Creation and Delivery of Complex Learning Experiences: the ELeGI Approach

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Abstract

The paper presents the main findings of the ELeGI project, namely its learning model and software architecture to support the creation and execution of complex learning processes.

The learning model defined in ELeGI promotes and supports a learning paradigm centred on knowledge construction using experiential based and collaborative learning approaches in a contextualised, personalised and ubiquitous way.

The software architecture has been designed and developed taking into account the learning model for the personalisation of complex learning experiences.

In order to validate our results, the paper presents and describes a case study relating to the implementation of a Unit of Learning for explanation of the Torricelli's law, and its execution on top of the Service Oriented Architecture.

1. Introduction

The dominant learning approach in Technology Enhanced Learning has been for many years the Information Transfer, which is based on the central figure of the teacher whose primary purpose is the provision of educational contents to be transferred to learners that consume these contents in a passive way. As a consequence, many eLearning solutions provide a "digitalization" of this approach and, in most cases, they are distance learning platforms focusing mainly on the educational resources (just an input of the whole learning process), on their delivery and presentation.

The aforementioned solutions are focused on a implementing just a specific educational model and this means to rid off from them all the complexity associated to the learning process. Just as example, current learning solutions: *i)* superimpose to learners how they have to learn without taking into account learner's dispositions or preferences, and *ii)* are pedagogically closed solutions constraining learners to learn and teachers to teach following a predefined approach.

In our opinion, e-learning solutions have to be subject to a real evolution where the main efforts must be focused on supporting the whole learning process, not only on specific part of it. The matter is how to relate the learning path to the learner and to formative objectives in a dynamic intelligent way to allow personalised, experiential and contextualised learning processes. This has been at the core of our investigations in the European Learning Grid Infrastructure (ELeGI) project [1].

The rest of the paper is structured as follows. Section 2 presents considerations on the human learning as a complex process. Section 3 provides information on the ELeGI project. Section 4 presents the general Learning Model, which the learning experience personalisation process is based on, and the Virtual Scientific Experiment (VSE) model, which the case study is referred to. Section 5 motivates the adoption of Grid technologies evidencing what is, in our opinion, the added value for eLearning of this technology. Section 6 presents the ELeGI software architecture and, lastly, section 7 presents the case study. Conclusions are drawn in section 8 together with the results relating to the evaluation of our case study.

2. Human Learning is a complex process

Among the different definitions of human learning, consider the one proposed in [14]: *"Human learning is the disposition of human beings, and of the social entities to which they pertain, to engage in continuous dialogue with the human, social, biological and physical*

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environment, so as to generate intelligent behaviour to interact constructively with change."

This definition emphasises:

- the importance of the dialogue and, in general, of the collaboration. As any other human disposition, it should be supported and improved taking in account learner needs and preferences
- the centrality of the learner with respect to learning strategies
- that human learning can not be separated from the social context in which it happens
- that the purpose of human learning is to generate intelligent behaviour, allowing human beings not only to act and to react to changes surrounding them, but also to reflect and to acquire knowledge about what surround them.

The above points are key for our approach. We propose, in fact, a more effective approach for human learning and teaching, not based on a particular educational model, but incorporating features of different educational models into a paradigm that focuses on the learner becoming the central and active figure of a complex process aimed to acquire, create and share knowledge.

Human learning is a process that we consider: (i) *complex* – complexity has different meanings in literature, for example [15] and [16], and it is not our purpose to analyse its meaning in this paper. We use the term "complex" to indicate that learning process consists of many interactions among the learner and other entities belonging to his social context. These interactions depend heavily one to each other and one interaction can have no predictable influences on one other. Furthermore, learning process is also function of the learner capabilities, that evolve during his life sometimes in unpredictable way; (ii) *knowledge based* – different levels of knowledge are required in human learning process. Domain knowledge representations are clearly necessary but they are not enough: knowledge about learner and his social context are important as well. Leaner features (e.g. his abilities, preferences, dispositions) can not be separated from social context in which learning process happens and both dynamically change during the life of the learner; (iii) *ubiquitous and pervasive* – not only anytime/anywhere but, more generally, the capability to support different pedagogical models and to automatically adapt them. Pervasiveness is another important aspect of human learning that is, by itself, a pervasive process. Every day, through our experiences, we learn something while we are immersed in the real world; (iv) *quality driven* – from the learner perspective, quality is a degree of satisfaction. Our process has to deal with different kind of qualities from Quality of Collaboration, taking in account dimensions like social cooperation and/or tutoring support, to Quality of (Learning) Experience, emphasising dimensions like interactivity with educational resources and/or multimedia enhancement.

In order to support this process, we need to create dynamic contexts where the learner is free to achieve knowledge and skills in an active way, and in which communities can identify their goals, in terms of knowledge and skills to be acquired [17].

The essence of our approach is, thus, to create contexts that provide adequate conditions for each learner (taking into account his features and social context, providing tutoring and enhanced presence), that support him during his learning process (also using technologies for collaboration, highly realistic virtual scientific experiments, real time simulations, personalized learning path definitions) and, finally, that let him free to reason about what is useful to achieve his goal.

3. The ELeGI project

The purpose of the ELeGI project is to radically advance the use of technology enhanced learning through the design, implementation and validation of a pedagogy-driven, service-oriented software architecture based on Grid technologies [7]. To achieve this goal, the project exploits a strategy, formalized through models, methodologies, and technologies, enabling to overcome the drawbacks of traditional eLearning solutions.

From a pedagogical point of view, a general learning model is defined. This model leverages on scientific studies and educational theories and arranges them in order to allow the implementation of a constructivist approach. To address the issues related to both formal and informal learning, the ELeGI project has been structured according two main Action Lines: ELeGI-f and ELeGI-i. This paper is centred on the main results achieved by the first action line, ELeGI-f, for formal learning.

4. The learning model

In the following a brief description of the theoretical learning model [2] is reported. The learning model allows to generate a "Unit of Learning" automatically and to adapt it dynamically according to the learner's behaviour. In the proposed model, a Unit of Learning (UoL) is anything delimited as an educational object, such as a course, a module or a lesson structured as a sequence of Learning Activities represented by Learning Objects (LOs) and/or Learning Services.

In order to produce an operational process, the learning model uses three specific models: Knowledge Model, Learner Model and Didactic Model, which interact to define the specific and personalised learning path. Such models allow to take into account the following:

i) the knowledge that is the learning objective

ii) context, where the educative process occurs

iii) the learning method and style

iv) the learner's preferences and demands.

The Knowledge Model describes the subject-matter to be attained according to the teacher's learning domain representation and acts in the system as a black-box allowing the construction of the UoL. Besides, this process allows an automatic construction and personalisation of the student's learning path thanks to the possibility to link LOs to the concepts of the knowledge domain. The student's personal knowledge will arise from a suitable interaction (implication) of the student himself with the LOs.

The Learner Model (LM) allows to represent the learners' characteristics.

The Didactic Model (DM) allows to formalise different pedagogical approaches to be used in a learning experience, both at macro-level (general structure of the UoL) and at micro-level (i.e. didactic guidelines, according to pedagogical theories, to enable the student creating some knowledge).

The main step of the logical workflow (graphically shown in Figure 1) whose output is the UoL can be summarised as follows:

i) Formalisation of the knowledge domain, taking into account the Context in which the learning experience takes place and the specific learner's characteristics.

ii) Specifications of the Learning Experience to build. This step requires the retrieval of the Learning Experience Model (LEM) in order to fix the whole structure of a course (e.g. if and when intermediate exams occur, test, self-evaluation, definition of general learning strategies such as collaborative or not collaborative, tutoring modalities); the retrieval of the Target of Learning (TL), consisting in a set of elementary concepts (atomic) to achieve in the course.

iii) Design of the Whole Learning Experience. Given a TL, the Knowledge Model allows to infer the Learning Path (LP), as a sequence of concepts to be acquired, while the Didactic Model gives the specifications of the Learning Activities, associated to each concept.

iv) Production of the UoL. The last step is the binding of the previous design with concrete learning material and services. The output will be a highly tailored UoL with respect to contextualisation and personalisation features. The learner's active involvement and interaction with such UoL allows him/her to construct his/her knowledge.

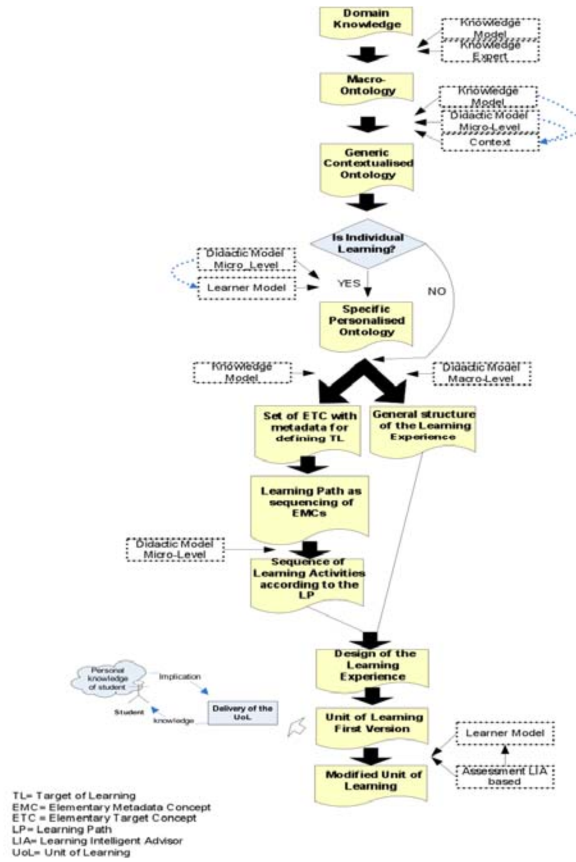

Figure 1 The Learning Model – Processes for UoL creation

v) Updating of the UoL. The UoL produced by the previous process is not a static object but instead a first instantiation. Indeed, according to the assessment procedures, making use of the Learner Model, the UoL can be dynamically updated. In case of failure of the assessment phases, an automatic procedure can be developed in order to compute a new Learning Path. Consequently, the process previously described can restart generating an updated UoL.

4.1 The Virtual Scientific Experiment model

In this section a Virtual Scientific Experiments (VSE) model is presented and large attention is devoted to its relationship with the above mentioned Learning Model.

VSE fits some experiential learning fundamental aspects within a cognitivist / constructivistic vision: the active role of the learner (user centred), the importance of context (situated learning) and collaboration (collaborative learning). These considerations generate a model, representing one of the many possible interpretations adopted by the current tendencies. The conceived model combines Kolb's approach [3] with the Theory of Didactic Situations by Brousseau [4].

For these reasons, the VSE model is seen as a particular didactic method based on an inductive – experiential approach. It is worth pointing out that the VSE Model is logically consequent to the general Learning Model, described in section 4, and is a physical part of the flow that the Learning Model generates. As a consequence, the VSE Model is not explicitly represented in Figure 1 being actually part of the UoL.

The VSE model is depicted in Figure 2, through a sequence of four macro-phases: *Presentation*, *Practical Situation*, *Abstract Situation* and *Institutionalization*.

The **Presentation** phase provides a description of the didactic experience that the student is about to start.

The **Practical Situation** represents the phase where the learner lives the concrete experience. This phase is characterised by the simulation and the presence of a collaborative environment where the concrete and personal learners' experience could be mediated from the interaction with other learners. The phases evolves as follows: i) *Active Situation:* the learner is personally, actively and interactively involved in the execution of a simulation, by moving and manipulating the objects of the simulation through a set of controls that modify the real-time simulation behavior, ii) *Collaborative Learning*: the learner is able to mediate his/her personal knowledge through peers interaction , iii) *Assessment*: a variety of questions, tables, and other activities useful to evaluate the learning process developed in early phases are here submitted to the learner, iv) *Addressed Situation*: the learner, in case of a failing assessment result, is involved in a facilitated didactic situation. During this phase, the learner can re-enter the collaboration (*Collaborative Learning)* with the other peers, to fill his/her gaps and, eventually, can be submitted to a new assessment *(Assessment)* in order to test his/her real cognitive state, v) *Knowledge Institutionalization*: the procedural and semantic correctness of the concepts, that the learner learned autonomously, is approved.

The **Abstract Situation** aims at extrapolating an abstract model representing, for instances, the law of an experiment. Therefore, the *Abstract Situation* has exactly the same whole structure as the *Practical Situation* although the simulation of the *Practical Situation* is replaced by an experiment, where the learner can interact either with theory or its practical implications.

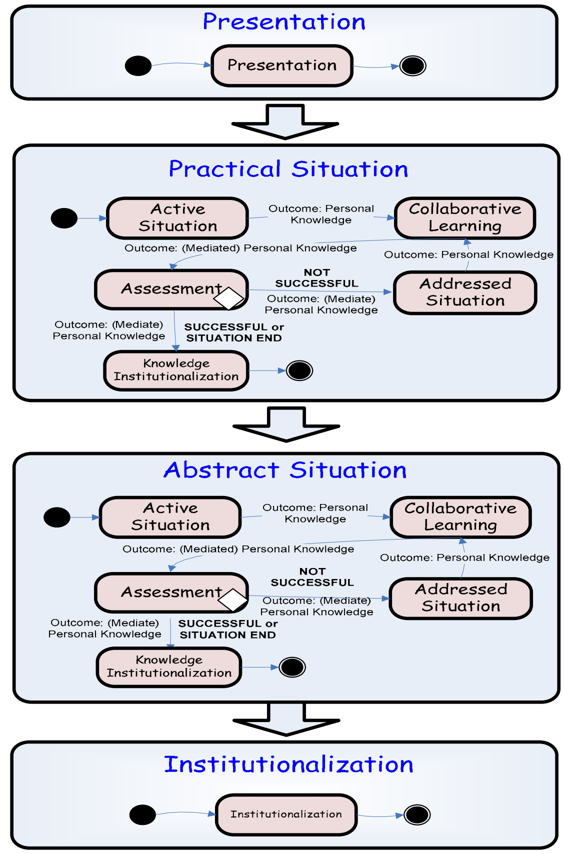

Figure 2 - Learning Model for VSE

Finally, the **Institutionalization** phase constitutes the transition from the intuitive knowledge, firstly extracted from the analysis of a *Practical Situation* and secondly from the *Abstract Situation*, to more advanced types of mental schemas.

The VSE model is delivered as a Didactic Method within the general Learning Model described in the previous section.

5. Why Grid?

In this section, we draw your attention to the added value of a Service Oriented Grid for education and, in particular, for the creation of the personalised learning experiences. The added value of Grid technologies is graphically shown in Figure 3. At the bottom of the picture some learning key issues (most of them addressed by ELeGI) are pointed out while at the top some Grid features are presented.

As shown in the mentioned figure, the Grid features have a direct impact and provide added value on the processes coming from the theoretic models of ELeGI (that are the ones in the middle of the picture). Actually, the picture is not able to show others features of Grid technologies having such a strong impact on the execution of the processes: dynamicity, adaptiveness, and ubiquitous and seamless access to heterogeneous resources.

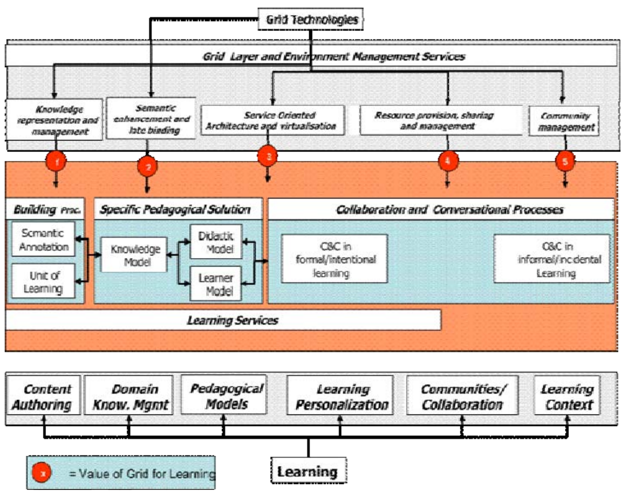

Figure 3 - The Grid added value in ELeGI

We have selected five Grid features providing added value to the learning processes. In the picture, each arrow points to the process on which it has the main impact even if all the arrows have (more or less) an impact on all the processes.

The first feature is the **Knowledge representation and management.** Typical of the Semantic Grid, this feature is widely adopted in the knowledge model and in the relative knowledge building process and, of course, can be adopted in the collaborative activities of the Collaboration & Conversational (C&C) processes.

The second feature we have pointed out is the **Semantic enhancement and late binding of services and resources** having a strong impact on the processes of UoL building and delivery (for late binding of educational resources matching the profiles), in the knowledge model and knowledge building process, as well as in the Collaborative activities whenever there is the need to perform the discoveryof services and tools.

The third one, namely the **Service Oriented Architecture and virtualisation**, is probably the most important of them. The advantages of a SOA for the Learning are presented in [13] and, in addition to those benefits, we have to consider also the benefits coming from the exploitation of the Open Grid Services Architecture reference model, that is a well defined set of services to manage a Virtual Organization..

The **resource provisioning, sharing and management** is adopted during the execution of learning experience. The advantages arising from this feature are noticeable since for instance in a community a collaboration group share resources in a transparent way and the resources themselves are provided on-demand. Furthermore, the feature is necessary in order to select suitable computational resources to deploy and execute UoL able to guarantee QoS and, as a consequence, the learner's satisfaction during the execution of the learning experience.

The **Community Management** feature, finally, has a direct and visible impact on all the C&C processes. Indeed, this feature is strongly based on the Grid capabilities to create and manage Virtual Organizations but it is enhanced through specific functionalities for role, identity and membership management as well as the support for virtual learning communities.

6. The ELeGI software architecture

The ELeGI Software Architecture for formal learning (a.k.a. ELeGI-f software architecture) can be defined as "*domain verticalization of the Semantic Grid improved with tools, services, standards and technologies for the Education & Training*" [11] and is presented in

Figure *4*.

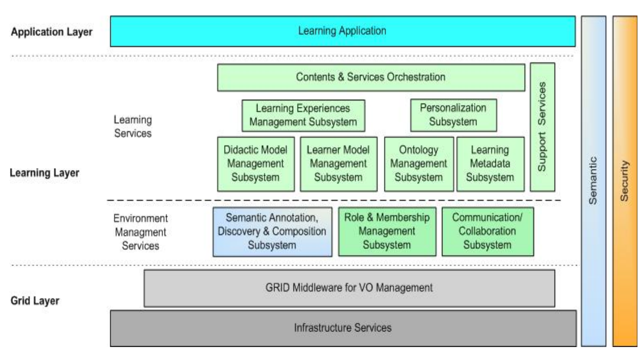

Figure 4 - ELeGI-f Software architecture

Readers interested in the details of the ELeGI software architecture can refer to [5], while in this section we just give an overview of the services implemented to instantiate the learning model and execute the learning process.

The effort to define and develop the architecture is focused on the top of the Grid layer and the most relevant services belong to the Learning layer, that is mainly devoted to the execution of the processes related to the Learning Model. This layer can be logically divided in two sub-layers.

The first one, the Environment Management Services sub-layer, provides services and tools to support the creation, operation, evolution, and maintenance of a learning community. Functionalities for semantic annotation, discovery and composition of educational contents and services are provided in the Semantic Annotation, Discovery & Composition subsystem, while functionalities allowing intra and inter community asynchronous and synchronous communications are grouped in the Communication/Collaboration sub-system.

The second one, the Learning Services sub-layer, provides services and tools to support the execution of the three processes of the Learning Model. Of course, there are services and tools to create and manage the Ontologies (Ontology Management sub-system), the Learner's Profile (Learner Model Management sub-system) and the Didactic Model (Didactic Model Management sub-system), that represent the three basic structures of the Learning Model. The Personalization sub-system aims at dynamically adapting and delivering educational contents and services, matching the learner's needs and preferences according to his/her profile.

The Learning Experience Management sub-system allows applications or other services to access and manage courses, modules, and other learning experience (e.g. allocating student, staff, etc.), while Contents & Services Orchestration sub-system deals with issues of UoL execution, which are described using the IMS Learning Design (IMS-LD) constructs [6].

7. The case study: execution of a VSE explaining the Torricelli's law

In this section we present and describe a VSE explaining the Torricell's law. In this context, we are mainly interested in presenting the research results of the case study. For a detailed description of the case study, interested readers can refer to [10].

Key to execute our case of study is the VCLab[1] tool. VCLab has been originally developed to support learners in control system design. It uses a 3D virtual user environment to recreate and to visualize experimenting plants. A learner can interact with a displayed scene in a similar fashion like with real devices. For more information and details on VCLab, interested readers can refer to [8] and [9].

From the ELeGI Service Oriented Architecture perspective, VCLab is seen as a set of resources and the process of discovery and instantiation of a VCLab resources is similar to the one implemented for other kinds of LOs. It is presented in the following Figure 5 taken from [9].

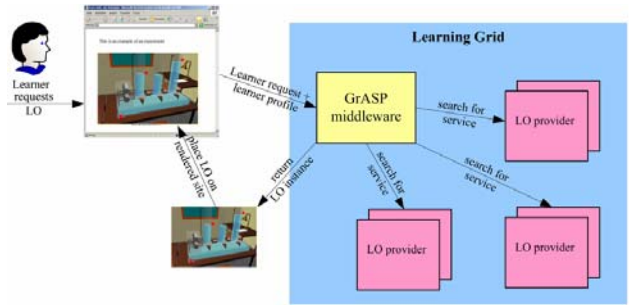

Figure 5 - Process of discovery and instantiation of the VCLab Resource (from [9])

In the above picture, the GrASP middleware [12] is the Service Oriented Grid middleware of the Grid layer of Figure 4.

In the Torricelli's law experiment, the LOs realizing the macro-phases of the VSE model in a UoL are generated using the VCLab Resource. Figure 6 presents the general structure of this resource.

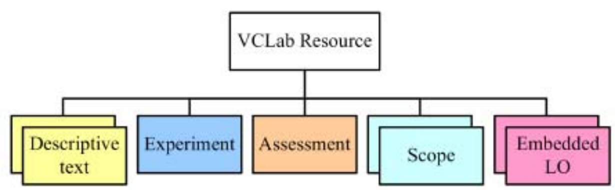

Figure 6 - VCLab Resource structure (from[9])

It consists of a set of optional abstract elements whereby some of elements may occur in multiple instances. Customizing this resource in a proper way will yield the different LOs of the VSE model. The appearance is also fully customizable by the sequence of elements in the resource as shown in

Figure 7. For more information on the single elements of the VCLab structure, interested readers can refer to [9].

1 Virtual Laboratory for Automatics and Control Engineering developed at the University of Bochum, in the scope of ELeGI. This tool can provide university students with easy access to engineering applications at anytime and from any computing environment

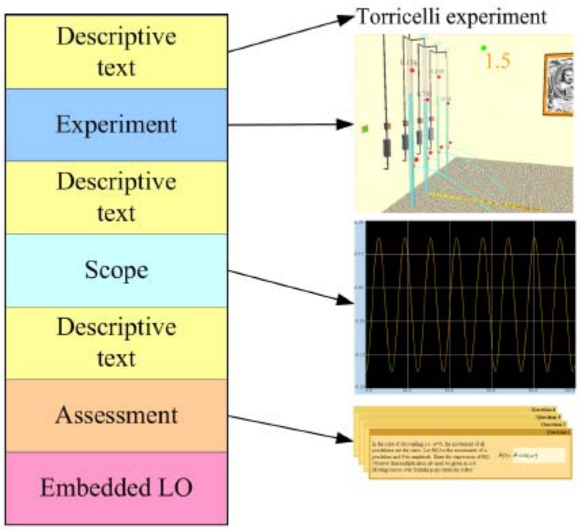

Figure 7 - Elements in a VCLab Resource (from [9])

There is a correspondence between the particular elements of the VCLab Resource and the macro-phases of the VSE learning model. The design of the VCLab Resource was directed to allow the delivery of content and implementation mainly for the Practical and Abstract Situations, nonetheless the Presentation and Institutionalization macro-phases can be easily implemented using descriptive text, enriched by recorded experiment scenarios in playback mode showing how to operate the experimental plant.

In case of the Practical Situation, the Active Situation is implemented by including the Experiment element within the resource definition. The Collaboration could be delivered by embedding an external LO, which provides a chat or video-conference capability. The Assessment is implemented by the Assessment element. Answers given to questions may influence the content of the Experiment element resulting in the Addressed situation depending on a grade of correctness. Lastly, the Knowledge Institutionalization is delivered as a Descriptive text element.

8. Conclusions

In concluding this paper, it is worth pointing out that the VSE of the presented case study allows a learner to execute, for example, the simulation and to provide self-assessment (e.g. using the results of a test to provide an addressed situation).

The description provided in the paper is very simplified, but quite meaningful for explanatory purposes, that is to assess: *i)* the educational benefits of the approach based on the VSE model in the experiment execution with respect to the same experiment execution by means of a more traditional approach having recourse to *naïve simulation* and classic lesson *ii)* the advantages coming from the adoption of Grid technologies in exploiting the proposed VSE model.

With *naïve simulation* it is intended the availability of an environment such as Mathematica [18] or MatLab [19], where numeric and/or symbolic computation can be performed but interactivity is very low (i.e. changing the time scale or re-computing an FFT on a different set of values need some work) and the environment does not support the student for the construction of knowledge about the relevant concepts of the experiment that remains strongly related to the learner's attitude.

The case study has been successfully executed in the ELeGI project and has given us a proof of our assumptions related to the added value of both the model and the Service Oriented Grid Architecture.

For the former, we have assessed that the VSE model is more suitable to drive the students during the process of knowledge acquisition with respect to traditional simulations, only able to describe the physical phenomenon and the underlying rules without taking care of the knowledge model and/or personal preferences. The VSE model mainly addresses issues such as: *i)* the active role of the learner and *ii)* the importance of the context, and from the performed experimentation it is possible to deduce that the added value of the VSE is exactly the combination of the abovementioned two point.

For the latter, the evaluated benefits relate mainly to: *i)* capabilities to access educational resources distributed over the network, that is relevant in achieving the personalisation of learning experiences, and *ii)* high level of dynamicity and adaptiveness in the creation and delivery processes of a the learning experience.

9. Acknowledgements

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