The Anatomy of the Learning Grid

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Abstract. Over the last few years, Technology Enhanced Learning (TEL) needs have been changing in accordance with ever more complex pedagogical models as well as with technological evolution, demanding for high dynamic and configurable environments for running multiple teaching and learning scenarios.. Grid technologies have started to be very popular even in education due to the advantages that they offer being based on a secure, flexible and coordinated way of sharing resources over Internet as well as on its enormous capability of information processing. A Grid may facilitate learning processes in allowing each learner to collaboratively use the resources already existing online, by facilitating and managing dynamic communication with other people and agents, through the implementation of dynamic Virtual Organizations allowing to share learning resources. Nevertheless, in order to be effectively used in TEL, Grid must be complemented with other technologies bringing to the concept of "Learning Grid" whose description is the object of this chapter.

Keywords. Technology Enhanced Learning, Grid, Semantic Web, Semantic Grid, Learning Design.

Introduction

Grid technologies are rising as the next generation of Internet by defining a powerful computing paradigm by analogy with the electric Power Grid. A Grid user is able to use his private workplace to invoke any application from a remote system, use the system best suited for executing that application, access data securely and consistently from remote sites, exploit multiple systems to complete economically complex tasks or to solve large problems that exceed the capacity of a single system.

Grid could be used as a technology "glue" providing users with a uniform way to access resources by means of several devices. These technologies can provide, in a natural way, a support for Technology Enhanced Learning (TEL) by enabling new learning environments based on collaboration, social interaction, experience, realism, personalization, ubiquity, accessibility and contextualization.

Nevertheless, to be effectively used in TEL, Grid must be complemented with other elements like semantics and educational modeling so bringing to the concept of "Learning Grid" whose description is the object of this chapter. In particular the first paragraph of this chapter gives some more details on enabling technologies making the Learning Grid vision possible while the second paragraph gives a formal definition of the Learning Grid concept also presenting an abstract architecture. Paragraph 3 moves

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the focus to learning approaches that are more suitable for a Learning Grid while paragraph 4 summarizes some related research work.

Following this trend, a Special Interest Group (SIG) of the European Network of Excellence Kaleidoscope [28] have committed itself to establish an observatory on Grid applications to TEL in order to study the field and to foster discussion among several research groups on the theme spread in Europe. Main results coming from this SIG (including this book) have been summarised in paragraph 4 too. The last paragraph presents concluding remarks.

1. The Enabling Technologies

As detailed in this paragraph, the three Enabling technologies that, duly integrated, constitute a comprehensive technological platform able to support the implementation of a Learning Grid are:

- Grid technologies,
- Semantics,
- Educational Modelling.

As shown in Figure 1, if we refer to the well known two axis diagram that places the Semantic Grid in a two dimensional spaces (the scale of interoperability and the scale of data/computation), the Learning Grid can be seen as a projection of the Semantic Grid on a third axis measuring the supported scale of pedagogies.

In the next three sub-paragraphs we provide more details about these three pillars referencing relevant scientific literature where needed. The next paragraph focuses instead on how such technologies can be put together and exploited as a basis to build pervasive and challenging TEL environments.

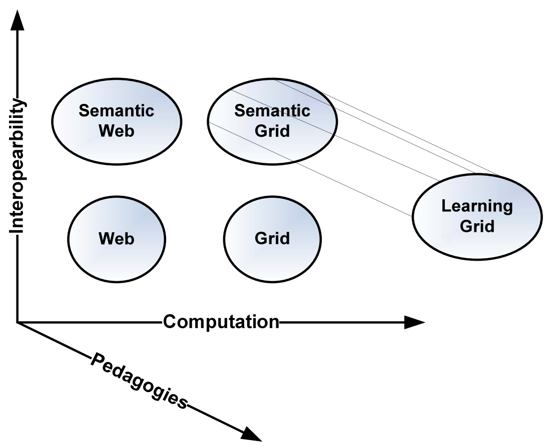

Figure 1. The Learning Grid with respect to Grid and Semantic Grid.

1.1. Grid Technologies

In the beginning, **Grid** was synonym of meta-computing and according to this first vision, Kesselman and Foster attempted a first definition of the Grid as “a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities” [14]. Research has brought to a new vision of Grid that became synonym of infrastructure to “coordinate resource sharing and problem solving in dynamic, multi-institutional virtual organizations” [14] where the focus is on the concept of Virtual Organization (VO).

Currently, the evolution of Grid is marked by the adoption of a service oriented approach in designing Grid architectures. The Open Grid Services Architecture (OGSA) integrates key Grid technologies with Web Services mechanisms to create a distributed system framework for integrating, virtualizing and managing resources and services within distributed, heterogeneous and dynamic VOs [18]. In addition, by adopting the Web Services Resource Framework (WSRF) [13] it is possible to define a Grid resource as a “stateless service acting upon a stateful resource” so applying a service model of an intermediate complexity between pure stateless services and pure conversational ones, thus allowing a simple way to compose services without loosing the advantages of state management.

Upon the OGSA model, different kinds of Grids have been raised like Computation, Data or Information Grid. Apart from the specific term, the key features of all these Grids are virtualization in term of services and dynamic policy-based provision of what is virtualized. Some of them deal with well known issues, like Computational Grid that provides the access to a large virtual computer and Information Grid permitting the access to a large virtual information source.

1.2. Semantics

Among them a key role for TEL is played by the **Semantic Grid** that was defined by De Roure and other researchers as: “an extension of the current Grid in which information and services are given well-defined meaning, better enabling computers and people to work in cooperation” [11], [22]. In other words a Semantic Grid is a Grid improved through standards and technologies of the Semantic Web [5] community, to make explicit and machine understandable the knowledge about resources and services as well as communities and individuals of communities.

A Semantic Grid relies on specifications like OWL-S [46] and WSMO [42] in order to semantically enrich resources virtualised through a service to let software agents compare the requirements of a service against its description to find the service that best satisfy the requirements. In this way it supports the automatic negotiation, discovery and composition of services.

Following this trend, the Service Oriented Knowledge Utility (SOKU) vision, as elaborated in [38], builds on a natural evolution and combination of concepts from Web Services, Grid technologies, the Semantic Web, distributed analytics and self-organising systems that have broad international industry acceptance. SOKU presents at the core of its vision the concept of service that is semantically described and can be dynamically composed, adapted and configured.

The Semantic Grid is a good enabling infrastructure for Technology Enhanced Learning (TEL) by itself being it able to fulfil many of the new needs coming from ever more complex pedagogical models [41] including:

- wide geographical distribution of learners and tutors who can potentially belong to many different educational institutions;
- multiple administrations from different organisations with specific educational policies;
- access from anywhere, on any learners' computer platform and any software;
- support for a growing load of learning resources, services and users who access resources and services;
- transparent access and share of an huge variety of such software and hardware learning resources and services in dynamic environments;
- flexibility to reuse pieces of learning resources and services of different granularity according to specific needs;
- support to the autonomous and dynamic creation of communities through the VO paradigm;
- learning personalization and knowledge creation, acquisition and evolution.

1.3. Educational Modelling

Nevertheless, in order to be fully exploited in the TEL domain, the Semantic Grid should be enriched with **Educational Modelling** capabilities through the integration of feasible Education Modelling Languages (EMLs) and the provisioning of services discovery and composition capabilities driven by such languages. An EML can be defined as a semantic notation for units of learning to be used in TEL to support the reuse of pedagogical entities like learning designs, objectives, activities, etc. EMLs involves the description of learning processes and methods from a pedagogical and instructional rather then content-driven perspective.

IMS Learning Design (IMS-LD) [26] is currently the widest diffused EML and, according to the next chapter of this book, the one more feasible to be used as the basis in a Learning Grid environment. Through IMS-LD it is possible to describe a wide variety of pedagogical models, including group work and collaborative learning. It does not define individual pedagogical models but provides an high-level language that can describe many different models. The language describes how people perform activities using resources and services, and how to coordinate them into a learning flow.

2. The Learning Grid

The integration of the above mentioned technologies bring us to the following definition of the **Learning Grid**:

A Learning Grid is an enabling architecture based on three pillars: Grid, Semantics and Educational Modelling allowing the definition and the execution of learning experiences obtained as cooperation and composition of distributed heterogeneous actors, resources and services.

This definition, coming from the Learning Grid Special Interest Group of Kaleidoscope can be seen as a generalisation of the "Semantic Grid for Human

Learning" defined by Gaeta et al. in [19] where the focus was on complex learning experiences based on experiential-based conversational processes.

Basing on such definition the next sub-paragraphs define a layered architecture for the Learning Grid and explain how it can be used as a basis to provide Learning Services and Applications.

2.1. Learning Grid Architecture

According to the given definition, a Learning Grid architecture is composed by the following set of services organised in three layers (see Figure 2):

1. the **Infrastructure Services** provide an implementation of the Web Service Resource Framework (WSRF) specifications in order to define the underlying service model;
2. the **Grid Middleware for VO Management** provides an implementation of the services identified by the Open Grid Services Architecture (OGSA) allowing to create and manage a distributed VO and integrate, virtualize and manage resources and services upon it;
3. the **Semantic Annotation, Discovery and Composition Services** provide learning independent functionalities based on specifications and languages for the semantic description of Web services (e.g. OWL-S) to allow the automatic negotiation, discovery and composition of Grid Services;
4. the **Educational Modelling and Execution Services** provide contextualised features related to the formal description of learning experiences basing on Education Modelling Languages (e.g. IMS-LD) and the automatic discovery, composition and execution of learning resources and services available on the Grid basing on such descriptions.

With respect to Educational Modelling and Execution Services it is important to note that languages such as IMS-LD are currently hardly exploitable in Semantic Grid

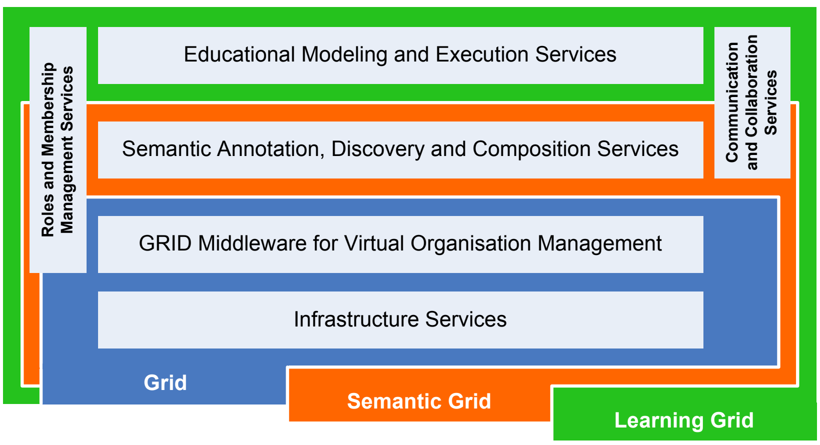

Figure 2. Architecture of a Learning Grid.

environments due to several limitations coming from design-time resource binding. This imply a lacks of dynamicity i.e. Learning Grid Services must be bind at design time rather that at execution time so hindering to fully exploit dynamic discovery and composition of learning services. To solve this problem [8] proposes semantic extensions to IMS-LD as we will further detail in the next chapter of this book.

The Figure 2 shows a layered architecture based on the above described services. As it can be seen, a Grid is composed by Infrastructure Services plus a Grid Middleware for VO Management; a Semantic Grid is composed by a Grid plus Semantic Annotation, Discovery and Composition Services; a Learning Grid is composed by a Semantic Grid plus Educational Modelling and Execution Services plus a set of "environment" services described below to support the creation, the operation, the evolution and the maintenance of a learning community:

- the **Role and Membership Management Services** manage users, groups, roles and membership inside VOs on the Learning Grid by supporting the Grid Middleware for VO Management as well as Semantic Annotation, Discovery and Composition Services and Educational Modelling and Execution Services;
- the **Communication and Collaboration Services** provide tools to support communication and collaboration among participants in groups, communities and actors involved in learning experiences by supporting Semantic Annotation, Discovery and Composition Services and Educational Modelling and Execution Services.

2.2. Learning Services and Applications

As summarised in Figure 3, the Learning Grid has to be seen as an enabling infrastructure able to be exploited for the implementation of several specific learning scenarios. In particular, several further learning services may be built on the basis of services provided by the Learning Grid, and several different learning applications may be built by leveraging on such services.

The fourth chapter of this book deals with different scenarios that may be built upon a Learning Grid while in the second section several systems based or inspired to this architecture are presented. Such systems, tough they aren't directly based on the definition given in this paragraph, use architectures that may be easily transposed on a Learning Grid.

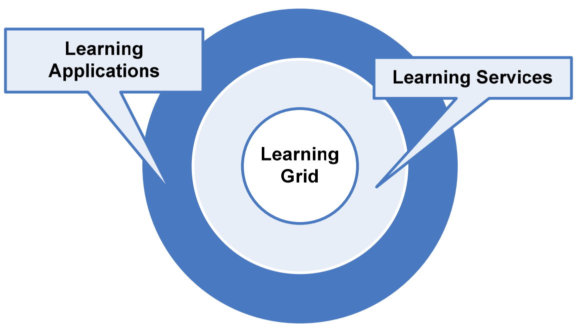

Figure 3. The Learning Grid as an enabling architecture to build learning applications.

3. Pedagogies and Learning Grid

This paragraph moves the focus from technology to pedagogy linked with the Learning Grid. It tries to show which kind of learning approaches are more suitable to be exploited in a Learning Grid environment in comparison with traditional e-Learning settings. Particular emphasis is given to learning approaches based on orchestrated learning activities and on communication and cooperation processes.

The dominant learning approach in TEL has been for many years the Information Transfer, based on the central figure of the teacher whose primary activity is the provisioning of educational contents to be transferred to learners that passively consume them. Consequently many e-Learning solutions provide a "digitized" version of this approach so, in most cases, distance learning platforms focus on educational resources and on their delivery.

This aspect, together with other relevant lacks, as the support for pedagogies, the contextualization of the learning experience and the centrality of the learner, lowers the effectiveness of the above learning solutions.

Nowadays, the need for e-learning systems supporting a rich set of pedagogical requirements (as those summarized in the first paragraph) has been identified as an issue of paramount importance. In this context, a Learning Grid allows the design, the implementation and the deployment of learning experiences based on the selection and the orchestration of different learning activities.

In the next sub-paragraph we try to demonstrate why Learning Grid is particularly suitable for the implementation and the deployment of such kind of learning experiences while in the second sub-paragraph we focus instead on a subset of pedagogical approaches based on Communication and Cooperation processes seeing, also in this case, the added value of the Learning Grid.

3.1. Learning Approaches based on Orchestrated Learning Activities

The Grid allows the deployment of complex learning processes based on knowledge, like the ones provided by IMS-LD scenarios. IMS-LD is used to model teaching and learning practices that go beyond simple traditional Web-based educational contents delivery. In [4] it is emphasized how IMS-LD adopts a two levels approach to fulfil this task, modelling both:

- the learning activities, to be defined as interactions between a learner and an environment, having the objective to achieve a planned learning outcome;
- the learning approaches, involving the selection and orchestration of the activities on the basis of the pedagogies ensuring, among other things, the reuse of their components.

As outlined also in [2], reuse and re-purposing is somewhat difficult to obtain by means of traditional technologies that are generally information oriented and URL based. Dynamicity and adaptivity features of (service oriented) Grid technologies can be so exploited to provide actual benefits from the viewpoint of reuse and repurposing of learning activities.

Indeed, to reuse learning activities in different contexts and to obtain different outcomes requires mechanisms for automatic discovery and binding of new suitable educational contents and services as well as self-adaptive mechanisms when deploying the learning activities composing a scenario, which are distinctive features of Grid. Work that investigates advantages and drawbacks of the integration between IMS-LD and Grid are presented in [6], [37] and [21].

- In [6] the authors propose and justify the adoption of IMS-LD for Computer Supported Collaborative Learning (CSCL), and the advantages of Grid technology to support CSCL. The main result of their work converges in a distributed system that can select and integrate Grid Services according to the prescriptions of IMS-LD documents.
- In [37], instead, the authors propose the Grid enabled Learning Object (GLOB) to allow the execution of learning activities exploiting mainly computational capabilities of a Grid.
- In [21] learning activities are bound to educational resources and services using semantic capabilities at learners' fruition time, in order to best fit their preferences and networked resources availability. They do not define a specific structure acting as interface to the Grid and, furthermore, they rely on semantic enrichment of IMS-LD documents in order to retrieve at run time educational resources through the Grid.

The need of a Grid-based approach in the creation of learning scenarios based on the IMS-LD specifications can be supported, moreover, by the Service Orientation and the Virtualization paradigms that are at the basis of the OGSA model. They are clearly useful in a learning approach that strongly relies on a composition paradigm allowing the creation of personalized learning experiences (re-)using data, educational contents, knowledge and tools virtualized as services and distributed across several organizations.

In addition, with respect to the other Service Oriented Computing approaches, the Grid approach provides a well defined taxonomy [17] able to solve many issues connected to the creation and management of a VO and, in accordance with this taxonomy, a set of capabilities have been already defined. This is a key factor in collaborative and community-based processes by supporting the dynamic creation of communities and their management as deepened in the next sub-paragraph.

3.2. Didactic Methods Based on Communication and Cooperation Processes.

Learning approaches based on Communication and Cooperation (C&C) processes generally bring to the creation and execution of learning experiences in which collaboration and communication among participants play a key role. There are several didactic methods based on C&C processes such as:

- Virtual Classroom that simulates on-line the characteristics of a real classroom;
- Synchronous Instant Communication relying on several means of synchronous communication among the involved actors;
- Problem-Based Learning in which students are engaged in the resolution of a problem related to learning objectives;
- Collaborative Apprenticeship based on the prior observation of a given task;
- Jigsaw method where each student's part is essential for the completion and full understanding of the final product.

In this context the Learning Grid is not only useful to reach the desired level of dynamicity and scalability for a group or a community and to manage its heterogeneity but also for transparent ubiquitous resource sharing. In fact through the virtualisation paradigm, traditional collaborative tools can be virtualised as services. This allows to add dynamicity since they can be provided on demand and it is possible to search and retrieve the most suitable tool on the basis of some parameters like, for instance, preferences of the group of learners and/or QoS.

Exploiting the distinctive features of Grid services (mainly lifecycle management and statefulness, but also manageability) it is possible to increase scalability and support management of interactions respectively. It is possible to create more instances of services to support the collaboration. Furthermore, the state management capabilities of Grid services allow to define and associate a state to each service (following the WSRF specification, the related stateful resource concept and implied resource pattern). This is an useful feature if we want to track data/information during cooperation and conversation among the learners.

As enabling technologies for learning-purposed VO, Grid provides support for geographically distributed community creation and management, logically defined as Virtual Learning Communities addressing issues like heterogeneity, single sign-on, group and community lifecycle management, localization and instantiation of tools and services, transparent resource sharing.

Table 1. Added value of the Learning Grid in C&C processes.

Needs	Traditional approaches	Learning Grid added value
Resources/Document sharing	Adoption of a centralised shared workspaces systems (e.g. BSCW)	Exploitation of VO functionalities for resources sharing (including tools) and management. Semantic capabilities to allow automatic search and retrieve of resources matching user needs and preferences
Awareness of the group members	Traditional tools for collaboration generally provide information on the availability on-line of members of a group.	Enhanced presence allowing to search and find peers/tutors with specific profiles, with specific interests, etc. To this purpose semantic capabilities and ontologies (like the Learner profile ontology, extending the W3C FOAF)
Creation and management of collaborative sessions inside a group	Traditional systems provide low support for this feature. For instance, the session has to be scheduled, participants have to join, the documents and materials for the collaborative session have to be uploaded in a shared workspace, etc.	Grid technologies and the Grid service container concepts allow to improve the creation and management of collaborative session allowing a dynamic adding/removing of services, resources and participants in the collaborative session. Semantic capabilities allows for automatic discovery of services and resources matching the specific needs of the group and/or the collaboration session.
Integration of different heterogeneous tools	Currently, many functionalities for C&C are provided by different tools that are difficult to integrate together in order to create a environment supporting C&C	The virtualisation paradigm and SOA (e.g. OGSA) approach allow to simplify the integration issue. Different tools can be virtualised and managed as services. Furthermore, they can rely upon functionalities of the Grid middleware to improve.

Dynamicity and adaptiveness of Grid technologies are key features in order to provide advanced mechanism for service discovery and instantiation on the basis of service-level agreements (SLA) documents and self-management, self-monitoring, etc. This allows, for instance, to deploy and execute a service on the most suitable host of a VO and to monitor at-run-time its SLA, control the resources access through policy based mechanisms, etc.

By exploiting flexible and standard based mechanisms for transparent resources reservation, sharing and accessibility, Grid also improves ubiquity and accessibility. Semantic Grid capabilities also allow semantic annotation of educational resources and services for automatic discovery and late binding of educational resources and services in the learning environment, improving the capability to support learning community creation and management.

The usefulness of these capabilities for learning is also supported by several research papers as summarised in [36] where a Semantic Web/e-Learning research issue correspondence map is provided. It is worth mentioning that in the case of creation of formal learning experiences based on the C&C approach, all the benefits that we have emphasised for the creation and execution of learning experiences based on other approaches apply as well.

In addition to what highlighted above, the table 1 summarises some needs of the C&C processes pointing out the benefits coming from the adoption of a Learning Grid with respect to traditional approaches.

4. Related Work

The concept of "Learning Grid" is defined as a synthesis of several, sometimes implicit, definitions coming from the most recent and significant scientific work on related topics. In the next sub-paragraph, according to [9], we will summarize some of these research works. In the second section of this book specific chapters are provided in order to give more details about some of the most relevant projects connected with the Learning Grid concept.

As already anticipated, a Special Interest Group (SIG) of the European Network of Excellence Kaleidoscope, following this research strand, have committed itself to studying the field and to fostering discussion among related research groups spread in Europe. More detail about the SIG are given in the second sub-paragraph.

4.1. Projects Connected with the Learning Grid

The Grid Service Based Portal for Virtual Learning Campus [45] developed an environment which makes use of the Grid capabilities so that to make possible the dynamic sharing and coordination of heterogeneous resources which are found dispersed in the network. The project focuses on the development of a video digital library based on Grid for a Virtual Campus that allows an easy access and implementation of several services. In spite of being a project that aimed to take advantage of the capabilities that Grid technology provides, it is limited on a unique type of educative resources, like video, which a structure of services is developed for.

In [33] it is described a TEL platform based on Grid service technologies. In this platform the supply of virtual learning services designed for students, instructors and course suppliers is based on the resource administration for group collaboration based on Grid, allowing ubiquitous access to information and taking advantage of the potentiality of the computer systems. On the one hand, the advantage of this proposal is that it is the first one that elaborates on the use of Grid resources and their description through Grid technologies, in particular WSDL. On the other hand, it dictates the need for the development of a semantic model description that enables a more complete description of learning resources.

ULabGrid, an Infrastructure to Develop Distant Laboratories for Undergrad Students over a Grid, [3] proposes a new architecture that allows the educators to design remote collaborative laboratories for university students using the Grid infrastructure. This project is one of the first in its type in trying to combine the facilities that Grid provides in a practical scenario in order to achieve resource sharing and motivate collaborative work. In this sense the design of Grid-based collaborative learning scenarios should be supported by semantic descriptions that allow the best tracking of resources available in the network.

Another work that aims at developing a Generic Engineering Framework for TEL Embracing the Semantic Web [32] proposes the convergence of TEL, Web semantics and e-business by introducing a generic engineering approach that labels learning objects with RDF for semantic e-learning and integrating it with a process oriented paradigm. This work can serve as one of the first approaches as regards the use of information modelling and RDF to label learning scenarios resources, making use of a process management approach, which if adapted to the Learning Grid will provide a new generation of applications.

A further work proposes an Agent-Based Collaborative Virtual Environment for TEL in the Service Grid [25]. In this virtual environment, all Web resources and services are accessed via service encapsulation, which may result in a more scalable and robust collaborative learning architecture. A very remarkable aspect of this work is the way it uses to implement complex services from more basic ones, though no use of semantic description is made to allow the automatic composition of complex services from lower level ones.

KGTutor, a Knowledge Grid Based Intelligent Tutoring System [48], proposes a model for the construction of intelligent tutoring in a more pleasant and effective way. The KGTutor is designed to provide better support to student cantered distributed learning. Students' characteristics, such as previous knowledge and learning styles, are used to choose, organize, and deliver the learning materials to individual students. During learning progress, the system can also provide objective evaluations and customized suggestions for each student according to their learning performance. This system provides a very important work as far as student centred learning concerns, though it could be further strengthened through the use of aspects of semantic description of learning services.

The Knowledge-Grid-Based Cooperative Learning Environment [49], supports the cooperation between a person and the computer at a knowledge level, and allows the enrichment not only of the resources in the Knowledge Grid but also of the users' knowledge by means of knowledge refinement, knowledge reuse and the online meeting of participants. The KGCL prototype has been currently applied and is available for online use. Experiments have shown that the environment can promote the effectiveness of group work. This system has also shown the great impact that Grid technologies can have even though no model of semantic description was implemented that could improve its performance.

The SELF project [1] proposes a learning environment that results from the integration of several technologies, specially the semantic Web, Grid technology, collaborative tools as well as customized tools and knowledge management techniques. SELF provides a mechanism for the intelligent search of services making use of semantic description tools. This project presents an important reference of the use of different technologies for the development of Grid-based learning scenarios, even though it is not based on semantic description models for the definition of its tools.

OntoEdu [24] is a flexible platform for online learning which is based on diverse technologies like ubiquitous computing, ontology engineering, Web semantics and computational Grid. It is compound of five parts: user adaptation, automatic composition, educative ontologies, a module of services and a module of contents; among these parts the educative ontology is the main one. The main objectives of OntoEdu are to obtain reusability of concepts, adaptability for users and devices, automatic composition, as well as scalability in functionality and performance.

The work developed in [31] presents a workflow framework for pervasive learning objects composition by employing a Grid services flow language. Learning objects are distributed in heterogeneous environments which have been used in order to allow effective collaboration and the reuse of learning objects; this fact can help users to learn with no limitations of time and space. This work shows the great opportunities that exist in those research groups which make use of Grid technology to develop innovative, pervasive and ubiquitous learning scenarios.

ELeGI (European Learning Grid Infrastructure) [40] aims to define and implement a software architecture able to unify the semantic Grid and information technologies in order to promote and give support to the definition and adoption of learning paradigms for the construction of knowledge that combines customized and ubiquitous techniques based on experiential, collaborative and contextualized learning. In this line, [23] presents a work about ontology based user modelling for personalization of Grid learning services. This work describes how the learning services of the Grid should support a user-centred, customized, contextualized, experiential and ubiquitous based learning approach. More details about ELeGI are given in the chapter 5 of this book.

In the work referenced as "Semantic Search of Learning Services in a Grid-Based Collaborative System" [47], the authors have constructed an ontological description for collaborative work tools that allow one to make a manual search of the diverse resources that these tools provide within a Grid environment with the minimum of technical knowledge. This work proposes a Grid-based tool called Gridcole, which can serve as a basis to implement different conceptual approaches of Grid-based semantic description of learning services, thus extending and endowing it with an innovative, pervasive and ubiquitous projection. More details about Gridcole are given in the chapter 6 of this book.

Akogrimo [27] is an FP6 project whose purpose is to obtain a convergence between grid and mobile technologies in order to provide dynamically concerted use of resources and services including e-learning services. In this context, grid services, comprising personalized knowledge and semantics, are allowing for ad-hoc, dynamic, and possibly federated formation of complex problem solving scenarios in everyday life, in business, science and learning to fixed, nomadic and mobile citizens. More details about the e-learning strand of Akogrimo are given in the chapter 8 of this book.

Finally, in [43], a Grid Service Framework for Metadata Management in Self-e-Learning Networks focuses on how the use of metadata can be critical for Grid systems. More specifically, the semantic description constitutes a very beneficial extension of

Grid environments. The Self e-Learning Network (SeLeNe) is used as a test application while a set of services is proposed which are implemented with OGSA. The project focuses on providing services that use learning objects metadata, based on a sufficiently generic approach so that they can be used by other Grid-based systems which need to make use of semantic descriptions. More details about SeLeNe are given in the chapter 10 of this book.

4.2. The "Learning Grid" Special Interest Group

Kaleidoscope [29] is a Network of Excellence funded by the European Commission which brings together European research teams in TEL. The key challenge that Kaleidoscope is facing is the scientific and structural integration of European TEL research. The challenge lies in the topic itself which is multi-disciplinary. Therefore, Kaleidoscope gathers researchers coming from various disciplines, from learning sciences to computational technology, which is critical since knowledge and meaning making are key to learning. The challenge lies also in the European dimension of the network, since European countries have different educational systems.

"Learning Grid" SIG [28] is a Special Interest Group of Kaleidoscope aiming at contributing to the achievement of an improvement in e-learning and training practices through the definition of open, distributed and pervasive environments for effective human learning. This view takes into account that effective learning requires an active attitude of learners and that learning is a social activity. Therefore, future learning scenarios require a technology that allows for active and realistic experiments, personalization, knowledge creation and evolution, as well as autonomous and dynamic creation of communities.

The Learning Grid SIG investigates on how Grid technologies can be exploited in future learning scenarios to support the learning processes by allowing learners to collaboratively use online resources, by facilitating dynamic communication with other people and agents on the Grid and by designing and implementing dynamic learning virtual organizations. The SIG also works on the concept of learning services and their deployment through Grid technologies.

SIG researchers cooperate to give a common answer on open issues about Learning Grid including the definition of new learning paradigms based on experiential, collaborative and contextualized approaches to exploit Grid technologies for addressing heterogeneous interoperability issues; the use and the extension of Grid technology for implementing Virtual Organizations to support the new emerging learning scenarios (collaborative virtual learning communities); the definition of evaluation models and strategies able to assess the efficacy and the effectiveness of Grid based learning models and systems.

SIG activities started in January 2004 on two main lines, the first one related to research, the second one to networking and dissemination activities:

1. the main aim of the research line is to pursue a common research program aimed to the resolution of the above mentioned issues allowing the full exploitation of grid technologies for effective human learning;
2. the main aim of the networking and dissemination line is to share SIG findings inside and outside Kaleidoscope boundaries in order to favour an in-depth understanding of the advantages offered by distributed and grid environments

in applying innovative learning paradigms and as enabling technology for creating dynamic Virtual Learning Communities.

From the **research** point of view, main SIG achievements can be summarized as follows. Several futuristic learning scenarios that aren't realizable with the current platforms/tools for distance learning have been defined, advantages introduced from a pedagogical viewpoint have been described, necessary features/services have been scratched, business benefits/drivers/needs have been emphasized.

A common set of concepts and terms related to e-learning infrastructures were defined; the need for a service-oriented approach in the context of e-Learning was justified; the nature of a service-oriented framework and its benefits for education was clarified; a methodology for constructing service-oriented e-Learning frameworks was defined; services to address the most pervasive challenges existing in education as a requirement to exploit the benefits of a service-oriented framework was defined; possibilities in developing an international service-oriented e-learning framework to extend the scope of the existing needs in education was explored.

A survey of existing languages and frameworks for the dynamic composition of distributed resources and services with particular regard to e-learning resources and services was performed and extension needed to use such languages in the context of a Learning Grid were defined.

From the **networking and dissemination** points of view, main SIG achievements can be summarized as follows. An observatory on Grid technologies for learning purposed to survey the field and report to the scientific community through a Web site and a quarterly newsletter have been established. The observatory also have in charge of disseminating main technological and methodological findings of related projects and advancements in standardization activities carried out by international bodies.

An yearly workshop connected with main events in the GRID and TEL fields collecting and publishing reviewed papers on SIG topics coming from inside and outside SIG boundaries is organized. Several dissemination activities are performed in conjunction with conferences and events.

5. Conclusions

This chapter described the concept of Learning Grid as defined in the homonymous Special Interest Group of Kaleidoscope (whose activities and main results have been also presented) and have contextualised it with respect to the relevant literature in the field. A formal definition of the concept was given as well as a reference architecture based on three overlying layers. Educational needs fulfilled by the learning grid have been presented and feasible pedagogical models have been introduced.

This chapter was a necessary introduction to the whole book and concepts here introduced will be detailed in the remaining chapters of this first section. The second section of the book will present instead some available prototype implementing or inspired to a Learning Grid.

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