# Cloud and Local Servers for a Federation of Molecular Science Learning Object Repositories

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**Abstract.** The G-Lorep project of the European Chemistry Thematic Network (ECTN), based on a federation of distributed repositories of Molecular Science Learning Objects, leverages at present a "hybrid" centralized/distributed architecture in which the central node hosts a shared database. The shared database deals only with the task of managing metadata to the end of synchronizing the information made available to the federation members at regular time intervals. In order to avoid missed synchronization (in the case of the failure of the central node) a scheme distributing the nodes, adopting a PaaS (Platform as a Service) strategy and ensuring network security, is implemented and related performances are evaluated. The efficiency of the developed new architecture of the federation is measured for a set of Molecular Science Learning Objects developed within some European distributed computing initiatives and adopted for the Theoretical Chemistry and Computational Modeling European Master and Doctoral joint courses. The evolution of the proposed Learning Objects is discussed also in view of the development of the Molecular Simulator Enabled Cloud Services (MOSEX) pilot project.

**Keywords:** Chemical reactions · Cloud · Distributed systems · Learning objects · Molecular Science · PaaS · Repositories · Security · Synchronization

## 1 Introduction

G-Lorep is a technology aimed at facilitating [18] the sharing of *Learning Objects* (LOs) among distributed repositories (whose typical scheme is illustrated in Fig. 1). For this G-Lorep leverages the assembling of a federation of repositories

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S. Misra et al. (Eds.): ICCSA 2019, LNCS 11624, pp. 359–373, 2019.
https://doi.org/10.1007/978-3-030-24311-1_26

among the members of a scientific community wishing to share their LOs and to offer them to other community members for further development. Each federate has a web server in its domain that resembles that of the other federates in order to make users feel, even visually, to be using the same environment even when they are operating on a different federate.

The network structure adopted by G-Lorep is hybrid. This permits each website to work stand-alone like (with no need to communicate with the other servers) and to use a central database to get information on the LOs made available on the network. Accordingly, each federate can contact autonomously the central node whose task is only the distribution of metadata so as to allow each member of the federation to update the information through a simple operation of synchronization occurring at regular time intervals. In particular, when an "update"request is received, the member refreshes its own database adding the new data received, creating an image of the LO equal to the original one and providing a link to the federate of origin.

In the G-Lorep initial implementation the central node was placed on a server physically located inside the University of Perugia. This, while guaranteeing a more direct control of the system, was reducing its fault tolerance in the case of Internet communication break-up causing miscommunication among the federates. An additional weakness of the initial implementation was the impossibility of guaranteeing that good practices of security (like the adoption of HTTPS, the automatic updating of Drupal and Linux, the configuring of SSH and Firewall) would be adopted.

Our choice to specialize G-Lorep on research driven Molecular Science (MS) applications [1–4] and, later, on Open MS Cloud [5,6] (see also VIRT& L-COMM.15.2018.4 in http://services.chm.unipg.it/ojs/index.php/virtlcomm/article/view/203) has further driven its evolution towards:

(a) an improvement of the technical quality of the service provided (like fault tolerance, availability, network survivability, etc.);
(b) the adoption of an evolutive policy in educational quality (integration of video and audio, easiness and traceability of the changes introduced, usability and evaluability of the product, etc.).

Accordingly, the paper focuses on the new architectural features of the G-Lorep federation obtained by moving the central node into the Cloud, using a PaaS approach, as discussed in Sect. 2 where the organization of G-Lorep in the cloud is described and Sect. 3 where the technique used to secure each G-Lorep server is detailed. In Sect. 4, then, the case study of the implementation of cooperative LOs related to the MS theoretical and computational foundations of the teaching course on Mechanisms and Dynamics of Chemical Reactions (MDCR) is analyzed in some detail. Finally, in Sect. 5, some conclusions are drawn and some directions of related future work are outlined.

## 2 G-Lorep in the Cloud

The new architecture of the G-Lorep federation with the central node moved into the Cloud according to a PaaS scheme is sketched in Fig. 1.

### 2.1 How G-Lorep Works

In the scheme of Fig. 1 each server runs a daemon called *server.php* whose task is to achieve the main architectural goal of the project: the synchronization of databases. Every $N$ seconds *server.php* makes a query to sharedDB (a database accessible from the outside) asking the list of metadata about all *linkable objects* whose domain of origin differs from its own (*Delegated Objects*). Then it runs `INSERT`, `UPDATE` and `DELETE` on its own database for each *linkable object* whose received content differs from the one already present in its own *Delegated Objects* table.

After completion of synchronization, it elaborates its own *linkable objects* list (*Owned Objects*) and uploads relevant metadata to the database by running again `INSERT`, `UPDATE` and `DELETE` for each *linkable object* having the same origin domain and different content.

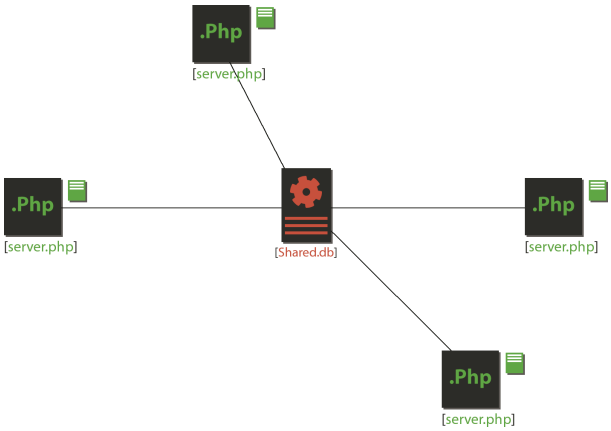


**Fig. 1.** The sharedBD based approach of typical federated repository of LOs.

### 2.2 The Shared Database

As already mentioned, sharedDB is a database accessible from the outside. It is a central node of a hybrid system acting like a meeting place where all federates can share their data sets. The shared database does not contain confidential information (like accounts or emails). It contains only meta-data of each repository (i.e. information like title, author, category, etc., which are all public information

readable from a guest user that is visiting any federate website). It is important, though, to protect this database because an attacker could use the server to send malicious data to the federates and through it attack them too.

This approach bears advantages and disadvantages as pointed out below:

- **Advantages** - In the proposed hybrid scheme a federate does not need to send its metadata to all the other members of the federation and can update at the same time its local database with meta-data from all the members of the federation through synchronization. Using a central system, on the contrary, when sharedDB goes down, all websites are unable to read data from the database because no federate has a local database of *linkable objects* and this leads to a malfunction of the website.
- **Disadvantages** - The use of sharedDB (instead of a server like RESTFUL API), could incur both security and, if the central node goes down, federation synchronization problems.

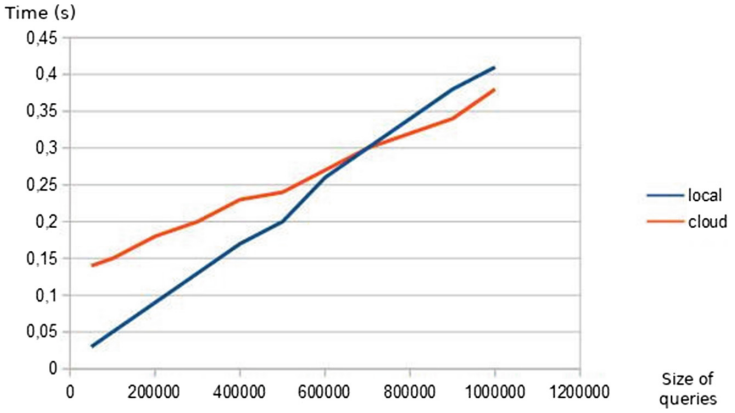


**Fig. 2.** Local (blue) and cloud (red) elaboration times for queries of different complexity (i.e. queries executed on tables with an increasing number of records) plotted as a function of size. The cloud elaboration is faster, but it requires a fixed time interval to send the output over the network (latency). (Color figure online)

In our approach security problems are, indeed, avoided by both using a firewall guaranteeing database access only to the IP addresses of the white-list of the federates and creating a user database for each member of the federation. If an account is violated, the data may become available only if the request is made by a G-Lorep member. In that case it is sufficient to create a new user database for that federate. In this way, the security is delegated to the database server, without the risk of creating new security exploits via either the RESTFUL API code or the daemon server hosting it.

Problems relevant to the central node fault tolerance, availability and network survivability are bypassed by inserting the node into the Cloud. In such case,

using the PaaS (Platform as a Service) of a service provider, the above mentioned problems, including the security ones, are reconducted to the responsibility of the service provider. After all, the cost of the limited size of the involved database and of the small number of the involved queries is negligible with respect to the gained advantages (as shown in Fig. 2 in which both local and cloud elaboration times are plotted as a function of the number of records (size) of the queries).

### 2.3 Moving SharedDB into the Cloud

**Choice of the Service Provider:** As Cloud Service Provider we adopted Amazon whose AmazonRDS PaaS is specifically designed for databases (in the remainder of the paper we shall refer to it as DBaaS).

**Creation of SharedDB and Data Import:** Once created a dump of sharedDB into the old VPS located in the University of Perugia, it is migrated in a MariaDB instance created from the Amazon RDS Console. After completing the creation of the instance, a client can connect to the endpoint using an ad hoc created DB user. These information are provided to G-Lorep by a configuration file. The AmazonRDS has a security group configured to accept only connections taken from a white-list of IP addresses. In this way unauthorized connections are inhibited.

**Performance Obtained:** Advantages and disadvantages of using the Cloud for this purpose are:

- **Advantages**: the database is more secure and available, not only in the case of attacks, but also in cases of loss of data and machine malfunction. The AmazonRDS console permits to automatize various services like hardware provisioning, updates, backups while showing to the administrators all the information about CPU and memory usage, connections established, I/O performed, etc. Moreover there are increments of performance about speed of computation of big queries because the hardware and software used by Amazon is optimized for this purpose.
- **Disadvantages**: the database is located geographically away from the federation members and this could create latency problems. G-Lorep, however, is not latency sensitive and this is important because, actually, the federation may easily contain truly geographically dispersed servers.

## 3 Securing Each G-Lorep Server

Compromised federates could be extremely dangerous for the network, because they can send malicious data to sharedDB and make them to be downloaded onto the other members of the federation. In order to guarantee a high level of security the following measures have been adopted for each federate.

### 3.1 Security Policies

In order to increase internal safety, everybody must have a different account on the server. This will guarantee optimal logging and no need to password change and redistribution in case of troubles.

All users must have as a username a word that is not part of a dictionary and a secure password (as usual the password must contain uppercase, lowercase, number and symbol characters and not contain words). In order to enforce the adoption of these rules, the `libpam-cracklib` was installed.

`Root` user has been deactivated and `sudo` permission has been guaranteed only to a few users.

### 3.2 SSH Configurations

To the end of securing the *SSH* server, *SSHD* has been configured so as to accept only connections originating from trusted IP addresses, and has been activated only for few users belonging to a given particular group. The authentication is performed via a private key instead of using a password. The *root* login is totally forbidden.

Furthermore, the *SSHD* does not address itself to the default port (22) because it has been moved to a different one that is known only to a few authorized users.

### 3.3 Network Security

In each G-Lorep server various levels of network security are adopted.

The first level of security is provided by the network firewall, that is configured to guarantee only connections to ports 80 and 443 (*HTTP* and *HTTPS*, respectively). Connections to the *SSHD* port are negated too for those G-Lorep servers which have a *VPN* service that permits a connection via LAN or, as an alternative, connection is permitted only to a white-list of IP addresses. If a list of trusted IP addresses can not be prepared, the network firewall opens both the 22 and the true *SSHD* port and an ad hoc created daemon will listen to port 22. The task of this daemon is to add to the firewall a blacklist of all IP addresses that contact it. In this way a port scanning coming from a single machine (that is the first phase of an attack) is inhibited.

The second level of security is provided by the internal firewall of Linux, `iptables`, which is configured as the network firewall. In addition it has rules created to avoid spoofing. For certain chains, `iptables` changes its rules dynamically via two daemons: one daemon is used to get the list of TOR (from The Onion Project API) nodes and add all their IP addresses to the blacklist, the second daemon (Fail2Ban) provides a defense from brute force attacks. It reaches its task by scanning logs of various services (*SSHD*, Web server, etc.) and by adding the suspicious IP addresses to the chain. It sends also an email to the administrator with the *WHOIS* of the attacking server. In the end, some rules of `sysctl` permitting the forwarding and the redirection of packets (these are routing functions) have been deactivated.

### 3.4 Web Server and Database Protection

At present G-Lorep servers make use of HTTPS, instead of HTTP, by adopting *Certbot* (a software provided by the project **LetsEncrypt** of the **Linux Foundation**) that installs automatically a signed certificate for free.

In order to prevent dangerous actions from an attacker, the web server has both the `AllowOverride` (G-Lorep does not need `.htaccess` to work properly) and the `Indexes` options deactivated (with the latter one being motivated by the need of avoiding the analysis of the structure of the website).

PhpMyAdmin is the interface used for managing DB from the browser, without needing to login via SSH. It has been configured to permit connection only to a certain pool of IP addresses and for certain ad hoc created users. Furthermore, its directory has been hidden in order to prevent brute force attacks (like those provided by *DirBuster*). This is strengthened by the presence of Fail2Ban.

The website makes use of a database user differing from *root*. Such user can be accessed only via `root shell`. The database also has activated a logging of failed attempts of login.

Drupal is the CMS currently used inside G-Lorep. It has been upgraded to the latest version and an automatic upgrade has been activated for small updates.

### 3.5 Improve Security Monitoring Files and Logs

It is really important to monitor logs, installed software and related files in order to improve a better level of security.

In the server there is no software using daily `wget` or `curl`. Because of this these two softwares are configured to logging their executions and send an email to the administrators every time they are used. Furthermore, every time a root shell is created (for example with `sudo su`), an email is automatically sent with the logs to administrators.

In all servers software has been installed in order to provide protection against rootkits and other malware. Both Rkhunter and Chrootkit are installed to create a more complete protection against these category of attacks, and both send alerts to the administrator when problems arise.

Finally *Logcheck* has been installed for providing log analysis in a wide number of files with reports being sent via email.

### 3.6 Backups

A possible attacker can modify the website by adding PHP or JavaScript codes for installing mining software or creating a backdoor with a reverse shell. Into each G-Lorep server daily backup and upload actions have been also established to the end of facilitating disaster recovery. Furthermore, it is important to backup the logging files and the web site into a different space located into the Cloud in order to contrast the possible deletion by attackers that try to hide their actions.

## 4 Cooperative Learning Objects for Mechanisms and Dynamics of Chemical Reactions

As already mentioned, the Molecular Science application considered here is a set of LOs designed for the MDCR (Mechanisms and Dynamics of Chemical Reactions) course being developed as a collaborative endeavour among theoretical and computational chemists, theoretical and computional physicists, kinetics and molecular beam scattering experimentalists.

### 4.1 The Demand for Learning Objects to Support Chemistry e-Learning

The development of the Molecular science LOs discussed here was prompted by the activities of the European Chemistry Thematic Network (ECTN) and its Association. ECTN was started in the year 1996 as a result of the approval of the homonimous Life Long Learning project (ECTN later named ECTN-1). ECTN-1 gathered together over 130 Chemistry departments to define the European Core Chemistry and related practical skills. The ECTN members designed and developed for this purpose a solid de facto standard by harmonizing at European level Higher Education curricula in Organic Chemistry (OC), Physical Chemistry (PC), Inorganic Chemistry (IC), Analytical Chemistry (AC) together with Mathematics and Physics. In the years 2000/2003 the ECTN-2 project focused on e-learning and on the development of the EChemTest® appropriate e-test Libraries of Questions and Answers (Q&A)s for General Chemistry 1 and 2 (GC1 for Schools and GC2 for Universities), Biological Chemistry (BC3), AC3, IC3, OC3 and PC3 at Bachelor level with the technical support of the Perugia and Vienna Universities. In the years 2003/2009 the next funded ECTN-3 and ECTN-4 projects developed educational tools to support students' mobility and the activities of the Virtual Education Community (VEC) including the adoption of multimedia and networked ICT technologies [7].

During the 2009/2015 period, the EC2E2N-1 and EC2E2N-2 projects extended the work to the support material for the MDCR LOs considered in the present paper. The attempt to disseminate support materials for the MDCR LOs relies on the adoption of a collaborative user/producer model (that is often referred to as Prosumer) in science and education [5,6]). In the Prosumer model the activities of the members continuously feed new information into the system both as producers and as users improving continuously so far its quality in a tight interaction of the feedbacks obtained from the usage and the requirements of the assessment process. The main features of such collaborative scheme are: self-consistency, modularity, availability, reusability, interoperability with no locality and no (or extremely limited) ownership constraints of the knowledge as is typical of cloud services. These features are highly desirable as they give utmost thoroughness to information by prompting knowledge provision be flexibly aggregated and readily used (and re-used) thanks also to the association with metadata which allow to verify the existence and the properties of the information.

### 4.2 The Collaborative Science and Technology European Initiative for Molecular Science

In the case of the assembling of the MDRC LOs the Molecular Science community has leveraged in the last twenty years the COST (www.cost.eu/) activities aimed at gathering related collaborative efforts. The Action most directly correlated to this endeavour is D23 (METACHEM, www.cost.eu/COST_Actions/cmst/D23 launched by the University of Perugia in the year 2000). D23 initiated the development of tools connecting the activities of different Molecular Science research laboratories operating on a shared computing platform made of a geographically distributed cluster of heterogeneous computers connected on a network (LAN, MAN or WAN) through a software co-ordinating them as a single virtual parallel machine [8]. This established a network of the so called European Meta Laboratories fostering innovative solutions for chemical applications and a new paradigm for collaborative research. In the year 2006 a new COST Action (D37—Grid Computing in Chemistry: GRIDCHEM) was started to the end of developing collaborative distributed grid solutions and paradigms for molecular science research. GRIDCHEM leveraged the creation and use of distributed computing infrastructures ("Grids") and drove collaborative computer modelling and simulation in chemistry towards new frontiers in complexity and a new regime of time-to-solution [9] including molecular simulators of complex molecular reactive systems. This evolution line was then continued by the initiatives CMMST (virtual research environment), COMPCHEM (a Virtual Organization), GEMS (the Grid empowered molecular simulator) initiatives developed within the EGEE (Enabling Grids for E-sciencE) and the EGI (European Grid Infrastructure) European projects with its pilot MS computational applications [10] and [11] under the umbrella of the COMPCHEM Virtual Organization (VO) [12] and the computational frame of the Grid Empowered Molecular Simulator GEMS [13].

### 4.3 The Driving Force for Designing the LOs

In particular, the driving force for designing related LOs was provided by the wish to foster the development of competences in:

- selecting the compute resources based on quality parameters and a composition of higher level of complexity chained applications through the coordinated usage of distributed hardware and software,
- fostering the use of specialized web portals and workflows facilitating the production of data and know how in science and innovation, the direct reuse of the produced data and knowledge for education, training and further research
- producing and providing computational means designed for dealing with molecular and materials disciplines when carrying out multi-scale treatments necessary to reproduce the observables of realistic systems in the area of energy, environment, materials, pharmacology, chemistry, biology, biotechnologies, medicine, etc.

- developing state-of-the-art first principles electronic structure and nuclei dynamics methodologies,
- designing high level of accuracy multiscale complex molecular systems,
- knowledge managing for training in sciences and technologies,
- collecting the requirements,
- validating the developed procedures,
- disseminating the outcomes, user support and knowledge transfer tools,
- adopting existing scientific gateways, workflows, data management and commons.

which are the common scientific and technological background for modern MS.

### 4.4 The Support of the European Educational Initiatives

A significant impulse to such endeavour was given by the Theoretical Chemistry and Computational Modeling (TCCM) European Master and by the homonymous ITN European Doctorate (https://tccm.qui.uam.es/) both coordinated by the Universidad Autonoma of Madrid. Within these two initiatives, the mentioned LOs are being actively used to form a new generation of young researchers able to tackle the development of modern chemistry, biochemistry, chemical biology and material science applications using state-of-the-art first principles electronic structure and nuclei dynamics codes, implementing accurate multi-scale simulators of smart energy carriers in combustion, energy storage, space missions, bioinorganic chemistry, exploiting both ab initio and empirically parameterized kinetic data, designing materials and modelling supra-molecular phenomenology, handling extended information systems for the investigation of the structure and processes of complex molecular systems relevant to pharmacology, medicinal and biological systems, and managing distributed knowledge processes. A particularly systematic use of the mentioned LOs is made in parallel with the use of the book "Chemical Reactions: basic theory and computing" [14]. The mentioned LOs were used also for the School of Open Science Cloud, (SOSC) (see https://indico.cern.ch/event/605204/overview and http://services.chm.unipg.it/ojs/index.php/virtlcomm/issue/view/25 held in Perugia on June 2017 and for the sessions of the one month long Intensive Course (IC) of the last edition of the already mentioned TCCM Erasmus Mundus Master (Perugia September 2018).

### 4.5 The Proposed LOs

Within the above mentioned development environment the following tentative list of LOs was made [15]:

1. **From the phenomenology of chemical reactions to the study of two body collisions**
   LO 1.1 From Kinetics to Bimolecular Collisions (The phenomenological approach, Realistic kinetic models, The Transition State Theory approach, Towards detailed single collision studies)

LO 1.2 Classical mechanics of two particle collisions (Reference frame and elementary interactions, The equations of motion, The deflection angle)
LO 1.3 The computation of scattering properties (Trajectories integration (Hamilton equations), Numerical computation of the deflection angle, Other collisional properties, The cross section)
LO 1.4 Popular scattering model potentials (The rigid sphere model, The Repulsive Coulomb potential, Sutherland and Morse attractive-repulsive potentials, The scattering Lennard-Jones (6–12) potential)

2. **The quantum approach to the two-body problem**
LO 2.1 Quantum mechanics and bound states (The limits of the classical mechanics approach, The 3D quantum problem and its decomposition, The Harmonic Oscillator)
LO 2.2 Quantum elastic scattering (The Coulomb potentials and the hydrogen atom, The formulation of quantum elastic scattering, The quantum elastic scattering cross section)
LO 2.3 Realistic Models for scattering systems (Continuum solutions for hydrogen-like atoms at positive E values, The rigid sphere, The Morse potential)
LO 2.4 Numerical integration of the Schroedinger equation (Expectation values of the operators, Approximation to the Laplacian, Approximating the wave function, The approximation to the potential)
LO 2.5 Numerical applications (Systems of linear algebraic equations, The structure of the wavefunctions, The Time-Dependent method)
3. **Ab initio electronic structure for few-body systems**
LO 3.1 Structured Bodies (The one-electron wavefunction approach, Quantum Monte Carlo, Many electron wavefunctions, The electronic structure of molecules)
LO 3.2 Higher Level ab initio Methods (Beyond the Hartree-Fock method, The CI and MC-SCF methods, Perturbation methods)
LO 3.3 Towards extended applications (Computation of other molecular properties, Density Functional Theory methods, The valence electron method, Dropping multicenter integrals)
LO 3.4 Full range process potentials (The three body internuclear coordinates, Global formulation of the potential energy surface
4. **The treatment of few-and multi-body reactions**
LO 4.1 The combined dynamics of electrons and nuclei (The N body dynamical equations, A direct integration of the general equations, The Born-Oppenheimer approximation)
LO 4.2 Three atom systems (Three body orthogonal coordinates, Atom-diatom reactive scattering Jacobi method, Atom-diatom time independent APH method, The atom-diatom time-dependent APH method)
LO 4.3 Beyond full quantum calculations (Reduced dimensionality quantum treatments, Leveraging on classical mechanics, Semiclassical treatments)
LO 4.4 Basic features of atom-diatom reactions (Energy dependence of the detailed probabilities, Quantum effects, Experimental observables, Periodic orbits and statistical considerations, The last mile to the experiment)

LO 4.5 Towards more complex systems (Full range Ab initio PESs for many body systems, Fitting PESs for reactive and non reactive channels, Four atom Many Process Expansion, Four atom quantum and quantum-classical dynamics, Last mile calculations for crossed beam experiments).

Some examples of the MDCR LOs produced in collaboration with the Multimedia Centre of the University of Perugia are accessible at the G_Lorep address https://glorep.unipg.it. The abstract of the course is given in the upper part of Fig. 3 while the screenshot of the summary of the introductory LO00 (preliminary to the above mentioned LOs) showing also the speakers is given in the lower box of the same Figure.

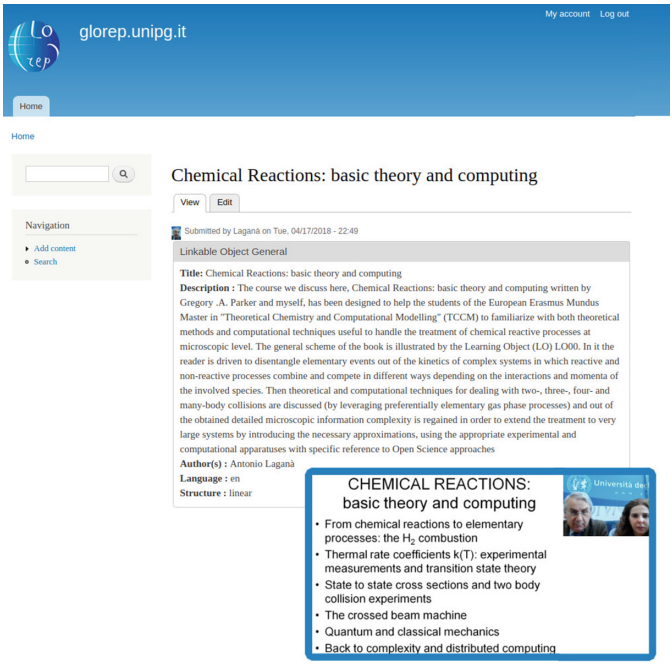


**Fig. 3.** Abstract of the MDCR course (upper part) and screenshot of the introductory slide of the initial LO (lower part).

### 4.6 The MOSEX Project

As mentioned in the programme of the OMSC (Open Molecular Science Cloud) workshop (see www.dcbb.unipg.it/euco2019) this effort is part of the plans for implementing MOSEX (MOlecular Simulator Enabled Cloud Services) as a European Open Science Cloud Pilot designed as a follow-up of the EGI COMPCHEM Virtual Organization (VO) activities. MOSEX aims to gather together and offer as a service on the cloud for the Molecular Science (as reported at the

last meeting of the CTC Division Board of EuChemS at the end of August 2018 in Liverpool and will be planned in more detail during the last part of the mentioned OMSC workshop next September 5 and 6 at the "Accademia Nazionale delle Scienze (dei XL)" in Rome) by implementing the Prosumer Model for the following applications:

- Molecular electronic structure and dynamical properties programs like GEMS (small molecules chemical processes (including ab initio determination of analytical Potentials), their Quantum/Classical dynamics efficiency and properties obtainable from the analysis of the wavefunction, the Molecular Dynamics on excited states, VMS: (Virtual Spectrometer)
- Drug design programs and related cloud services (QSPR and 3D QSPR models)
- CHEMCONNECT (Distributed repository of molecular science data), IOCHEM (organization, publication and storage of molecular information on materials)
- Dissemination and evaluation of molecular knowledge like in MolSSI (Molecular science software tools development and training) and VIRT&L-COMM (e-magazine for virtual community activities dissemination).

## 5 Conclusion and Future Work

As discussed above, the organization of our G-Lorep federation of distributed repositories is suited to assemble MS Learning Objects in a cooperative way. This has been found to be extremely useful when dealing with LO materials implemented for supporting ECTN EChemTest Self evaluation assessment sessions. In the particular case discussed in the present paper, the LOs of the Mechanisms and Dynamics of Chemical Reactions course, one has to build on the expertise of theoretical and computational chemists, theoretical and computational physicists, kinetics and scattering experimentalists, to succeed in that one has keep the LO contents continuously updated and correct. The best products in fact can emerge only as a result of a continuous interaction between usage and production.

According to the high potentiality shown by G-Lorep in dealing with the LOs we plan also to consider in the near future the migration of G-Lorep from Drupal 7 to Drupal 8, the rewriting of part (if not all) of its modules using a PHP Framework and the abandoning of the use of a CMS to further improve security when needed. We are considering, as well, to create an image of Debian containing a version of G-Lorep pre-configured with the policy described in the present paper in order to simplify its installation and allow a better integration of new federates. This will imply the writing of a script that, once launched, customizes the system by changing all private information (like accounts and database credentials and related configuration file of the web server). It will make it easier to register as a member of the G-Lorep federation once that a new user database is provided to its server and is inserted into the white-list

of the sharedDB node. A third future task of future work will be the creation of a general G-Lorep located in the Cloud where everyone can insert their own learning objects regardless of their institution of origin.

A further future improvement, being already experimented [16,17], is the introduction of the semantic metadata created by the G-Lorep Taxonomy Assistant in the standard format for use in the learning object exchange.

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