readingReport: allows consumers or producers to update readingReport information.

We have evaluated the platform with 12 participants and 278 reading reports. The participants spent about four weeks using the platform to perform their daily activities such as summarizing their readings, writing articles, searching for relevant reading reports, etc. After that, we asked participants to evaluate the platform through an online form (survey). The results of the survey are illustrated in the graphics of Fig. 5 and Fig. 6(a, b, c). They show that **75%** of the participants agreed that the resource representation in PRISE is useful for them, and **83.33%** of them also agreed that the PRISE resource model allows collaboration between resources and users (producers and consumers), but only **41.67%** agreed that it connects consumers and producers.

Another evaluation carried out concerns participants’ feedback about using PRISE digital resource model. **67%** are interested in the function that enables third party service for the digital resource such as connecting the resource with *easychair* service (to allow the resource to be automatically sent to *easychair* or *HAL* or *shareLatex* with their grants). **33%** agreed to enable calling external services in the resource such as translator services to adapt the digital resource language to translate the resource in their native language.



	It enables modelling goodly the digital resource	It enables connecting digital resource with people, other digital resource, etc.	It helps people to gain visibility as it connects digital resource with the people who authored them or commented them.	Other reasons
■ response	75,00%	83,33%	41,67%	0,00%

Fig. 5. Digital resource feature modeling evaluation in PRISE.

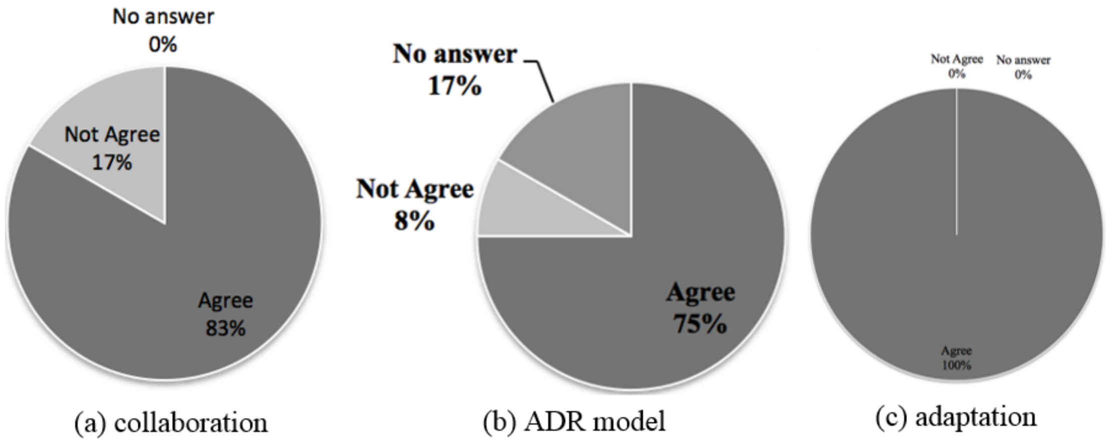


Fig. 6. Collaboration, ADR model and adaptation characteristics evaluation.

A. Interoperability Enhancement

The results of PRISE experimentation can be interpreted by a high interest of participants in the resource model provided by PRISE platform. As shown in Fig.7(d) and Fig.7(e), users perceived the adding of a third-party for digital resources, as means to implement interoperability feature is useful and relevant to assist the user in resource management and use. The contribution value can enhance resource interoperability in a personal digital environment such as PLE, RBLE or Scenario-based systems.

B. Collaboration Enhancement

Digital resources represent a good opportunity to enhance collaboration among users sharing same interests. In the PRISE experiment, *83%* of participants of the platform agreed that digital resources allow users to collaborate (Fig. 6(a)). The collaboration is implemented through resource evaluation, sharing and comment. We think that collaboration is the main function since many participants expressed a high interest in it in the PRISE digital resource model, which enhances resource quality.

C. Adaptation and Reusability Enhancement

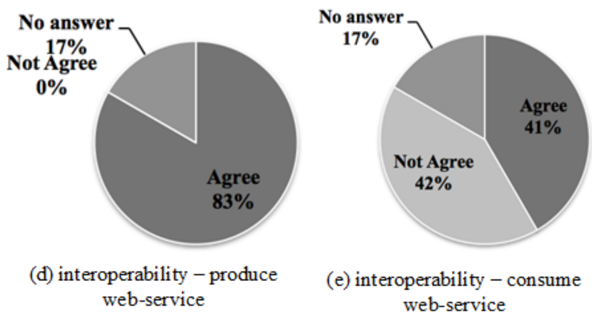


Fig. 7. Interoperability evaluation.

The resource design model we proposed enables adaptation mechanism for the user. RESTful is stateless which means that each digital resource can be contextualized according to the user characteristics and reused in any situation. According to feedback received from the participants. 75% are interested in filtering the content of each resource according to their interest and expertise. 58,33% are interesting in getting additional or complementary detailed information associated to the resource. All of the participants agreed with the adaptation characteristic (Fig. 6(c)).

VI. Related Work and Discussion

Modeling digital resources with RESTful and platform thinking concept enhances digital resource usability in terms of retrieving, interoperability, adaptation and collaboration. In RBLE, PLE, LMS, MOOC, etc. the main component, which interests users, is the resource management and use. For example, MOOC systems are mainly short video-based resource that involves users in a learning activity to get knowledge through these resources.

To our knowledge, few works have been carried out in the field. In [9], the authors argued that the process used to integrate multiple resources into a coherent learning environment has not been well established. Learners and designers are accustomed to using resources for specific purposes. Users are not generally accustomed to reuse resources developed for one purpose for another [39]. Research is needed to demonstrate how resources can be linked to meet various needs. Strategies to assist learners in analyzing and interpreting resources in terms of their validity and reliability are also needed [40]. Our objective was to well define this process to integrate multiple resources into a coherent learning environment based on the digital resource retrieval and interoperability enhancement.

Learning Object Metadata initiative published in 2002 [41] is one of the widest adopted standards for educational resource description. IEEE-LOM gives the opportunity for education resource producers to describe their resources. But for their retrieval, we need to build search engines such as MERLOT or GLOBE. The main issue of these systems lies in the lack of web service that allows consumers to integrate the resources retrieved into the user personal environment. Therefore, IEEE-LOM repositories do not really use the potential of web service capacities and do not express the value of education resources in terms of interoperability and collaboration. They only propose means to search resources based on keywords.

In [42], the SCORM Run-Time Environment (RTE) represents an opportunity for education resource designers and developers to launch Learning Object in SCORM compliant system. This model enhances learning object interoperability in different LMS. But, the SCORM model is difficult to adopt or to implement and use [13]. The authors in [13], proposed to externalize the SCORM RTE functionalities and to offer them as service according to Service Oriented Architecture (SOA) model. Despite this proposal, SCORM model is limited to LMS and faces many difficulties to be adopted by developers.

Our proposal to use RESTful approach, which is largely adopted by developers, can help to solve digital resource compliance with LMS.

As well-known, LTI [43], [44] and xAPI [45], [46] use API model to respectively connect learning tools and tracking learning activity data. These interesting works prove the interest of web service API in enhancing interoperability between platforms, but they do not focus on digital resource interoperability. Thus, our approach mainly aims to enhance resource usability in terms of interoperability (retrieving and integration), collaboration and adaptation and in much more to create a system as a platform where digital resources produce value for both producers and consumers. This approach can enhance resource usability, resources repositories adoption by their users and resource integration in PLE and RBLE.

VII. Conclusion

The exponential growth of digital learning resource production raises challenges concerning their usability and interoperability. This research work aims to prove that well digital resource modeling can optimize and enhance their integration and use in users' platforms.

We found that modeling digital resource with RESTful-based API methodology and platform thinking approach actually enhance digital resource usability capability in terms of retrieval, interoperability, adaptation and collaboration. Thus, in the context of learning environment, the contribution value enhances PLE and RBLE capability to integrate multiple digital resources into the user platform. We plan to extend digital resource adaptation mechanisms to enhance resource usability in terms of digital resources personalization.

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