Services, Semantics and Standards: Elements of a Learning Grid Infrastructure

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Abstract

There has been considerable political pressure, and much hope invested in, the use of Communication and Information Technologies to provide wider access to education, while improving quality and reducing costs. Unfortunately, many of the responses to the challenge of these aspirations have consisted of simple Web technology-driven products which have failed to progress effective learning. We outline the characteristics and pedagogical goals of a learning paradigm that is used to drive the technical requirements, rather than being constrained by what is easily achieved in XHTML. We identify and explain the key roles played by services, semantics and standards in meeting pedagogical goals of novel learning situations, and illustrate with some scenarios which build bridges between traditional learning contexts and future possibilities and, finally, describe an example of a methodology for the creation of future learning scenarios.

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1 Introduction

Traditionally, formally structured learning takes place in a variety of situations and contexts. The classroom or lecture theatre, the library, the laboratory, the field trip, training "on the job", and the tutorial or small discussion group are all examples of formal learning situations. There has been growing political pressure across Europe in recent years to provide wider access to education, to reduce costs, while maintaining or improving the quality of learning, and these traditional contexts are now seen as expensive and as barriers to wider access. Communication and Information Technologies (C&IT) have therefore been extensively promoted as the only feasible way forward for "education providers". For example, the most recent major report on the future of higher education in the UK[1] stated:

"*Advances in communications and IT (C&IT) will radically alter the shape and delivery of learning throughout the world. Over the next decade …. institutions will rely heavily on C&IT to teach quality, flexibility and effectiveness of higher education. The potential benefits will extend to, and affect the practice of, learning and teaching and research. C&IT will have a central role in maintaining the quality of higher education in an era when there are likely to be continuing pressures on costs and a need to respond to an increasing demand for places in institutions. C&IT will overcome barriers to higher education, providing improved access and increased effectiveness, particularly in terms of lifelong learning.*" [12]

Reciprocally, with so much emphasis being placed on the use of C&IT to enhance education and meet these ambitious political goals, there is an emergent software industry in "e-Learning" products, and even speculation that they could be the next "killer app" [13].

Unfortunately the current generation of "e-Learning solutions", which has arisen in response to political pressure, has adopted the rather narrow pedagogic paradigm of "information transfer", which features the teacher as someone who selects particular pieces of information and makes them available to students on the Web. This approach very conveniently gives the surface impression that C&IT is being put to good use. However, there is no evidence that this approach to technology enhanced learning is in anyway effective. It has been adopted simply because it is an easy way to use the Web's basic facilities – material is selected and organised by the teacher on a web site, and students then browse and download it. Failures, such as massive drop out rates, are usually explained by a lack of staff awareness in the use of the Web, rather than critical reflection on the limits of this approach. Furthermore, it is not even clear that it has achieved reduced costs [14]. Indeed, the recently evaluated UK E-University has been castigated by a UK parliamentary watchdog committee for squandering €70M of public funds before catastrophically failing and ceasing operation[2].

So, the question remains – how can we provide better access while maintaining or improving quality of learning through the use of C&IT? The aim of ELeGI, the European Learning Grid Infrastructure project, is to progress *effective* human learning by promoting, supporting and demonstrating a learning paradigm shift from the current information transfer paradigm, to one that focuses on knowledge construction using experiential and collaborative learning approaches in a contextualised, personalised and ubiquitous way. ELeGI has adopted a service-oriented model, which is deeply intertwined with the use of semantic tagging, and has aligned itself with the global community who are developing learning resources which are OGSA (Open Grid Services Architecture) compliant. This paper reviews the rationale for ELeGI – its pedagogical goals, their technical implications, the key concepts of *services* and *semantics* and its alignment with *standards* associated with OGSA and the Semantic Web - and illustrates the flexibility and power of this approach by showing how traditional learning situations can be abstracted and treated as metaphors for supporting future learning scenarios through the dynamic combination of services to suit particular contexts.

[1] The Report of the National Committee of Inquiry into Higher Education (1997), chaired by Sir Ron Dearing, was charged with making recommendations for Higher Education in the UK for the next twenty years.

[2] http://news.bbc.co.uk/1/hi/education/4311791.stm

2 Pedagogical Issues

Actually, no-one really knows how we learn! However, we do know that some characteristics and approaches are more likely to be effective in formalized and structured educational programmes. In order to advance effective learning we incorporate these features into an educational paradigm that focuses on the learner and on new forms of learning. In our approach the learner has an active and central role in the learning process. Learning activities are aimed at facilitating the construction of knowledge and skills in the learner, instead of the memorisation of information. Information transfer will still obviously exist in scenarios engendered by the new paradigm, but only as a simple component, not the main goal. Accordingly we can say that the new paradigm subsumes the old one in its displacement.

Knowledge construction occurs through new forms of learning based on:

- the understanding of concepts through direct experience of their manifestation in realistic contexts (i.e. providing access to real world data and scenarios) which are constructed from sophisticated software interfaces and devices, and represented as services;
- "social learning" – active collaboration with other students, teachers, tutors, experts or, in general, available human peers, by using different kinds of collaboration technologies, especially enhanced presence.

In this approach collaboration is considered as a complex conversational process that goes far beyond a simple information exchange. In order to support such a "ubiquitous conversational process", one must consider the social context where the learning process occurs. Accordingly we do not consider the learner's ability in an abstract way, but relate it to a specific situation (the context). In this ambit the term "ubiquitous" does not refer simply to "anytime / anywhere", but more generally to the ability to support multiple diverse learning contexts and automatically adapt to them.

As we consider human learning as a social process, collaboration implies community membership, it means working together, providing added value, sharing and executing tasks in order to reach a common goal. Learning is no longer an isolated activity – it implies mutual trust, shared interests, common goals, commitments, obligations, exchanging of services, a genuinely proactive, motivated behaviour.

In order to foster these new approaches to learning we must create dynamic contexts where the learner "achieves" knowledge and skills in an active way instead of simply acquiring and storing information. Communities will have the right to identify their goals, in terms of knowledge and skills to be acquired, instead of just asking an authority to define a curriculum for them. Goals will therefore genuinely correspond to needs, and be highly dependent on the local culture and its priorities.

The point is *when* do Communities express their needs: *before* or *during* the collaboration? Most "pedagogists" would like needs to be expressed before, so that pedagogically validated methods would be activated for the Communities. In the view of human learnng as a dynamic process the client's need is not necessarily expressed in advance. Thus it is not known what a "client" may eventually receive from the "server" in order to satisfy a need. It is *inherent* to services that the expression of the need is the *result* of interactions, not the starting point (as in classical query systems).

According to this new learning paradigm we consider *realism* as the cornerstone of the learning environment. For example, highly realistic virtual scientific experiments have only recently become possible through the use of advanced technology – high-speed computation and virtual reality interfaces for example.. Innovative aspects include the definition of didactical models for the achievement and representation of such experiments. In this type of model a learner is immersed in a specific context, which through appropriate simulations, develops active learning processes with progressive abstraction levels, leading to the construction of their knowledge in a dynamic way. In this learning mode the student can also receive the support of other users (collaborative aspects) and from the comparison with them, they can build a new "mediated" knowledge.

To complement this freedom in knowledge construction, we allow the definition of personalised and individualised learning paths. This means that in a specific context we need, from one side, to create learning conditions that are adequate for a learner's preferences (individualised learning) and, from the other, guarantee that the learner will reach a cognitive excellence through different learning paths according to their skills and knowledge. Accordingly, we seek to define specific models for representing knowledge that take the learners preferred learning styles into account. A beneficial result of allowing learners the right to construct their own knowledge is that richer and more diversified learning contexts can arise, necessitating the dynamic integration of different kinds of information and communication technologies.

3 Technical Implications: Services, Semantics and Standards

In order to support ubiquitous, collaborative, experiential and contextualised learning in dynamic virtual communities a learning environment should provide the following features for learners:

- Collaboration; Socio-constructivist: group working should be routinely supported as well as the more traditional model of the solitary learner – this includes support for self-organising online communities who share common educational goals
- Experiential; Active Learning: learning resources should be interactive, engaging, and responsive – active learning and knowledge formation should be emphasised above simple information transfer
- Realism: real-world input should be easy to incorporate, as should simulations, ranging from simple interactive animations to immersive VR
- Personalised: students should find themselves at the centre of their online environment, with their individual needs addressed - the quality of the learning experience should be continually validated and evaluated
- Ubiquity and accessibility:
  - wider, more flexible access to educational resources should be provided, often referred to as "anytime/anywhere" learning
  - multiple different types of devices, interfaces, and network connection types should be supported where possible
  - participants with special needs should be catered for automatically
  - language barriers should be removed through automatic realtime translation
- Contextualised; Adaptive: appropriate learning contexts may naturally be short-lived, as well as the more traditional static situations such as the classroom and the library – this calls for dynamicity in the creation of contexts

The pedagogical goals outlined above have highly demanding technical requirements, many of which are also the concerns of distributed systems research. Group working implies shared interactive services and resources, necessitating both concurrency control and awareness of others activities. Active learning requires interactive resources (*services*) many of which will only be engaging if they are suitably responsive – a *quality of service* (QoS) issue that depends on many components of a distributed system – the low-level infrastructure (hardware, OS, network), the middleware and the interface software. Concurrency control and interactive responsiveness can make conflicting demands on a system. Real world input, such as live stock market prices, or current remote sensing data makes a network connection mandatory, and this again raises QoS issues such as fault detection, masking and tolerance for the learning environment.

Accessibility, as in "anytime/anywhere", requires availability, which may be supported through replication of resources, but this creates further tensions with responsiveness and concurrency control due to the need to maintain state across replicas. Accessibility also means adapting to available capabilities. For example: can the same learning environment be delivered through low-bandwidth mobile devices and high-bandwidth multimedia workstations? Accessibility also means supporting the special needs of an individual, such as disabilities. More generally, the individual user should be recognised and catered for, and this personalisation requires *semantic tagging* and profiling that can be difficult to formulate, both conceptually and in terms of machine representation. *Standards* efforts such as IMS[3] and IEEE LOM[4] have been particularly slow in addressing this problem. This is because they are basically centered on standardising the *description* of the content of learning objects and ways to *transfer* that content. They implicitly adopt the Information Transfer paradigm. The goal of the new paradigm is to *contruct* shared knowledge - not to transfer some ready-made one.

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[3] IMS (Instructional Management System), http://www.imsglobal.org/
[4] 1484.12.1: IEEE Standard for Learning Object Metadata, http://ltsc.ieee.org/wg12/index.html

Contextualisation requires a move from the traditional view of an online learning environment as a stable long-lived entity (e.g. during the lifetime of a teaching module) – to one where the environment may evolve and change much more frequently – a dynamicity that is alien to current e-Learning products. Context may include the student's personal profile: identity, special needs, their current position(s) on learning topic trajectory(s), learning style preferences, record of previous achievements, their current location (mobile services), their current interface device options (PDA, standard browser), audio/video, VR capabilities, available network QoS, available computational capabilities. These types of contextual information are essential for the selection and generation of appropriate learning services for the student, at that point in time. For example, a low-bandwidth mobile PDA connection would suggest different types of graphical output than a high-bandwidth desktop screen or Head Mounted Display.

We believe that these technical requirements can best be addressed by building on the open distributed service model that has evolved exploiting Grid and Semantic technologies.

3.1 Services are not products

An open distributed service model is based on the concept of service that, in our context, is a kind of predefined combination of processes yielding some result (the goal of the service) from distributed, heterogeneous, asynchronously communicating and available resources. A service has access to some distributed heterogeneous resources and assuming the communication language is known to each resource, it performs a series of operations (queries of information, requests of computation, controls, redirection, ...) by interacting with these resources.

The basic difference between a service and a product, we believe, is in the "truly" conversational, dynamic nature of services. In order to clarify the difference, we consider the following salient features of the two entities:

- a product is developed by the producer with a clearly predefined goal for the potential consumer; a service is offered within a service domain – or competence area – so, the consumer-specific objectives have to be defined during the initial conversations between the provider and the consumer of the service
- a product is supposed to correspond with a well established and clearly identified need; a service often anticipates a customer's combinations of needs that were not clearly recognised as such by him/her
- a product is usually designed and prototypically developed once, then produced many times - the value added by a product increases with the number of copies distributed; a service must be conceived, designed, developed and distributed once for all, as it is custom made for a specific customer with specific needs; the value added by a service increases proportionally with the customer's satisfaction that entails an indirect publicity for the service producer and generates new customers ready to invest more resources in order to have similar services;
- a product's evolution is slow, as it requires modifications in the conception, design and development - a revision of the whole life cycle. A service evolves naturally as it is a combination of basic services and products on the fly as a consequence of service definition and tuning during the conversations with a customer - forcing requirements for services to be pre-defined, identified and specified out of the context of use, is inconsistent with the notion of service
- a product is often chosen as a solution for an established need, even when the customer does not really "trust" the producer's performance (e.g.: even if I dislike cars and prefer a car-less city centre, I need one for very practical reasons, and I choose the cheapest one because I plan to use it as little as possible); a service requires trust by the customer on the producer (e.g.: I do not go to a dentist or a lawyer unless I believe (s)he is trustable).

According to the needs of real applications, we can try to classify services in:

- "stateless services": these are represented as pure functions. The advantage of easy composition of purely functional services comes at the cost that they can hardly represent state
- "conversational services": these are the most generic stateful services. These are difficult to realise within a distributed and asynchronous context, heavy to be supported and maintained, they however

maintain their fundamental interest for the most advanced applications. We believe that higher level services such as those emerging from semantically rich domains will require this model to co-exist with the other ones.

So for example, stateless services are epitomized by read-only web pages, where interaction is limited to downloading some content, and the user is an unknown anonymous entity. The server maintains no state, simply a log that a particular node on the Internet downloaded a set of files at a particular time. By contrast, considerable work is put in to "e-commerce" style transactions on the web, where state is desperately maintained by both the client and the server, sometimes using cookies, sometimes other ad hoc devices, to enable a sequence of incremental steps to be followed culminating in a transfer of real money for some commodity. We note that an interactive learning environment places no less stringent demands on maintaining shared state than e-commerce – indeed, the learning process may last a lifetime! The awkwardness with which the Web deals with this fundamental requirement for service-oriented-architectures is of course part of the motivation behind the stateful approach taken by the Grid.

Recently, Grid community efforts are related to the definition of a base framework for an Open Grid Service Architecture [4]: the Web Service Resource Framework (WSRF) [5]. Starting from experience gained from the definition of the Open Grid Service Infrastructure (OGSI) [9], WSRF proposes an evolution of the Grid Service, which can be classified as a "conversational service", towards a "stateless service acting upon a stateful resource". The WSRF proposal is involved also in defining service and its needs, and the proposed definition is a middle way between pure stateless services and stateful conversational ones, thus allowing a simple way to compose services without loosing the advantages of state management.

4 Why Grid?

The Grid [3] was originally designed for e-Science and was primarily concerned with supercomputing applications, but the framework it engendered to realise effective sharing of distributed heterogeneous resources (OGSA: the Open Grid Services Architecture) is now being applied to many other areas, especially enterprise computing and e-Commerce. Reciprocally, by progressing Grid technologies for learning, we will also contribute towards the advancement of the open Grid service model itself, specifically in the learning domain. We see the use of the Grid to support a paradigm shift in pedagogy to advance effective learning as a natural step in the recent historical progress of C&IT in learning: Internet → Web → Grid.

OGSA leverages open standards, including those developed by W3C[5] and the OGF[6], and provides an holistic view of Grid computing based on the concepts of 'Services', 'Distributed Collaboration' and 'Virtual Organisation'. At this point, future learning scenarios enter the picture: the user-centred, contextualised and experiential based approaches for ubiquitous learning imply the full exploitation of location-transparent access to distributed services such as simulation environments, real-world input, 3D visualisation systems and digital libraries, in the framework of a Virtual Organization. This allows a transition from current content-oriented e-Learning solutions towards a user-centered, reflective, collaborative model.

The next generation of Grid solutions will increasingly adopt the *service-oriented model* for exploiting commodity technologies. Its goal is to enable as well as facilitate the transformation of *Information* into *Knowledge*, by humans as well as – progressively – by software agents, providing the electronic underpinning for a global society in business, government, research, science, education and entertainment (*semantic aspects*) We refer to these efforts as the "Semantic Grid".

The Semantic Grid brings together Grid and Semantic Web technologies[7]. Semantic Web and Knowledge technologies are mainly focused on giving a well defined meaning to resources, services and information dispersed on the Web [6], they provides tools for knowledge representation and management, annotation of data and resources, discovery of services and resources based on their meaning and function, automatic composition of services and inference over metadata and ontologies. Current technologies, based on industrial standards and initiatives (e.g. UDDI [8], BPEL4WS [7]), allow composition of services with an a priori knowledge of

[5] http://www.w3.org/
[6] http://www.gridforum.org/
[7] http://www.w3.org/2001/sw/

services meanings and processes between services. In contrast, Semantic Web and Knowledge technologies provide an expressive and semantically enriched description of services, by the use of ontology description languages as OWL-S [2], and allow for the automatic selection, location and composition of services in order to achieve required objectives.

In summary, ELeGI seeks to develop an OGSA compliant service oriented software architecture and realise a corresponding prototype infrastructure in order to support effective learning environments which exemplify the new paradigm.

5 Future Learning Scenarios

It is of course essential that a conceptual bridge is provided when moving from traditional learning environments to new ones. In order to demonstrate the suitability of an open services environment such as that envisaged by OGSA to support new learning contexts we consider how traditional *contexts* can be used as metaphors for *learning services*. We list a series of scenarios showing how a service-oriented approach can be used to dynamically create novel contexts that combine traditional ones. Combinations can feature arbitrary mixes of real and virtual versions of common contexts. The virtualised contexts are metaphors for traditional (real) contexts that are realised through dynamic service generation. As the exact mix of components required will be determined by numerous factors, often unique to a particular learner at some point on their own learning trajectory, it is important that combinations can be produced dynamically. We outline three scenarios, and then use a table to summarise them in terms of how they mix traditional contexts with novel ones that are supported by a service-oriented framework.

5.1 Scenario One: Featuring Immersive Virtual Reality

A student goes to a real library and studies aspects of water table and aquifer behaviour through interacting with books and some multimedia resources. They learn so much, but ideally need to go on a field trip to various regions of the world to gain first hand experience of discovering and understanding native water resources. A dynamically generated set of services are brought together and delivered to the student, in the real library, to create an immersive virtual reality situation where they can explore and develop their own personal understanding and knowledge, without physically leaving the library. They may encounter other students from other locations in the world sharing the same virtual reality due to similar interests. They can converse with each other (courtesy of an real-time language translation service) and learning occurs naturally as a by product of conversations and social interaction.

5.2 Scenario Two: Featuring the Virtual Laboratory

Students are in the classroom and reach a point where they need to carry out experiments. Real equipment and facilities are expensive but they can call up highly realistic virtual laboratories to carry out their experiments; they can compare results with each other, with other students using the virtual laboratories, and with professional practitioners who are also using the same virtual laboratories. They can further reinforce their understanding and increase either knowledge by taking a virtual field trip and carrying out tests in context. They can a "rewind" experiments to some point and choose new branches, suspend simulated realtime sequences of events, and then start them again at a later point in elapsed time, possibly through a different type of interface.

Within the ELegI project the Virtual Control Laboratory (VCLab)[8] has been re-engineered as a set of Grid services for learning about Control Engineering. VCLab combines realtime mathematical modeling as a set of back-end Grid services, with Virtual reality Markup Language (VRML) based output. The decoupling of the

[8] C. Schmid and S. Muller, A Contribution to Control Engineering Education on the Web, *Proc. 4th IFAC Symposium on Advances in Control Education ACE'97*, Istanbul, Turkey, 1997.

functionality (services) from the interfaces allows for a variety of interfaces to be developed, not only VRML output, suitable for standard browsers, but others, more suitable for handhelds, or even audio-only.

5.3 Scenario Three: The Field Trip

This scenario, based on the traditional field trip augmented by appropriate use of information and communication technologies, illustrates experiential, contextualised, collaborative and personalised learning for knowledge creation and sharing. Figure 1 depicts the scenario.

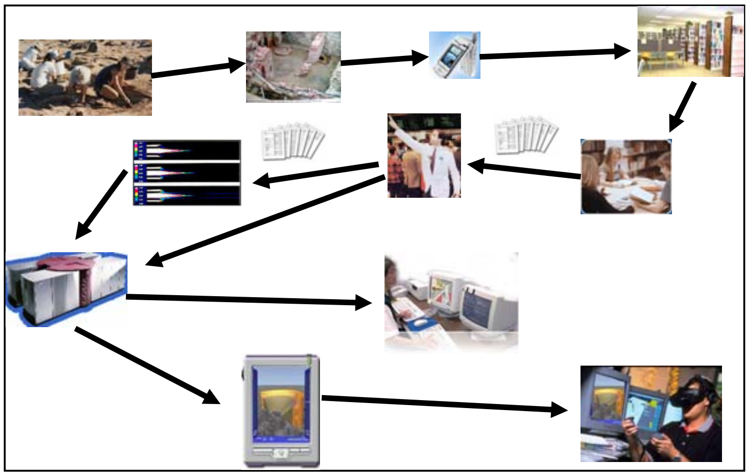

Figure 1: A Technology Enhanced Field Trip Scenario

There is a group of students, all equipped with a 4th generation PDA, that for their Archaeology spring exam are working on the Field Trip project. During their activity they store information, experience, emotion, in terms of photos, video clips, text notes, audio comments, etc. The PDA, using the user profile and context dependent information automatically indexed these contents using appropriate metadata standards. The information collected by all students are send via the appropriate network (the PDA will negotiate with the network service provider operative in that zone which kind of network communication will be used according to the bandwidth necessary, the price, etc.) to the Field Trip (FT) grid service created by the teacher of the course for their project. The PDA will use user biometric data for secure access to grid based virtual learning organisation and for data ciphering. The FT grid service, orchestrating speech to text grid services (provided by Company A) and advanced semantic tool for text interpretation virtualised as grid services (provided by Company B), will analyse the student's information comparing them with the learning objective foresees for the project experience and formalised in an ontology based knowledge representation (concepts to be learned, goals to reach, relationships, etc.). It summarises them from the learning point of view in term of progress and weakness to the teacher. It stores all the information in a multimedia repository grid service. At the end of the day the students working in the field trip meet for sharing their experiences and for consolidating the knowledge acquired. They will use the PDA speech recognition capability for sending commands to the search engine in order to retrieve the information and for their visualisation. During these sessions it is frequently necessary to consult digital libraries (provide by different organisations) for finding new information or for checking some hypothesis done and/or evaluations made about the provenience of discovered objects.

During the daily work in the field trip some collaborative sessions with other students in the school are needed in order to share their experiences. To this purpose the students collect with their PDA some photo of the field trip and the objects discovered and send them to the Virtual Collaboration grid service asking to make them in 3D. The VC grid service invokes the high performance 3D modelling and rendering tools (provided by the High Performance Computing Centre of the University) virtualised as grid services in order to make the 3D reconstruction and rendering them. In order to make more productive the experience the FT grid service, using the context data and the information collected by the single student, provide them the possibility to discuss with selected (by the teacher) experts on the field (historical period, zone, objects nature, etc.). Moreover, using semantic based grid service searching and location capability it will provide information about the availability of other groups in the same zone or in different zones but with affinity with their work and belonging to different grid enabled virtual learning organisations in order to share their experience.

5.3.1 Summary of Scenario Features

Table 1 summarises the various combinations of traditional contexts in these three scenarios.

Learning Contexts	Scenarios: 1 Immersive VR	Scenarios: 2 The Virtual Laboratory	Scenarios: 3 The Augmented Field Trip
Library	Traditional (Real)		Service (Virtual)
Field Trip	Service (Virtual)		Traditional (Real)
Classroom / Lecture Theatre		Traditional (Real)	Service (Virtual)
Laboratory		Service (Virtual)	
Tutorial Group			Traditional (Real)
Project Group		Traditional (Real)	
Ad Hoc Discussion Group	Service (Virtual)		Service (Virtual)

Table 1: Overview of Traditional Contexts in Advanced Scenarios

5.4 IMS-LD: A Tool for creating Service-based Learning Scenarios

Standards are of course essential to achieve genuine interoperability and meaningful interaction in open distributed systems. The service marketplace must be underpinned by recognised and open standards. At present, IMS Learning Design (IMS-LD) [1] provides a promising approach for representing different didactical approaches allowing the use of a wide range of pedagogies in online learning. While other IMS standards are mainly focused on content and on the single learner, IMS-LD provides a way to design learning experiences allowing interactions between many roles. It defines a language for the representation of different pedagogies rather than trying to capture specific aspects of the pedagogies, thus allowing a formal specification of different learning scenarios.

IMS-LD consists of three parts:

- *Level A*: describes core-elements of simple units of learning and a meta-language for the definition of different didactical approaches,
- *Level B*: extends Level A introducing a definition of properties and conditional situations within a unit of learning. This can include conditions on learning activities based on learner preferences, needs and skill,
- *Level C*: extends Levels A and B including notification mechanisms between system components, activities and roles. Level C features allow, for example, the start of activities triggered by the completion of other activities.

In practice, a Learning Design is an XML document that describes roles, activities, learning goals and the objectives of a learning scenario. The lifecycle of a Learning Design is made up of three phases: i) Analysis and Modeling of the Learning Design, ii) Development of a XML document representing the Learning Design, and iii) Delivery of the Learning Design.

IMS-LD tries to address a specific and complex challenge: the modeling of learning and teaching practices that go beyond simple traditional web-based LO's delivery. As emphasized in [15] IMS-LD adopts a two level approach to fulfill this task. It models a) the *learning activities*, which can be defined as interactions between a learner and an environment to achieve a planned learning outcome, and b) the *learning approaches*, involving selection and orchestration of the activities on the basis of pedagogies.

IMS-LD, together with reference architectures, open source projects and commercial initiatives, is described in [16]. We foresee the impact that it may have on the creation of future learning scenarios as the ones described in the sections above, especially if it can rely upon a set of dynamic, collaborative, adaptive and standard based service technologies, such as the Grid ones. For example, it is likely that IMS-LD can be used to orchestrate the traditional learning contexts composing the aforementioned learning scenarios (see Table 1) and it is also clear that many of the attractive features of IMS-LD, e.g. support for multiple delivery models, support for reuse and re-purposing of units of learning or their component elements, and many others, are common requirements in our learning scenarios. However, we need suitable middleware technology to relaise the full potential of IMS-LD - the Semantic Grid [17].

As argued in the conclusion of [16] "*it takes time to move a specification out into the world, and Learning Design, being a large specification, can reasonably be expected to take longer than most. But an encouraging number of developments are underway that suggests that this timescale can be shortened.*" In [18] the advantages and drawbacks of the integration of IMS-LD and Grid are investigated, and the authors propose and justify the adoption of IMS-LD and Grid to support Computer Supported Collaborative Learning. Our approach is close to this, but in addition, we will also investigate the importance of semantics and knowledge technologies in order to provide dynamic and knowledge-driven binding of resources and services in a learning scenario described by an IMS-LD document.

6 Towards the Semantic Grid for Human Learning

We have been motivated by the failure of technology-driven e-learning "solutions" to identify features of successful pedagogical models and then look for technologies which can provide these features. The pedagogical features we have identified include collaboration, personalization, learner-centricity, context-awareness, realism, personal learning profiles, personal special needs, ubiquity, accessibility and availability. In order to create a framework which can support these features we need to use the key concepts of services, semantics and standards. Services provide us with a flexibility and dynamicity that is foreign to products, standards provide us with the potential for interoperability and meaningful interaction, and semantics give us the crucial ability to imbue machine comprehensible meaning to learning artifacts. We have decided to align our work with OGSA because it already provides a generic and open framework for services, standards and semantics. Accordingly, we refer to this vision as the "Semantic Grid for Human Learning".

The Semantic Grid for Human Learning can be seen as a domain specialisation of the generic Semantic Grid equipped with tools, services, standards and technologies for Education. It is based on the OGSA model, so it inherits all the features of that architecture. Two aspects, in particular, are important: i) the *openness* of the architecture, where open means extensibility, vendor neutrality, and commitment to a community standardization process; and ii) the *service orientation* and *virtualization*, where the first is related to definition of service interfaces and the identification of protocols that can be used to invoke a particular interface, and the second is related to the encapsulation behind a common interface of diverse implementation, so everything (tools, resources, scientific instruments, activities, etc…) in this environment is a service.

The Semantic Grid for Human Learning must also provide support for the various phases of a Learning Design. Authoring tools for the production of learning scenarios can make use of knowledge-based decision making systems to suggest the best pedagogical models and/or activities for a learning scenario, and also use Grid knowledge (e.g. starting skills, personal profiles, etc…) about the actors in the scenario. Furthermore, experts can exploit the collaborative features of the Grid to cooperate in order to model the scenario. In this way, the

Semantic Grid for Human Learning supports the analysis, modeling and development phases of Learning Design documents. Next, the goal of the delivery phase is the understanding of the Learning Design document and the execution of its content in order to i) reproduce the didactical experience for the learner; and, ii) supply the teacher with the capability to support a didactical requirement.

The Semantic Grid for Human Learning uses knowledge in order to bind the learner preferences and the pedagogical model against the appropriate tools, resources and activities available on the Grid. This is performed using high-level inference engines to browse:

- OWL-S ontologies indexing core elements of a unit of learning virtualized as services. OWL-S provides three types of knowledge about a service: the profile that describes what the service does, the model that describes how a service work and the grounding that describes how a service can be accessed [11],
- meta-ontologies on the previous ontologies to define cross references between high level figures representing learner preferences, skill, needs and resources/activities.

In some conflict cases, where more than one appropriate resource is found, knowledge based support systems can help the expert in the selection. To support interactions among the actors involved in a scenario, trusted group can be dynamically created where learners and teachers can join and resign the scenario.

The Semantic Grid for Human Learning makes available a learning scenario with all its “implicit knowledge” (pedagogical model of the scenario, learning goals of the scenario, resources and activities involved, etc…) as a building block for creation of more complex and interactive learning experiences composed by different scenarios. A learning scenario, once produced and virtualized as a Human Learning Service, can be indexed and stored in a knowledge base, thus becoming a shared unit of knowledge reusable in other contexts. How does this differ from traditional content storage and transfer? It is the productive steps in the construction process that are being remembered for possible re-use – not chunks of information.

We summarise by emphasizing how our vision of the Semantic Grid for Human Learning presents some of the properties described in [10] and is projected towards the Next Generation Grids:

- *it is open and standard based* – our vision is based on widely adopted standards and specifications
- *it is secure* – even if not emphasized in the paper, the Semantic Grid for Human Learning has to address many security aspects from both technical and legal viewpoints
- *it is person centric* – our Grid manages knowledge in order to satisfy learner requirements and preferences also on the basis of what the Grid know about the learner. Also the goal of the learning scenarios is person centric: they try to stimulate group of persons to acquire knowledge in many different fields
- *it is transparent, easy to use and program*– an expert wishing to produce a learning scenario has only to learn how to use an authoring tool. He hasn’t to know tools and resources of the Grid: the Grid itself, by the use of its knowledge, suggests the appropriate core elements available in the Grid. Furthermore, the adoption of expressive languages, as the OWL-S, could be a success factor from a programming viewpoint
- *it is scalable* – our mechanism for indexing resources integrated with Grid tools for resource management allows for an easy and transparent joining and resigning of “nodes” in the Grid. Furthermore, indexing the resources brings the Grid to have some knowledge about its infrastructure, thus simplifying monitoring and self management of the infrastructure
- *it is pervasive and ubiquitous* – our vision is based on the anytime-anywhere-anyhow paradigm inherited from the Grid (in some way, it is part of the Grid paradigm). But, from our viewpoint, the term “ubiquitous” is referred, more generally, to the ability to support multiple diverse pedagogical models and to automatically adapt them. Furthermore, the Semantic Grid for Human Learning allows creation of pervasive learning scenarios: an actor is immersed in all the aspects of a learning process that takes care also of cultural and social context

Finally, we conclude by noting that this is only a beginning, but a very promising one, for utilizing advances in information and communication technologies in a principled and structured way, to advance effective human learning.

7 Conclusion

In this paper we have emphasized the importance of services, semantics and standards for the creation of innovative learning scenarios that go far beyond conventional web-based information transfer. We have presented our vision of the human learning process that provides a paradigm shift from the traditional information based transfer of contents towards a collaborative, user centric and knowledge based approach immersed in the social context in which the learning process happens. The adoption of Grid technologies was justified and the vision of the Semantic Grid for Human Learning was presented. Work currently being carried out in the ELeGI project seeks to validate the approaches described in this paper through a range of service elicitation and exploitation scenarios in both formal and informal learning contexts which will contribute towards the fulfillment of the Semantic Grid for Human Learning.

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