Andrea Molinari

INTEGRATION BETWEEN eLEARNING PLATFORMS AND INFORMATION SYSTEMS: A NEW GENERATION OF TOOLS FOR VIRTUAL COMMUNITIES

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Abstract

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This research focuses on re-designing the architecture of a Learning Management System (LMS) to facilitate and increase its usage inside an information system and achieve a more profound and better integration. LMSs offer many valuable services in various educational contexts. However, most of these services are typically inefficiently used because they are primarily redundant within other functionalities of an LMS or with services provided by other information systems. Services such as file sharing, forums, blogs, polling, voting, videoconferencing are often available within LMSs, but modern organizations also have access to these services via other systems. This thesis shows that with a deep re-design of the software architecture, LMSs can have broader application opportunities than only the educational setting and can be competitive compared to similar services provided in other formats.

This thesis has followed two main research lines formulated as questions: a) how to intervene in an LMS's architecture and functionalities to create a more generalized, collaborative environment not only devoted to the educational setting; b) how to facilitate the integration of LMSs into corporate information systems, while avoiding duplication of services for end-users and improving their Total Cost of Ownership (TCO). A central issue of this thesis has been identifying what these duplication and integration problems are based on. We observe that a central problem is found in the core architectural concepts of an LMS, the foundational metaphor underlying these platforms: LMS's intimate structure is based on concepts such as "class", "course", "student", and "teacher". These concepts relate strictly to education, thus preventing LMSs from being used in a conceptually native way outside these contexts. Indeed, these concepts are unsuitable for collaborative settings, such as a meeting, a research group, a recreational community, a conference, a community of evaluators, a secretariat, a labor union association, etc. We cannot manage a research group the same way as a "class", or assign the head of the research group to the role of a "teacher". We should consider a research group as a community that uses digital services to support its activities, i.e., a virtual community. In this vein, this dissertation aims to demonstrate how a re-design of an LMS architecture around this thinking can potentially solve and improve the possibilities for an LMS to become central within modern information systems. Here the envisioned re-design places the concept of "virtual community" at the center of the architecture of the platform, replacing current concepts like "class" or "course". This novel approach represents a radical change to the internal architecture of an LMS, from the design of classes used in the code, to the persistence layer, to the services provided to the end-user. We could even talk about a new category of software platforms, i.e., a "Virtual Community Management System" or simply "Community Management Systems", not to be confused with social media platforms. These systems provide their users with different services oriented toward education, communication, collaboration, multimedia management, videoconferencing, file sharing, project management, support to decision processes, time management, lifelong learning services etc.

This thesis presents insights into the internal architectural changes of an LMS, the consequent new services developed, and how these changes can facilitate the integration of the new design for an LMS inside the information system stack of an organization. As a real-world test of the envisioned changes and as a partial validation for the applicability of the notions presented, artifacts created in the form of (primary) services within a software platform named "Online Communities" and the transformation of the platform to a virtual community are presented. The platform has been (re)designed according to the paradigmatic shift presented in this thesis. We also consider this re-design process successful because public and private organizations have adopted the platform. The platform has also enabled numerous fundraising activities, generating a spin-off company for the commercialization of the platform. The role of the author in this design process has initially been that of a designer, software architect, and partially software developer. During the process, due to the possible implications of the practical activities undertaken and the number of experiences collected, our role has become that of an external researcher looking at the phenomenon from the outside, and action researcher looking at the artifact creation from the inside.

Keywords: e-Learning, Information System, Virtual Community

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Finally, my beloved wife, Lucia, and the rest of the crew, my children Elena and Luca, thank you for your love, patience, support, and understanding.

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October 2022
Lappeenranta, Finland

Contents

List of publications

This thesis is based on the following papers. The publishers have granted the right to include the papers in the dissertation.

Publications in journals and books

Paper 1. Molinari A. (2021), Project Management and Learning Environment: A Case Study, Journal of Visual Language and Computing, KSI Research Inc., Pittsburgh, USA Vol.2 N.1 2021, DOI reference number: JVLC2021-N2-020, pp 21-32

The candidate is the only author of the paper.

Paper 2. Coccoli, M., Maresca, P., & Molinari, A. (2020). Big Data, Cognitive Computing, and the Future of Learning Management Systems. In C. Hong & W. Ma (Eds.), Applied Degree Education and the Future of Work, Lecture Notes in Educational Technology. Springer: Singapore. DOI:10.1007/978-981-15-3142-2, pp. 329-340

All authors contributed equally to all parts of the manuscript.

Paper 3. Coccoli M., Maresca P., Molinari A. (2019) Collaborative E-Learning Environments with Cognitive Computing and Big Data, Journal of Visual Language and Computing, KSI Research Inc., Pittsburgh, USA Vol. 9 N.1 2019, DOI reference number: 10.18293/JVLC2019N1-07 ISSN 1045-926X pp 43-52

All authors contributed equally to all parts of the manuscript.

Paper 4. Molinari, A. (2015). Designing Learning Objects For Italian Public Administration: A Case Study. Problems of Education in the 21st Century, Scientia Socialis, Siauliai, Lithuania Vol. 68 N.1, ISSN 1822-7864 pp. 52-63

The candidate is the only author of the paper.

Paper 5. Bouquet P., Molinari A. (2016) A New Approach to the Use of Semantic Technologies in E-Learning Platforms, International Journal of Advanced Corporate Learning (iJAC). Vol 9, No 2 2016 , ISSN: 1867-5565 pp 5- 12

The candidate is the primary author of the paper: prof. Bouquet provided the review and the semantic technologies references

Paper 6. Casagranda, M. , Colazzo, L. , Molinari, A. (2014) Estimating the Effort in the Development of Distance Learning Paths, Communications in Computer and Information Science, Springer, Vol. 456, 2014, Pages 160-179, ISBN 978-3-662-44787-1 ISSN: 1865-0929

The candidate is the paper's primary author: the other co-authors provided the review and contributed to sections 4 and 5.

Publications in conference proceedings

Paper 7. Bouquet P., Molinari A. (2019) Sport, Dual Carriers and Education: The E-Learning Way, In: Proceedings of the 11th Annual International Conference on Education and New Learning Technologies. EDULEARN19, Palma de Mallorca (Spain), 1-3 of July, 2019, ISBN: 978-84-09-12031-4 / ISSN: 2340-1117, DOI: 10.21125/edulearn.2019, pp. 6467-6473

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Paper 8. P. Bouquet, A. Molinari (2019) E-Learning and Project Management: Adding New Features to Learning Management Systems, Proceedings of ICERI2019, 12th annual International Conference of Education, Research and Innovation, Seville (SP), 11-13 Nov 2019, ISBN: 978-84-09-14755-7 / ISSN: 2340-1095, DOI: 10.21125/iceri.2019.2468

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Paper 9. Maresca P., Molinari A. (2018) Implications of Learning Environments on the Information Systems of Educational Institutions, Proceeding of DMSVIVA2018, 24th International DMS Conference on Visualization and Visual Languages, San Francisco June 29 - 30, 2018, ISSN: 2326-3261

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Paper 10. Molinari A (2017). Learning Management Systems and the Integration with Social Media Services: A Case Study. In: ASONAM '17 Proceedings of the 2017 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining 2017. Sydney, Australia, July 31 - August 03, 2017, doi: 10.1145/3110025.3110104, ISBN 978-1-4503-4993-2, ISSN: 2473-9928 pp 775-781

The candidate is the only author of the paper.

Paper 11. Molinari A, Bouquet P (2016). Big Data and the Impact on E-Learning Platforms: A Case Study. In: Proceedings of the 8th Annual International Conference on Education and New Learning Technologies. EDULEARN16, ISBN: 978-84-608-8860-4, ISSN: 2340-1117, Barcelona, Spain, 4-6 Jul 2016, doi: 10.21125/edulearn.2016, pp. 5232-5240

The candidate is the primary author of the paper: prof. Bouquet contributed to the review and the big data references.

Paper 12. Molinari A. (2015), Supporting Decision-Making Processes in Virtual Learning Environments. Proceeding of ICERI2015, 8th annual International Conference of Education, Research and Innovation, Seville (SP), 16-18 Nov 2015, ISBN: 978-84-60-82657-6, ISSN: 2340-1095, pp 6498-6508

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In Appendix A, the reader can find other papers produced during the PhD period relevant to the argumentation presented.

Nomenclature

In the present work, variables and constants are denoted using *slanted style*, vectors are denoted using **bold regular style**, and abbreviations are denoted using regular style.

Abbreviations

AI	Artificial Intelligence
CMS	Content Management System
DBMS	Data Base Management System
DMS	Document Management System
DSS	Decision Support System
ENS	Entity Name System
FOSS	Free Open Source Software
HR	Human Resources
ICT	Information and Communication Technologies
IT	Information Technology
IS	Information System
LCMS	Learning content management system
LMS	Learning Management System
LRS	Learning Record Store
LO	Learning Object
NLP	Natural Language Processing
OLC	Online Communities
ROI	Return on Investment
SaaS	Software as a Service
SCORM	Shareable Content Object Reference Model
TCO	Total Cost of Ownership
TEL	Technology-enhanced Learning
VLE	virtual learning environment

1. Introduction

1.1 Background and motivation

This research investigates the integration between learning management systems and an organization's information system. A learning management system is a (web-based) software application designed to provide different services to educational stakeholders, such as handling learning content, interacting with users asynchronously or synchronously, supplying assessment tools and reports of learning progress and students' tasks [1][2][3]. Learning management systems are very complex software, because they include a variety of platforms or services: course management systems, record management systems, content management systems, videoconferencing solutions, web portals, instructional management systems, multimedia processing, and so forth. [4].

In this thesis, the term “information system” is used as a singular noun to refer to an integrated set of technological components that collect, process, and store data for providing information knowledge to its users. From an architectural point of view, we intend an information system as the result of the composition and integration of different software platforms or components, such as Customer Relationship Management (CRM), Supply Chain Management (SCM), Enterprise Resource Planning (ERP), Geographic information system (GIS), Human Resource Management (HRM) and more recently, learning management systems. We adopt, therefore, an organizational view of this notion rather than a purely technical one. Nowadays, there are so many different software platforms (or information systems in a narrow, technical sense) that a global view of them is needed because they need to be managed in an integrated manner. In this thesis, an organization's information system is viewed as the integration of these different software platforms to create an integrated ICT solution to manage whatever kind of information the organization has to manage.

Since the early years of their appearance on the market, learning management systems (LMSs) have reached a high level of maturity, providing professional solutions to almost any educational need. Nowadays, the availability of many different cloud-based collaboration tools puts the specific characteristics of LMS services and pedagogical approaches to learning in the shade. The dramatic pandemic that started in 2020 highlighted the importance of technology-enhanced learning (TEL) as a crucial part of the information system of any institution.

This research explores the possibility of integrating an LMS with the rest of the services of an information system, providing collaboration, communication, accounting, authentication, recording, and document sharing solutions [6], optimizing the user experience and the total cost of ownership. It focuses on developing an LMS towards it being a more collaborative platform, in the sense of providing IT-based collaboration services for the users of the information system of the hosting organization. The research focus is on technical aspects of this optimization, i.e.:

a) what kind of internal structure should a learning management software platform have to provide support to both educational and other collaboration activities;

b) what kinds of services are missing and should an LMS provide an adequate container of collaboration needs (also beyond the scope of learning-related tasks)?

The primary motivation is to demonstrate how learning systems could be a building block for any information system, as they can provide a set of essential services for corporate IT. Above all, they can be used as educational tools and generalized tools for collaboration. We want to stress how e-learning can be considered a more comprehensive collaboration between teachers and learners. This consideration has been reinforced by recent research trends that have adopted new educational theories and practices [7]. There is a much less unbalanced teacher and learner relationship versus a more peer-to-peer one. As examples, we can mention approaches related to co-learning, flipped classrooms, and all the approaches in which we must consider participants as peers and not simply as "students". More appropriately, they are components of a knowledge-transfer process with educational and training, professional, and vocational purposes.

During the research, seven services have been created as extensions of an in-house developed LMS. The author has been responsible for the software team, software architect, and designer for the business and the application's persistence layer. This LMS is based on the "virtual community" metaphor, a container of activities made online by its members. The founding principle is that educational tasks are just a subset of collaboration activities in any organization that are not solely concentrated on education. Accordingly, providing collaboration services inside an LMS could enhance learning performance and allow an LMS to be used in other (and all) collaboration contexts.

The rationale for this research starts from optimizing the IT services provided by the information systems stack of an organization. There are many overlapping services and tools between what IT departments provide for different uses and what modern LMSs offer. Indeed, let us consider what IT departments provide to their employees/partners to support collaboration and coordination of activities: LMSs provide the same services, probably with different labels but with the same functionalities and often the same users.

1.1.1 The advantages of e-learning

Unlike traditional teaching methods, e-learning has many recognized advantages that usually attract the attention of public and private organizations. A listing of the main advantages of e-learning is presented here [8]. We note that a complete analysis of the benefits of e-learning is beyond the scope of the present research.

- **Scalability.** Scalability is the property of a (technical) solution to scale up without significant resources with a (sudden) increase in the number of users. In modern information systems, this property is typical of cloud-based solutions. Still, in terms of the scalability of e-learning, the most exciting aspect is derived from the lack of obstacles involving the physical space. While in a classroom, we have a rapid and exponential degradation of the quality of a lecture. When the number of participants increases, e-learning outcomes, and the learning effects are not severely impacted by the number of users, provided that the platform is managed correctly from a technical perspective. Massive Open Online Courses (MOOCs) have demonstrated this significant characteristic, allowing hundreds of thousands of students to participate in a lesson without any degradation in the learning derived from the number of students, depending on the technical characteristics of their connection and the delivery platform.

- **Independence of location.** Contents are available anywhere and anytime. Using self-paced, personalized content, learners can use educational services and access updated content whenever needed, from wherever, using any device connected to the Internet, a mobile phone, a tablet, or a PC. Students can therefore learn at their comfort, following their requirements. These remarkable changes impact how the content is accessed, consumed, discussed, and shared, allowing online educational courses to be taken at a suitable time for the participants, any time of the day, and any day of the week. There are no more dependencies on the availability of the physical place where education is delivered, but only on the availability of an Internet connection and the appropriate content.
- **Lectures can be followed (potentially) an unlimited number of times**. This item represents another relevant difference (and advantage) compared to traditional learning. E-learning allows learners to access the content unlimited times (with some exceptions such as time limits in MOOCs), rewinding and reviewing the content at their own pace. In a traditional classroom, missing attendance means relying on others' notes or recordings of what has been taught or self-studying the missed topic.
- **Speed of lesson delivery.** Just-in-time services have become a mantra in our society, and e-learning makes no exception. Compared to the traditional classroom teaching approach, the delivery cycle of e-learning content is much quicker and more reliable. A recent analysis of the e-learning market [8] claims that the time required to approach the learning content decreases by 25%–60% compared to traditional learning. The main reasons are the quick start of lectures, quicker wrap-up sessions, and quicker educational program roll-out. On the learner's side, the possibility of adapting and customizing the speed of learning to match individual capabilities without following the speed of classmates can impact the available time devoted to the learning process. Learning at one's own pace, optimizing the learning process to create knowledge, preference, time slots, etc., could lead to a shorter learning process [9].
- **Content continually updated**. Thanks to the Internet, a significant benefit of learning online is the availability of fresh and updated content if the content provider has an appropriate policy. In this way, the learning process becomes extremely attractive and suited for some areas such as high-tech and scientific content. It can be synchronized with up-to-date information that could be crucial, especially when the alignment between operational resources and contextualized knowledge is needed.
- **Quality of the educational process.** E-learning allows educators to communicate the educational message in a more profitable, more consistent way, with a higher level of quality due to multimedia technologies. Another element increasing the quality of delivered content is the customization of the educational path. Examples include AI techniques (supervised/unsupervised machine learning) to classify users, inferring the best content for learners' needs, or adapting the content according to feedback provided by the learner voluntarily or involuntarily [10][11].
- **Positive impact on training costs.** The cost-effectiveness of e-learning has always been used as a primary lever to convince educational managers to switch to distance learning methods. It is evident that e-learning, especially with large numbers of participating students, has always presented a "total cost of ownership" that is primarily advantageous compared to traditional educational processes. Even with a low number of participants and not even considering the overall aspects of the total cost of ownership, distance learning methods have a better and unrivaled impact on the cost-structure of educational

processes. This cost reduction is due to learning quickly and easily, using cheaper technologies than physical settings and delivering at an almost constant cost to large masses of users. Physical, in-presence lectures cannot compete with e-learning on cost. Let us move to a global analysis of the cost structure of educational activities. Costs can be drastically reduced because trainers save a lot of training time travel, and the associated expenses are not needed. Course materials can be produced, replicated, and distributed quickly and inexpensively without accommodation costs. "Traditional" educational institutions tend not to consider these costs, but they are essential outside these contexts. The cost-effectiveness also impacts the organization's profitability, and we can find win-win situations for the stakeholders involved. Furthermore, let us consider the costs for individuals studying at their place. When there is no need to move, we make the same travel expenses (e.g., accommodation) savings and can reduce pollution [12].

- **Effectiveness of learning through e-learning**. Effectiveness is a controversial issue, mainly because it depends on numerous factors related to the quality of the e-learning process and the content delivered. If we look at well-design materials and processes online, e-learning has a general positive influence on learners. Motivated people who fit with the "ideal" e-learner profile find much higher satisfaction in e-learning processes (compared to others), because of the costs, delivery time, modality of fruition, freedom in choosing educational paths, and relative contents. It can be noted that "nothing" compares to live teaching by top teachers with excellent communication and content capabilities. However, on average, the effectiveness of e-learning on large masses of people is at a good or outstanding level in many different disciplines [13][14] [15] at different levels of age/scholarship [16][17].

1.1.2 History and evolution of learning management systems

Since the beginning of the Internet era, LMSs have played an important role in successful educational initiatives, thanks to the services and tools provided to all the involved stakeholders, from learners to teachers, from tutors to administrative personnel [18][19]. If we go back to the origin, LMSs can probably be traced to the Program Logic for Automatic Teaching Operations (PLATO), created in 1960 at the University of Illinois and the earliest networked learning system. PLATO had two aims, to utilize computers for education and build a cost-effective educational system to support teaching and learning [20].

In recent times, 1990 was the year FirstClass™ was introduced in the market, running on Macintosh computers, with simple features like members' email and forums. To see fully-fledged platforms with proto functions like those we know today, we must wait until 1997, when BlackBoard™ released its Interactive Learning Network. In 1998, our research team at the University of Trento released a platform called "Online Courses", a web-based LMS and the first implementation of a Virtual communities system, overcoming the idea of the "classroom" as a pillar of such a system [21]. Then in 2004, the first LMSs such as Moodle started to be available. The story of LMSs completely changed, transforming LMSs from niche products available only to well-ICT-equipped, high-budget institutions to popular solutions freely available also to small institutions with low budgets. Moodle and similar platforms like Docebo, Sakai, Classroom, Sakai, TalentLMS, Edmodo, OpenLMS, Forma, etc., have changed how we teach and learn today, which is probably a role that our society has not recognized enough.

Then ICT, specifically the world wide web evolution, spread improvements into the LMS arena. In 2008, the first LMSs (such as Eucalyptus) were introduced with APIs and cloud-based backends such as Amazon-Web-Services. After 2010, cloud-based LMSs became popular, providing many features with no need to be installed and all the advantages of cloud-based technologies. Users can use the LMS through a browser without worrying about installing the software and buying a database server to store the information [22][23][24]. Incorporating cloud-based LMSs has contributed to the diffusion of new approaches and instruments for learning, such as blended learning and flipped classrooms [25], [26].

The availability of different, valid, and cheap solutions puts educational institutions in the favorable position of having innovative and productive means of knowledge delivery for their audiences. This allows keeping apace of rapid changes in educational settings and society (teleworking, remote learning, or the last dramatic pandemic), as well as gaining a competitive advantage to survive the challenges of distributed knowledge production systems where educational contents play an essential role ([27] [28]).

From the teacher's perspective, the first period of adoption has been characterized by individual experiments with teachers using self-made forums, blogs, wikis, websites, etc. After this pioneering phase, software products devoted to supporting learning processes started to be available on the market thanks to the diffusion of stable, high-speed, cheap Internet connections. Educational institutions started formalizing didactics' support by providing centralized, managed and supervised LMSs.

The evolution of LMSs, together with the advent of social media, smart devices, mobile technologies, and in general, the availability of efficient, cloud-based collaboration tools [29][30], usable on-demand and even for free [31], raises a set of questions regarding LMS evolution [32]. One of these questions is where this thesis is mainly focused, i.e., proposing and designing interconnections between the LMS and the rest of the information system architecture of the hosting organization [33]. Many organizations have separated the e-learning system from the rest of the information system or even externalized it, thus considering the educational activity as an external body to all the other IT activities when facing the opportunity of distance education. Third parties frequently take care of the technical support for educational tasks, which will impose their way of managing educational processes.

1.1.3 Different types of LMSs and their services

The LMS market offers several LMS platforms that support the e-learning sector slightly differently. The first group of LMSs comes from free, open-source solutions, readily available at no cost of acquisition (if the configuration needed by the educational institution is relatively simple). With source code available, while making changes requires in-depth technical knowledge, these systems can be modified, extended, and customized. These aspects have created an interesting market for consultancy and services devoted to customization for specific needs, such as integrating LMS with other information system services. Well-known platforms, such as Moodle™, belong to this group.

The second group of LMSs includes the so-called "closed" or "proprietary" solutions, in the past linked to significant software-industry players, now primarily developed based on specific requirements expressed by customers. In this category, we can find many different examples, with solutions created from scratch, customizations of open source LMSs, or customizations of other software platforms created for other purposes "forced" to become technology-enhanced learning environments. A frequently found example is the customization of Content Management Systems (CMS), like Joomla ™, Drupal ™, WordPress ™, etc., to cater to educational needs.

Recently, a third group of software solutions for education can be identified, which takes advantage of the many positive aspects of cloud computing. Usually, these platforms are the software porting of one of the categories mentioned above or native platforms only available via cloud services. While a complete analysis of the LMS market is not within the scope of this research, we suggest the interested reader see [5] to recap the main characteristics of open source LMSs.

An LMS lives inside an organization's information system as a separate world or entity. Some single-sign-on services are integrated with the rest of the information system to allow LMS users to use the same credentials for other applications. Nevertheless, an LMS (especially with the level of services added during the pandemic) is a powerful software application whose services can be used in any context involving electronic collaboration between participants instead of being limited to purely educational purposes. This availability of services implies duplication of services inside the information systems, increased costs, and confusion for the end-users.

To understand the e-learning market, let us analyze the (long) list of services needed in educational processes. Many well-established solutions exist for each of these different needs: collaboration tools, videoconferencing systems, document management systems, single sign-on infrastructures, CMSs, ERPs, records management, attendance certification management tools, project management solutions, to-do lists, trouble ticketing, etc. All these tools have their market segment as separate products, or sometimes they are aggregated in integrated platforms. The problem is that these tools are chosen to provide a single vertical solution to an educational need, most of the time not integrated with other tools that support educational stakeholders. This forces users and IT departments to use different solutions from different providers in different contexts, leading (especially in large organizations) to an uncurbed and uncoordinated proliferation of tools and platforms with associated costs and inefficiencies.

An integrated educational solution would greatly help these tasks in terms of organization, speed of execution, quality of results, the total cost of ownership, and so forth. For example, collaboration tasks are recognized as crucial in companies. Still, they share many services with educational tasks: aggregations of users (classrooms vs. groups), file sharing, emails, managing agendas, posting on forums, attending videoconference sessions, etc. Services supporting these everyday tasks are usually available in top-level LMSs. Services like these are standard in education and collaboration environments but often duplicated because they are available on both platforms with substantially the same (software) functionalities.

To generate further confusion and overlap, recently, we observed the widespread usage of cloud-based Software As A Service (SaaS) solutions such as document sharing or CMS/LCMS. They have become fundamental in collaboration activities and were initially integrated into most LMSs. Now, in contrast, solutions such as Google Classroom ™ rely on cloud disks for the document sharing of a (poorly equipped) e-learning solution. So it is prevalent in educational institutions to find users using two different platforms for the same service. If we take, for example, file-sharing services, we can find the same user:

- on one side, using an LMS for their educational activities and sharing contents using the file sharing service of that platform;
- at the same time, outside the educational context, forced to use Google Drive™, Microsoft Onedrive™, or Dropbox™ to share a file with a colleague simply because that colleague is not involved in educational processes and cannot access the LMS;
- in another situation, such as participating in a video conference call, for example, organized in Microsoft Teams™, or sharing files using a Sharepoint™ repository;
- finally, looking to own files on a shared network disk on a file server provided by the IT department.

This prevailing situation can create, as said, inefficiencies and confusion for the end users.

Another example comes from the crossing between LMS services and the Customer Relationship Management (CRM) world. Evolved CRMs need a trouble-ticketing system to support customer problems with products/services. Still, the same need is present in educational settings, where participants need help from tutors, teachers, or the IT department. While it is not reasonable to buy a trouble ticketing system just for educational activities (but if the institution has large numbers of users, they should), it is strongly recommended to have one. The ICT department or the HR department will be otherwise flooded by telephone calls and users complaining about trivial issues related to educational tasks.

The FOSS world provides several solutions for specific purposes, thus incrementing the number of platforms needed for managing an educational process. In this respect, in the interaction with IT teams, they tend to provide different solutions for similar problems. At the same time, they do not consider LMSs as a possible solution for a more extensive set of collaboration problems than "simple" educational tasks. E-learning is usually seen as something separate from the rest of the information system, a sort of external service that is another source of problems to be managed: not as an asset providing services to solve collaboration problems. On the contrary, e-learning platforms would benefit from integration with the rest of the information systems in many respects, from authentication/authorization templates to integration with the HR subsystem, from social network integration to accounting, from directory services integration to email services, etc. The need for these integrated tools inside organizations is very high, and e-learning platforms, if adequately developed and extended towards closer interaction with the rest of the information system, could become a pillar application in response to these needs for the whole corporation.

We can address the full potential of this sort of integration if we precisely clarify the role and the services of e-learning systems. Even though they have been available to educational stakeholders since the last century, e-learning has been addressed under various terms to mean the use of Information and Communication Technologies (ICT) to support educational tasks. Distance learning, e-learning, remote learning, and technology-enhanced learning (TEL) all share some items but have other components that are not in common. E-learning has been explained as a fundamental component of our educational activities since the beginning of the 1990s. When the Internet became mature and reliable, multimedia technologies became available to large masses of users on personal computers, and teachers started understanding the potential of computer-mediated communication.

The pandemic has drawn distorted attention to TEL due to the emergency and not its intrinsic value. It is not surprising that the general comments about e-learning have mainly been negative (other than recognizing its usefulness during the pandemic) because of the lack of physical contact between the participants during the educational processes. Since its appearance, e-learning has been loved and hated and loved again, depending on the hype of the moment. It has been seen as an indispensable tool. It has been viewed as a source of student incompetence, to finally being the panacea of all physical presence problems when this was no longer possible. The controversial attention peaks have created confusion around e-learning, specifically concerning LMSs. It has changed the nature of these software solutions. It has impeded a broader vision of its use inside educational institutions and public and private organizations that carry out training initiatives for their employees from various perspectives, even if the core business is not education.

Communication approaches and tools inside organizations have seen an incredible number of innovations, probably a revolution, mainly because of the phenomenon of social media and web 2.0. One of these innovations profoundly touches the e-learning world: non-IT users can produce content on the web without depending on IT personnel. This fact generated the flourishing of communication and interaction tools in educational settings, both synchronous and asynchronous. These communication tools (forums, blogs, web pages, FAQs, questionnaires, whiteboards, etc.) were initially used outside the corporate information system, but they have been internalized for security and confidentiality reasons. We can find many examples in many modern information systems. Today, various tools are part of our day-to-day tasks inside any organization: discussion forums, corporate blogs, shared agendas, task lists, resource profiles, shared documents, etc. Due to these different needs, the organizations' information systems have been enriched with a series of tools of different provenance, sometimes available on the market, sometimes available in the Free/Open Source software (FOSS) domain, and sometimes even created ad-hoc as a customized software created by external collaborators or as an internal effort of the IT department.

The above examples are representative of the situation in most organizations today. These internal or off-the-shelf platforms, accessible or available through the cloud, provide substantially similar services, if not identical, to those available on e-learning platforms for decades. This fact has brought a series of disadvantages and inefficiencies within the corporate information system, which will be discussed in the following chapters. This thesis, therefore, starts from these considerations and the current trend of attention toward e-learning solutions. The aim is to demonstrate how most collaboration services acquired today could be taken from e-learning platforms and integrated into the information systems more structurally. This integration could save and optimize investments while promoting uniformity in the user experience, thus reducing the number of platforms to manage.

The lack of integration has several disadvantages. The first significant disadvantage is a practical aspect that generates much confusion among users. E-learning platforms (like Moodle, Sakai, Docebo, WebCT, Blackboard, etc.) have been created mainly for teaching activities, focusing on trainer/learner needs. Consequently, they approach services and solutions to users specifically to solve educational issues, even using specific terminology and vocabulary. To give a trivial example, sharing a file is considered sharing educational material. Virtual spaces for users to interact with other users are simplified to "My Courses". The curriculum for participants (if not called only "students") is flattened to "Competencies". Services such as those illustrated below include a “Gradebook”, “Copy Course” function, “Download Instructor Files”, or “Outcomes” clearly demonstrate that an LMS (Fig.1) cannot be easily used outside learning contexts.

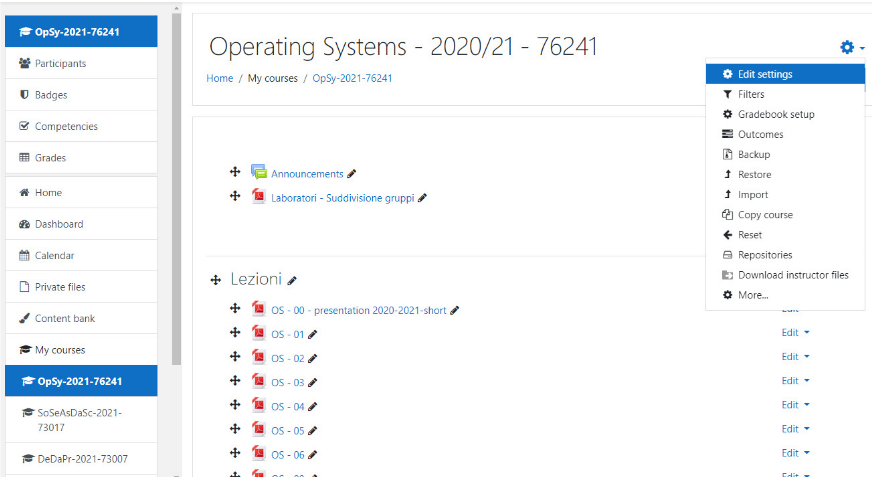

Fig 1: An example of principal services in Moodle©.

Additionally, from the administrative point of view, even if services could be beneficial outside learning contexts, it is tough to transform an LMS into a collaborative platform (Fig. 2).

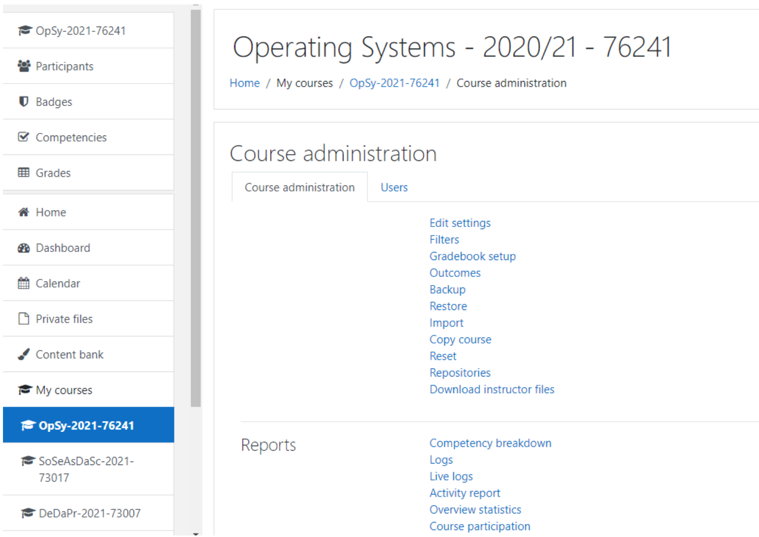

Fig 2: The specificity of services for educational contexts.

The duplication (at best) of services is evident, and users of IT services complain about this fact when documents dedicated to non-educational domains are shared using corporate repositories. In contrast, they could use what is provided by an LMS, but we have an extra issue. To allow users to use a file-sharing service from an LMS for other purposes outside the educational domain, we should create a classroom/course just for this purpose, using inappropriate labels for this context. This fact represents an evident twisting of using an LMS and, most of all, an integration problem. Indeed, users looking for their files inside the LMS should use (at least) a single sign-on mechanism and appropriate authorization settings from the central information system to preserve the proper rights, thus avoiding dangerous breaches in corporate confidentiality and privacy.

Even more profound is the problem deriving not necessarily from the service design and vocabulary but from the intimate concepts of the persistence layer of current LMSs. Retaking a representative example from Moodle (fig.3) as the most used LMS globally and looking at the database schema where all data are stored, we can quickly identify sections of Moodle functionality and the respective database "areas", i.e., groups of tables.

Assignment	Analytics	Badges	Book
Chat	Choice	Course	Data
Enrolment	Feedback	Forum	Lesson
LTI	Page	Quiz	Scorm
Survey	Users	Workshop	Wiki

Fig.3: Areas of functionalities in a standard Moodle© instance.

As can be seen from Figure 4, the group of tables ("sections") of the database uses an educational vocabulary for the core components (Assignments, Lesson, Book, Course, etc.). When we examine the tables' details, the LMS's binding with educational contents is intense and not easy to decouple, as we can see in Figure 4. Consequently, the perspective of using an LMS as a general-purpose collaboration platform is substantially impossible.

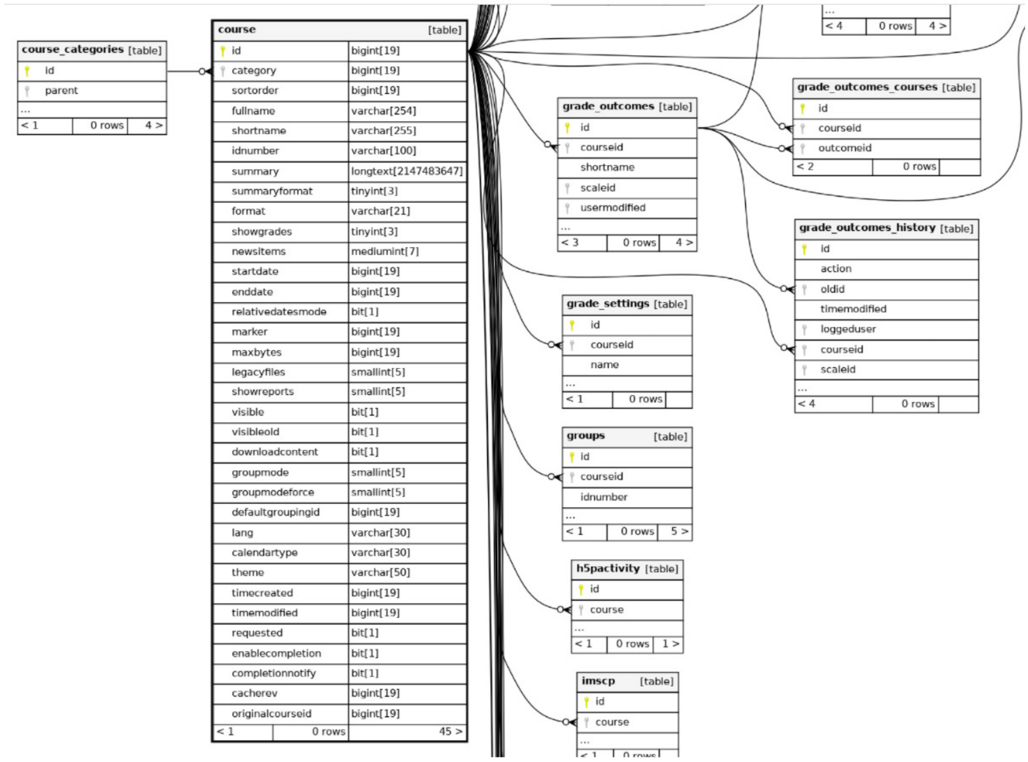

Fig. 4: A fragment of a Moodle database schema related to a "Course".

Looking at other LMSs, like the open-source Docebo™ forking called FormaLMS©, we can see the same approach: all the relevant tables are strictly related to educational concepts: "learning_catalogue", "learning_calendar", "learning_certificate", "learning_course" etc. If we go deeper into the table's structure (Fig. 5), this deep coupling between data structures and educational concepts is even more evident.

\`idCourse\` int(11) NOT NULL AUTO_INCREMENT,
\`idCategory\` int(11) NOT NULL DEFAULT '0',
\`code\` varchar(50) NOT NULL DEFAULT '',
\`name\` varchar(255) NOT NULL DEFAULT '',
\`subscribe_method\` tinyint(1) NOT NULL DEFAULT '0',
\`img_course\` varchar(255) NOT NULL DEFAULT '',
\`course_demo\` varchar(255) NOT NULL DEFAULT '',

`difficult` enum('veryeasy','easy','medium','difficult','verydifficult') NOT NULL DEFAULT 'medium',
`show_progress` tinyint(1) NOT NULL DEFAULT '1',
`show_time` tinyint(1) NOT NULL DEFAULT '0',
`show_who_online` tinyint(1) NOT NULL DEFAULT '0',
`show_extra_info` tinyint(1) NOT NULL DEFAULT '0',
`show_rules` tinyint(1) NOT NULL DEFAULT '0',
`course_type` varchar(255) NOT NULL DEFAULT 'e-learning',
`course_edition` tinyint(1) NOT NULL DEFAULT '0',
`classrooms` varchar(255) NOT NULL DEFAULT '',
`certificates` varchar(255) NOT NULL DEFAULT '',
`course_quota` varchar(255) NOT NULL DEFAULT '-1',
`course_vote` double NOT NULL DEFAULT '0'

Fig. 5: Sample of columns from the Table "Learning_course" from FormaLMS

Looking at the amount, quality, and usefulness of the services provided by these excellent platforms, it seems to be an absolute waste of an opportunity for LMSs. "Courses" could become "communities" with some extensions, "students" can be "participants", "lectures" could be "meetings", "grades" can be "votes", "assignments" could be "tasks". Instead of a "simple" educational role, we could look at these terms and their collaborative counterparts. Considering the enormous number of users for these platforms, we can imagine the enormous potential of a revisited LMS as a comprehensive collaboration platform. Moodle Corp., in 2020, claimed to account for over 200 million users and more than 150,000 websites. A conceptual and technical abstraction into the collaboration services of these educational concepts could have the advantage of using consolidated platforms for different purposes. These consolidated platforms, in turn, could be a unique point of contact for any need for collaboration and idea-sharing inside an organization, regardless of whether the services are related to educational contexts.

1.1.4 A new vision for LMS architecture

Modifying consolidated software platforms with years of presence on the market and millions of users worldwide is unrealistic. This thesis proposes a different approach: designing and creating a new generation of e-learning platforms from scratch, using pervasive metaphors related to collaboration instead of education for the software artifacts of the platform. Suppose we conceive an LMS not just as a mere container of educational tasks. Still, we generalize these tasks as more general collaboration tasks and abstract the concepts inside the platform accordingly. In that case, we could have a single platform that could be used in both contexts, thus being more acceptable and integrated inside the information system of the hosting organization.

This paradigm shift in the design can be done by adopting a new metaphor for constructing these software platforms. The building blocks of this new generation of software platforms are virtual communities as an extension of what Rheingold described in [34], i.e., virtual meeting places where people use IT services for the most varied collaboration purposes, including educational activities. The consequence is a complex, demanding, and (probably) expensive (in terms of TCO) software platform that could absorb these side-effects through its support to a plurality of needs, not only training. Companies' budgets for IT investments in e-learning are generally minimal compared to their training needs [35][36]. The cost of a dedicated LMS would find many obstacles inside a typical IT budget [37]. When approved, e-learning is almost exclusively seen as an instrument for saving money rather than empowering the company's workforce or as a highly flexible tool to achieve training objectives.

Having a virtual collaboration platform would also allow information system managers to take advantage of the internal, multi-purpose, extensible services to which the various users can refer due to many different needs, not only for educational purposes. During this research, we have analyzed the structure of some widely used learning platforms, both open and proprietary, to evaluate how virtual collaboration and a virtual community can facilitate the integration and spread of online learning inside modern organizational systems. This analysis involved an in-depth study of technology associated with LMSs. We added a series of more collaboration-oriented tools to the LMS and used the LMS as a container for the collaboration processes.

This research is grounded in experience, which started in 1998. According to these convictions, the decision was to design, create, and pervasively use a virtual community platform called "Online Communities" (OLC), entirely created from scratch without any inspiration from current LMSs, based on the metaphor of virtual communities without only educational services in mind. This has a twofold effect: on one side, we had a comprehensive and documented appreciation from the users because of its usability in different contexts. On the other side, we had the chance to add new collaboration services, which are advantageous also in learning contexts.

The platform's original kernel was created in 1998 with collaboration and integration needs in mind, in a period where even social networks did not exist, aiming at full integration with the hosting information system of an educational institution. The platform has been used in many different academic and non-academic contexts. Currently, it is in use by more than 250,000 users in the public sector and within the insurance, finance, and education industries. It has provided services to traditional educational providers and providers of collaboration services, thus avoiding redundancies and providing optimization.

The possibilities for using the platform not only in educational settings but (mainly) outside these contexts for any community need has profoundly impacted the TCO of the platform. The condition required was to design it so that its integration with the rest of the information system of the hosting organization is the lightest possible. There are many limits that e-learning platforms have shown in their extensibility and usability outside educational contexts. Importantly, platforms with an "original" approach are oriented more towards collaboration rather than learning, and have shown higher flexibility in adapting to various situations where users need a technological collaboration tool.

A clear witness to this is the usage of Content Management Systems (CMSs) and Document Management Systems (DMSs) in place of LMSs. Tools such as Joomla©, Wordpress©, or Drupal© have been used in educational contexts, or even by individuals by adapting them to educational needs. Another example is the flourishing of private websites of single teachers based on these tools, mostly when the educational institution was not providing adequate support for their tasks. Even the big players in social media, such as Facebook™, have substituted the role of e-learning services due to the lack of collaboration services of LMSs. The same story happened even here: teachers not supported by their institutions started to create Facebook™ pages for their students to take advantage of the many collaboration services of this platform.

It is difficult to find organizations with no core business in the education but with a DMS or CMS for managing the corporate website to use an LMS. Indeed, adapting these tools to educational needs has been made for two main comprehensible reasons: a) to optimize investments b) to avoid including another platform inside their management tasks. In a certain sense, the recent diffusion of Google Classroom™, Microsoft Teams™, and similar videoconferencing environments went through the same sort of development, i.e. from collaboration/document sharing services, on top of which a learning platform was created or at least a prodromic version of it. Especially during the pandemic, Microsoft made a considerable investment in collecting their many different collaboration tools (from Office™ to Sharepoint™ sites to PowerApps) to create a unique platform providing different services among large organizations with appropriate IT infrastructures substantially found an e-learning solution. This fact sounds like a path traced for many other players. Google uses Google Classroom™, Google Drive™, and Google Docs™ to provide a similar service. Most of the videoconferencing solution players are coming to the same conclusions: collaboration features are desirable for the world of education. Consequently, enriching their videoconferencing platforms with collaboration services for educational purposes could open new market perspectives.

This plethora of alternative platforms improperly used for e-learning has had an evident depressive effect on the usage of LMSs. Unfortunately, the current pandemic exacerbated this feeling of under-usage of e-learning platforms, leading users to confuse e-learning services with videoconferencing tools that have become familiar to all of us during these terrible times. Paradoxically, a potential favorable situation for the relevance of e-learning has instead turned into a pancake for the e-learning sector. Today's analyses of the effects of e-learning on society during the pandemic are primarily negative [38][39][40].

All this considered, in this research, we want to demonstrate how there is a need for a heavy re-formulation of e-learning platforms to compete with other solutions occupying the educational domain without being specialized in it. This is the only possibility to insert them as multi-purpose tools in the context of information systems of any public or private organization, including educational institutions. The e-learning platforms are currently used inside organizations to distribute teaching materials and create virtual rooms for synchronous collaboration and other services. This research focuses on two emblematic cases: the well-known Moodle platform analyzed in different contexts and the already-mentioned "Online Communities" platform, built according to the approach based on the central idea of virtual communities. Seven collaboration services that could be a turning point for LMSs to gain a larger space and a more significant role inside information systems are presented. For each of these services, a specific section will present the architectural design, implementation, and the results obtained during the experimentation with these services inside the "Online Communities" platform. These results are summarized in the twelve papers presented as a part of this doctoral dissertation.

Another fertile area of investigation related to this paradigm shift is the platform's persistence layer, where data collected is stored. The long-term experimentation with users and the availability and complete knowledge of the source code of OLC allowed us to experiment with a series of significant innovations in the representation of educational processes. The platform has been built from scratch by a team led by the author. The group consisted of 50+ people (full-stack developers, UX experts, psychologists, software architects) who have worked together since 1998. From this 20+ years of experience in different contexts, the immediately evident results are that learning platforms contain an enormous amount of knowledge represented by teaching materials created by multimedia elements and by all the teacher-learner interactions represented in the various blogs, chats, and forums.

The knowledge base created inside the LMS has always been stored within these powerful platforms through a relational data model representation and implemented through a relational database managed by a DBMS (e.g., MySQL™, Oracle™, SQL Server ™). All the most successful learning platforms on the market have a relational database that models the knowledge domain into a relational schema. The persistence layer of a software application has recently seen a radical innovation movement, with the introduction of ontological, semantic representation of the domain (from a conceptual point of view), and with the advent of a vast number of NoSQL alternatives. These conceptual and technical innovations have stimulated the research on applying non-relational persistence layers to learning management systems. The main reason for this research has been the great potential of knowledge representation given by the ontological representation of the domain. The advent of big data in the data management sector has been another stimulus (more on the technical side) to evaluate the possibility of substituting the traditional, relational-based persistence layer with more efficient tools to work in a big data context.

The cited availability of the source code pushed us to experiment in both of the above directions, with different ways of representing educational knowledge that, alongside the representation of structured data through a relational model, supports a semantic representation of data using ontologies and graph representation [41]. Inspired by applying the semantic representation of knowledge in other contexts [42], we adapted this idea to the e-learning world, providing a unique approach linked to representing entities present in the educational knowledge base for their reconciliation [43]. This experimentation of content representation (documents, blogs, forums, FAQs, etc.) as a knowledge graph with named entities is still a frontier for more research. To the best of our knowledge, it is almost unique in the panorama of large-scale learning solutions [44]. It has provided some reflection points about extending the learning platforms to managing the corporate knowledge base and facilitating communication and collaboration services in corporate information systems. These research areas should benefit the LMS market and technology-enhanced learning because they could create a new frontier of evolution and enlarge the field of applications for LMSs inside corporate information systems.

1.2 The positioning and focus of this research

The role of education has become a crucial part of organizations for various reasons. The first reason is the awareness of lifelong learning processes that characterize any organization [45]. Today's workers are flooded with more information to manage and will need to know far more than any individual can retain. Lifelong learning is a fundamental challenge for organizations, not a luxury [46]: it challenges organizations on essential new dimensions of learning such as self-paced learning, training-on-the-job, collaborative learning, continuous learning, organizational learning, learning-by-doing etc.

Sadly, the pandemic has demonstrated the second reason for the centrality of education in modern organizations. Organizations realized the need for good software platforms to support collaborative processes, including educational ones. Due to these two elements (among the many) relevant to our argumentation, information system managers are constantly facing the typical dilemma of modern organizations when needing process automatization. The dilemma refers to answering these education needs using a software platform. It is a typical "make or buy" dilemma, enriched today with new alternatives coming from service outsourcing and cloud solutions:

- acquire a new software solution/service
- lease an already existing solution/service
- adapt an existing software solution
- make a new solution from scratch

This research will try to answer this dilemma a) by identifying the limitations of current LMSs that could be acquired or leased and b) by providing indications for adaptation of existing platforms or for those created from scratch to extend the use of LMSs inside an organization. This research is therefore located in the overlap of two different areas: a) software engineering for information systems, i.e., how to provide effective and efficient software solutions (on-premises, SaaS, or cloud) to organizational needs, and b) technology-enhanced learning, i.e., the use of technology to maximize the learning experience inside organizations.

With these two research areas as general frameworks, this research investigates software solutions created for this specific area of overlap, i.e., LMSs. In particular, the thesis investigates the re-engineering and extension of services provided by LMSs as we know and use them today. By extending them in these directions, LMSs can move from their current marginal, accessorial role inside the information system to a central position in the ICT strategy of any organization, becoming a cornerstone for the provision of collaboration services. This re-foundation is a complete change of paradigm in providing services to LMS users, oriented towards more collaborative and cooperative services and much higher integration with the rest of the information system. To achieve these ambitious role changes, we need to change the foundational paradigm used in designing and implementing an LMS. This thesis wants to explore the needed changes in the founding pillars of an LMS, enlarging the focus on educational aspects and the technical solutions provided to the market, i.e. the LMSs. Still, the research answers could be interesting to the information systems field because they could be helpful for IT managers to optimize investments and maximize software platform usage.

Another interest of this research is for the academic and business communities because of the need to dismantle what we define "e-learning disillusionment". The generalized poor usage of e-learning tools (mainly limited to document sharing), particularly evident during the pandemic, contributed to this disillusionment. A pandemic could have been the moment for the final celebration of e-learning tools as indispensable for any organization. In contrast, we have seen a) the exaltation of videoconference tools as a unique solution for e-learning, b) the addition of trivial services to videoconference platforms to assist educational needs, c) the consequent marginalization of LMSs, because of their rich set of features have been considered too complicated and unneeded.

The interests presented above can generate many possible extensions of educational services: among them, this research touches on the analysis, design, implementation, and testing of four different areas of evolution for a modern LMS. In a typical multi-layer architecture for a software platform, these four areas of research/intervention start from the very bottom layer of the platform, the concepts endemically implemented in every layer of the software, and move up towards the services provided to final users. The areas of the upper layers take advantage of the re-engineering process made in the below areas. In Figure 6, we present the four areas of revisitation/evolution of an LMS experiment in this research work. The papers have a primary, non-exclusive central topic within the four areas.

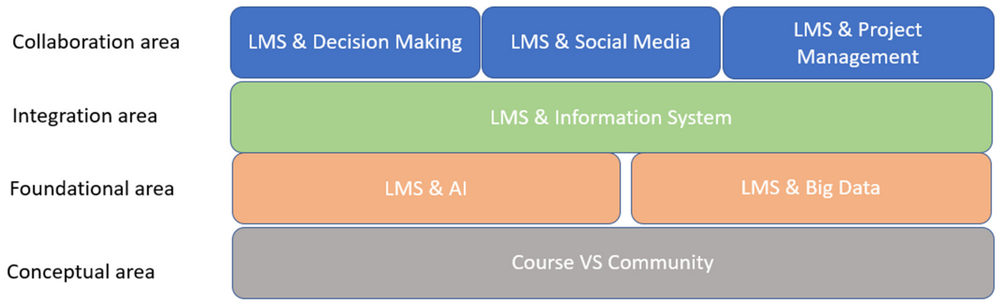

Fig.6. The focus of this research: four areas of evolution for an LMS with seven foci.

The first area is called the **"Conceptual area"**. The research actions in this area have been directed towards extending the core concepts reified into an LMS from a simple "course" container to a broader "community", allowing communities of different types with different aims to be managed. This paradigm shift is a radical innovation in the complete services provided by the LMS. It implies a complete revisitation of the platform and a pervasive re-engineering of the services provided, data stored, and even user interface metaphors and proposals. Our past work has chiefly inspired this research front.

Nevertheless, the founding pillar of "virtual community" instead of "class" has been implemented, and it has been revealed to be a winning factor for the evolution of LMSs. The second area of investigation is called the **"Foundational area".** This re-foundation of an LMS deals with the persistence layer of any LMS. The investigation dealt with the first set of topics related to adding artificial intelligence extensions to LMS services, wherever a richer representation of learning contents is needed or wherever a conceptual description of the domain could be helpful for the activities inside the community. Representing inside the LMS database the richness of concepts and features needed to manage a virtual community is very difficult because of the limitations of conceptual representation in a relational model. A more semantic-oriented representation of concepts was explored, moving from a relational model of the application's persistence layer to an ontological model. In this way, it was possible to foresee an application closer to supervised and unsupervised machine learning applied to such a rich knowledge base.

Furthermore, the second topic in this area relates to the influence of big data technologies questions on e-learning platforms, i.e., if these systems could be a potential source of generation of big data-enabled contexts. The answer is positive: learning contexts that embrace more extensive definitions of "learning" such as pervasive learning, life-long learning, learning-on-the-job, continuous learning etc. will have to collect enormous amounts of multimedia, real-time data from learners. This context is that of big data under any perspective of the famous "V" of the big data sector ("Volume", "Variety", "Velocity" to stay with the 3V definition of big data). However, currently, LMSs are not conceptually or technically equipped to face this situation. Managing big data in an LMS context is intensive and involves large volumes of data.

The third area of investigation is the "**Integration area".** As explained in the previous section, the research conducted in this area has explored how to integrate LMSs with the rest of an organization's information systems, providing the best-of-breed of services, thus optimizing ICT investments. When introduced into organizations, the LMS produces immediate effects:

- it requires an integration with other sub-systems existing in the organization, from the simplest ones (single-sign-on authentication and authorization) to more complex integration processes with ERP, CRM, HR systems;
- it overlaps some LMS/Virtual communities' platform functionalities with pre-existing functionalities in the organization's information system, raising questions of opportunity to have them duplicated or to not have them at all. Examples: document repository, mailing distribution, virtual room management, forums, etc.
- it fires competition with social media services acquired by the organization, mainly due to similar functionalities available in any (serious) LMS.

These are the most insidious aspects because none of the systems (LMS and other information systems) can satisfy the specific needs of educational stakeholders. However, all of them can supply part of the functionalities needed. A typical example we found was support for easy document sharing. In many examples of integration collected during these years, the structure of an LMS based on educational concepts and tools is not typically suitable for complete and satisfactory integration and forces the IT department to provide workarounds or simply abandon the LMS. An LMS based on virtual communities is a much better candidate. The on-the-fly creation of a virtual community with a set of services available for the members is a perfect solution for many of these situations, not necessarily related to educational activities. Figure 7 represents the envisioned evolution of the relationship between the LMS and the information system. Including new services such as the collaborative services presented in the following area, inside e-learning platforms, and integrating these services with the hosting information system represents a challenge for developing new advanced e-learning platforms. Instead of having LMSs as separate "islands" inside the hosting information system, our research demonstrates that tight integration between these components can benefit the whole organization.

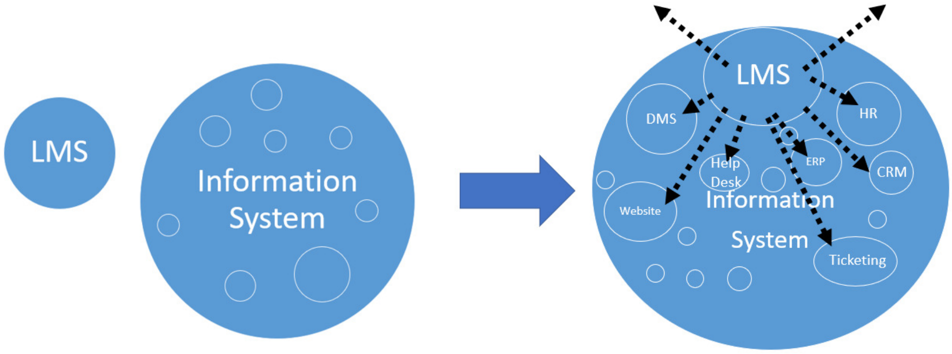

Figure 7. The focus of this research: understanding the transition from an LMS as a separate entity in the information system to integrating the LMS's services with other information system components.

The last investigation area is defined as the "**Collaboration area**" of expansion for an LMS, the one devoted to providing collaboration services to its users. In this context, there are three lines of study: new services for tighter integration with social media services, new services for decision-making support inside LMSs, and the third line of research on integrating project management tools inside an LMS.

The evolution of LMSs has been evident in the collaboration area, especially after the explosion of social media usage in the student population. The competition created by social media used as e-learning tools is a clear message for LMSs creators. The work underlying this research has provided social media-like features inside the LMS, thus improving the collaboration between users in a more user-friendly, socially-oriented way.

Multi-criteria and multi-expert decision-making tools were also explored and provided by the created platform to support the various moments inside the life cycle of a virtual community, where decisions must be taken, ranging from the evaluation of students to the announcement of the winner of a public competition. This expansion has very few (if no) examples in a learning environment. The main advantage of the developed services has been the organization's ability to use these "collaboration" situations without buying or adopting another information system. The most evident example of adopting these tools has been the creation of a collaboration service for the management of public competition notices, the loading of applications, the management of the evaluation commissions, and the publication of the competition results.

Finally, we have experimented with the whole stack of innovation areas introduced in our LMS by adding project management-enabled services, thus allowing users to manage all those tasks with the characteristics and the needs of a project with professional, adequate tools. According to the nature of learning processes and the tools needed in every work environment, this evolution towards a collaborative environment is natural for e-learning. Recent years have seen the widespread usage of LMSs for managing and operating e-learning courses in different contexts.

Nevertheless, in LMSs, we find minimal support for tasks not strictly related to the "classroom" metaphor, i.e., all those tasks are part of educational processes but do not necessarily involve slides, videos, or any other educational media. Again, the founding educational metaphors used in structuring current LMSs ("teacher", "class", "grade", "lecture" etc.) do not support this evolution. The primary usage has been the distribution of learning objects, but many other functionalities and features unrelated to educational aspects should be added. These functionalities, like the enrollment of students, public tenders and concourses management, and support for group decision-making or project management tasks, are usually not available in an LMS and are often available separately in other systems. This fact implies two main concerns for IT managers:

- the availability of duplicate functionalities, with respective problems of budget justification or removal of one of the duplicated systems
- the integration of the different systems and the consequent development and maintenance costs.

Analyzing the different implementations of the above research areas implied a) focusing on existing software with similar tools and services, b) understanding how they work and what they provide to users, and then c) creating new services in our LMS but counting on different conceptual and foundational structures, and providing integration mechanisms for the rest of the information system when relevant. This process took a long time, which goes beyond the work period for this research (2014-2022). The author has performed implementation and testing jointly with the research group he has managed since 1998, involving about 50 people who have collaborated with the author and the research group over the years in different roles. Only specific technical parts (social media integration, data warehouse ETL, project management algorithm, community management) have been directly developed by the author of this research. An analysis of systems, analysis of user needs, design and test of the added features, and the conceptual/foundational aspects of the re-engineering of the original platforms have been the core contribution of the author to the research presented in this dissertation.

1.3 Objectives of this research and connected questions

As discussed above, the main objective of this thesis is a profound and foundational redesign of the architecture of LMSs, to allow a more extended usage of provided services beyond pure education contexts. LMSs are complex platforms with many valuable services for the information system's users. However, most of the time, these services are confined to educational settings. At the same time, as proposed here, they could be more profitably used to support many other organizational tasks.

This thesis explores the grounds for a new generation of LMSs, more suitable for collaboration and more integrated into the hosting information system, supplying collaboration services to the rest of an organization's users. Accordingly, services provided under the e-learning umbrella should be heavily re-engineered compared to their original structure. They must be generalized in the internal data and software structure, from a specific learning context to collaboration.

Below are the three specific research questions that this dissertation aims to answer.

Research question #1	Should an LMS be re-engineered to facilitate an advantageous integration with the rest of the information system, thus allowing a more significant and quicker ROI?
Research question #2	What form would the well-working conceptual and software architecture of an LMS take to facilitate and improve collaboration and integration mechanisms with the rest of the information system?
Research question #3:	What services should be added to an LMS to promote this integration, demonstrating the advantages of adopting an enriched LMS based on the virtual community metaphor as a pillar for collaboration tasks?

The achievement of these objectives has been documented in several research papers that can be aggregated in the four areas presented in Figure 8 and the number of papers related to that area. Each of the twelve papers has not exclusively investigated one single area. Most of the twelve papers are transversal to different areas. Other papers produced during this research complete the work performed and are listed in Appendix A.

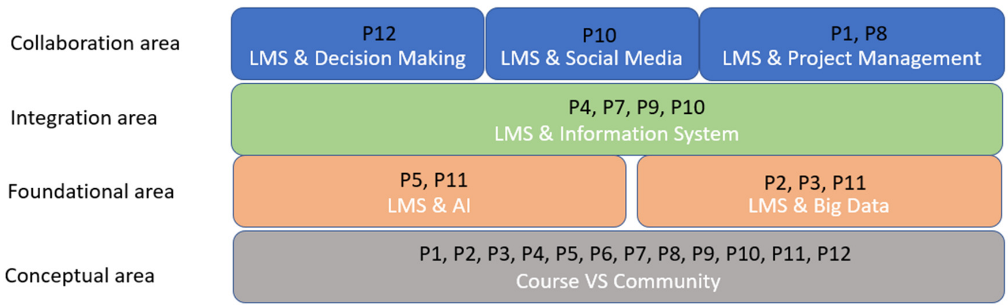

Fig.8. The focus of this research and the location of the papers

The following table presents a correlation between the research questions and the papers.

Research question #1	*Should an LMS be re-engineered to facilitate an advantageous integration with the rest of the information system, thus allowing a more significant and quicker ROI?* Paper 2: Coccoli M., Maresca P., Molinari A. (2020) Big data, Cognitive Computing, and the Future of Learning Management Systems Paper 3: Coccoli M., Maresca P., Molinari A. (2019). Collaborative E-Learning Environments with Cognitive Computing and Big Data. Paper 4: Molinari, A. (2015). Designing Learning Objects for Italian Public Administration: A Case Study

	Paper 6: Casagranda, M. , Colazzo, L. , Molinari, A. (2014). Estimating the Effort in the Development of Distance Learning Paths Paper 10: Molinari A (2017). Learning Management Systems and the Integration with Social Media Services: A Case study Paper 11: Molinari A, Bouquet P (2016). Big data and the Impact on an E-Learning Platform: A Case Study Paper 12: Molinari A. (2015). Supporting Decision-Making Processes in Virtual Learning Environments
Research question #2	*What form would the well-working conceptual and software architecture of an LMS take to facilitate and improve collaboration and integration mechanisms with the rest of the information system?* Paper 2: Coccoli M., Maresca P., Molinari A. (2020) Big data, Cognitive Computing, and the Future of Learning Management Systems Paper 3: Coccoli M., Maresca P., Molinari A. (2019). Collaborative E-Learning Environments with Cognitive Computing and Big Data. Paper 5: Bouquet P., Molinari A. (2016). A New Approach to the Use of Semantic Technologies on E-Learning Platforms Paper 7: Bouquet P., Molinari A. (2019). Sport, Dual Carriers and Education: The E-Learning Way Paper 12: Molinari A. (2015). Supporting Decision-Making Processes in Virtual Learning Environments
Research question #3	*What services should be added to an LMS to promote this integration, demonstrating the advantages of adopting an enriched LMS based on the virtual community metaphor as a pillar for any collaboration tasks?* Paper 1: Molinari A. (2021) Project Management and Learning Environment: A Case Study Paper 8: P. Bouquet, A. Molinari (2019. E-learning and Project Management: Adding New Features to Learning Management Systems Paper 10: Molinari A (2017). Learning Management Systems and the Integration with Social Media Services: A Case study Paper 11: Molinari A, Bouquet P (2016). Big data and the Impact on an E-Learning Platform: A Case Study

1.4 Outline of the thesis

The thesis consists of five chapters organized as follows: Chapter two introduces the theoretical background of this research, focusing on the seven identified research areas within this thesis and presenting the relationship between the areas. Chapter three is a description of the methodological framework used in the research. Chapter four presents the enclosed research papers with their main findings. Chapter five is devoted to discussing the overall findings and conclusions, presenting the contributions of this research, and addressing the original research questions. Finally, directions for future research are proposed.

2. Background and Literature

This section presents a literature review of the seven research areas underlying and investigated in this thesis. The literature on the relationship between ICT and e-learning is enormous, while the discussion on the technical aspects of the platforms that support e-learning is not so deep. Most of the current research is a profound reflection on the role of technology-enhanced learning inside educational institutions, and the Covid 19 pandemic has stimulated this reflection. Not many reflections have been made on the role of LMSs: they and their structure and services have been taken as they are, mostly because they are quite efficient, most of the time free, and easy to manage. In this sense, the dominance of a platform like Moodle™, with its pros and cons, perfectly represents what can be supposed to be most educational managers' "good enough" judgment.

As already highlighted in sections 1.2 and 1.3, this thesis studies a research direction that has not received a lot of attention, i.e. how a "radical" change in the founding pillars of LMS platforms could positively impact the role and the diffusion of LMSs. To substantiate this position, there have been four research areas . We have concentrated the research on seven foci that relate LMSs to specific problems inside these areas. Many other research directions in e-learning can be explored: we can find tracks on e-learning, mostly in every computer science topic. Technology is a critical element of research, but most of the attention is devoted to the effectiveness of e-learning inside the organization. New models of delivering e-learning have recently appeared, and new ideas like the Massive Open Online Course paradigm have attracted much attention, especially in academic institutions. Serious games, possibilities for using mobile devices in educational contexts, course design issues, and measuring e-learning effectiveness are all research areas that could help create successful learning initiatives. This thesis has touched on these research directions to deepen their relationship with the software platform providing these services to end-users.

The seven foci of the research this thesis concentrates on in the context of the future evolution of LMSs are:

- LMSs and the course vs. community dilemma
- LMSs and the integration with the rest of the information system
- LMSs and social media services
- LMSs and decision-making tools
- LMSs and artificial intelligence tools and techniques
- LMSs and big data
- LMSs and project management services

This choice is mainly related to the evolution of users' needs, the evolution of tools and techniques in other fields that could help the e-learning world, and the explosion of new phenomena that could affect the e-learning world. These research foci have a set of common elements: a) they could be relevant for the improvement of educational processes; b) they go in the direction of improving the collaboration of subjects inside virtual communities; c) they could be a relevant innovation in software platforms such as LMSs; d) they are not present in state-of-the-art LMSs. Each of these foci has been explored in one or more papers within this research. Below, the background for each focal area is presented in terms of reviewing the focus-relevant previous literature.

2.1 Courses VS communities

The first research focus is the concept of a virtual community. We want to understand whether the idea of a virtual community could be a suitable substitute for a "course" as a foundational pillar for LMSs, thus expanding the use of LMSs beyond purely educational settings. The term "virtual community" is used frequently in different contexts, and only recently has it become common in education. Some definitions of virtual community are so broad that they refer to any group of people whose communication is mediated by ICT [47][48][49][50][51]. Due to this lack of definition precision, we might argue that using the term for any online group can lead to the loss of real meaning for the concept [52].

When examining what the authors of social subjects say who have deeply analyzed the relation of the "community" vs. "society", the different definitions are not suitable for explaining the phenomenon of virtual communities in their multiform configuration, which can be observed. For various reasons, the approach adopted in this research takes inspiration from studies grounded in sociology concerning the concept of "community" by Tönnies [53], Durkheim [54], and also by Schmalenbach [55], and finally by Turner [56]. The above studies, in any case, do not succeed in comprising the entire variety of virtual communities we have on the Internet today. Similarly, the approach followed by Max Weber [57] and other sociologists, which have been refounded and reunified by Parsons [58], refer to the theoretical formulations as a "societal community". In their view, the term "community" has a technical meaning opposite to that of society. A "society" is an association of individuals in which various interests are conflicting and therefore must be regulated by law. Instead, the community is an association founded on unitary values and a common feeling. In this sense, Weber characterizes it with a rational action based on values. The origin of the community is a process of an approach based on shared values and feelings. These concepts are partially found in ICT-based communities, as explained in [59]. Nonetheless, it is in the difficulties encountered in the definition of the concept of "community" that we can find the first link to its telematics equivalents [60] [61] [62].

The concept of a virtual community (VC) used in electronic environments today, and that has been implemented in the LMS used as a "test-bed" for this thesis, is significantly different from the concept of a community studied by the fathers of modern sociology. The implementation of virtual community is slightly different from the proposal by some authors, such as Beamish [62], who consider the virtual community as a group of people who communicate using computer-mediated communication tools. The participants in these communities are physically in different places but can exchange information on shared interests [47]. Other researchers support the idea that virtual communities can increase involvement in face-to-face communities by increasing community activism, such as participation in democratic life [64]. Another aspect to consider is the emotionally positive effect of talking about a (virtual) community. This positive emotion creates an intrinsically rewarding reason to continue participation in the group as explained in [65][66]. The key factor in our concept is that, according to the various research threads on this theme, even if virtual community groups have social and practical importance, not all virtual groups are communities.

Better support for our idea of re-engineering the LMS comes from the definition found in Rheingold [34], who is the first author to present a complete definition of VC as an emerging social phenomenon. Jones [61][62] has influenced the definition adopted in this research about the technological structure of VCs (called a virtual settlement). In his opinion, researchers need to distinguish between the technology used by the virtual group and the actual virtual community. In [62], in line with others [67][68], he proposes the idea of first considering the "virtual settlement" within which virtual communities exist. Virtual settlements are the virtual places where people interact, similar to what is done in archaeology when models are developed. An archaeologist understands a village by understanding the uncovered cultural artifacts: we should understand virtual communities by understanding the artifacts of its virtual settlement, such as postings, structure, and content. The existence of a "virtual settlement" is set when we have a) a minimal number of b) public interactions, c) with a variety of communicators in which d) there is a minimal level of sustained membership over some time.

This framework for understanding virtual communities also states that even if virtual communities and virtual settlements are conceptually separate, we have found a virtual community if we find a virtual settlement. The completion of the framework for a virtual community as a foundational concept for educational settings can be found in [69]. The authors focus on the feelings and social relationships that develop within the virtual settlements and recognize that these feelings substantially create a psychological sense of community, arguing that a sense of community is an essential characteristic of virtual communities.

Virtual settlements are needed but not sufficient conditions for a virtual community. The sense of community distinguishes virtual communities from mere virtual groups. Consequently, examining the characteristics of the sense of community by other researchers [70], we have found an interesting stimulus for considering a virtual community platform as a good place for educational processes (other than community processes). Feelings of belonging to the community, having an influence on it, and being influenced by it, integration and fulfillment of needs, and shared emotional connections are the characteristics of a sense of community.

Following these different inspirations, we decided to refactor the previous learning management system by completely removing every reference to educational communities and artifacts, and substituting them with concepts and artifacts supporting the creation and management in a life-long perspective of virtual communities. The concept of the virtual community we have implemented is very contiguous with what is commonly defined in Web2.0 contexts [71] [72]. Looking at technological evolutions and the pervasiveness of the Internet, each serious educator has attempted to create a space for students to involve, motivate, and stimulate them, rather than only mono-directionally transfer knowledge to them. Through the application of modern technologies, this collaboration space became "virtual" as opposed to "real" [73].

This pervasive refactoring of the LMS has been facilitated because we played all possible roles in the construction of the new platform:

a) the role of designers of any aspect of the technological infrastructure of the platform, completely free from the influence of external providers;
b) the roles of software architects and developers for the whole software components, through the contribution (over time) of more than 40 people;

c) the role of power users of the system, mainly as teachers and administrators of communities with different core activities (a secretariat, labor union, faculty senate, sports association, research group, chess association, volunteer community etc.);
d) the role of system administrators of the platform, thus having the possibility to create, modify, and analyze any service inside the platform.

Therefore, this degree of freedom allowed us to see the full spectrum of the issues related to such a radical change in the LMS and TEL's role in educational processes.

Especially in specific sectors, such as health and social care, virtual communities are familiar places for professionals who use virtual communities of practice (VCoPs) for learning, support, continuing professional education, knowledge management, and information sharing[74]. Results from implementations of virtual communities in educational settings have confirmed that these communities could contribute to student learning, even if they are not the only mechanism [75]. The advantages of virtual communities are well-known: they stimulate continued learning, and if kept alive over time, they promote a sense of fellowship and identity.

However, an active, thriving community does not develop without forethought, and collaborative technologies do not guarantee success. The pandemic has put this element under the spotlight. The needed sense of belonging to a (virtual) community is typically derived from regular face-to-face contact with people and places, and videoconferencing is not enough. Issues such as student retention, digital accessibility, and hybridized physical and virtual realities are serious issues created by this situation [76]. The "blended" approach to managing virtual communities emerged as the best option in all these situations. Secondly, the "course" container where the educational tasks are confined within an LMS is insufficient to integrate real connections. In educational settings, participants will often experience a profound sense of belonging and connection (in the light of the "sense of community explained before) to their peers when the community is alive and open to different tasks other than educational ones. At the same time, online communities may benefit members if we remove the sense of isolation often felt in traditional "distance learning" classrooms [77].

The refactoring project started in 2003 and had the first large-scale application in the "Elle3-lifelong learning" project in 2007. The project lasted more than ten years, overlapping the early phases. It has been an unrepeatable opportunity to understand the applicability of distance learning and virtual communities in educational settings, specifically in the public sector [6]. "Elle3" has been a cornerstone for the evolution of the Italian public administration towards TEL. The first extensive e-learning experimentation has been based on an entirely new, built-from-zero, non-commercial LMS. This uniqueness is due to:

a) the number of subjects involved (more than 5,000 users);
b) the temporal extension of the project;
c) the topics faced during distance learning sessions;
d) the involvement of the organization in all the distance learning activities.

In the refactoring process, the building pillars of the LMS have been substituted by virtual communities, artifacts, and concepts, as explained before, and a completely new conceptual structure has been created. Instead of limited concepts such as a "classroom", "teacher", or "course", we implemented new concepts to encourage more collaboration activities on the platform. This result has been achieved through the pervasive implementation of a virtual community as a container of activities and collaboration. A community has a parallel concept in educational institutions, i.e., the "course" or "classroom". The "course" is the primary type of community used in educational institutions. Still, there are other types: communities related to common learning paths, aggregation of people around a specific interest, administrative communities like the teaching staff, the principal's secretariat, a working group on a new educational project, etc. [78]. This way, the platform's services are related to learning goals and collaboration services.

2.2 LMS and the information systems

For many years, one of the most efficient and effective ways of dealing with educational needs inside organizations has involved information and communication technology (ICT), with a definite improvement in performance, cost reductions, and overall easiness in managing the training process. Many types of research under this umbrella have been devoted to e-learning from the content production perspective. In contrast, our research is focused on the platforms that should deliver that content. On this line, little research has been conducted on integrating an e-learning platform and the rest of the information system. One perspective has been to define, evaluate, and promote e-learning success from an information systems perspective, focusing on the three stages of the development of an e-learning environment: the system design, the system delivery and the system outcome.[79] This thread is based on information systems implementation success models [80][81], which identified six success factors: system quality, information quality, use, user satisfaction, individual impact, and organizational impact. Other past researchers have focused on formulating an information system design theory for information systems used to support e-learning within higher education institutions [82]. The attempt has contributed to a better e-learning environment where the original existing solutions were limited in terms of variety, quality, and explicit theoretical guidance.

According to Brandon Hall Group's 2018 Learning and Development Benchmarking study [83], learning goals inside organizations are tightly related to business goals, while performance-based and competency-based learning is the predominant approach to learning. Considering that millennials are growing as a component of the workforce of any organization, it is probable that this generation will strongly prefer more personalized, collaborative, just-in-time, social-based learning methods. Providing ICT services in response to these needs is very easy nowadays. Since the dawn of e-learning, learning management systems (LMS) have played a crucial role in successful initiatives [84][85], thanks to services and tools provided to all the stakeholders involved, from learners to teachers, from tutors to administrative personnel [86] [87]. LMSs appear to solve the many problems of limited time and place for training tasks and the number of meetings between teachers and students [88].

The evolution of LMSs, together with the advent of Web 2.0, social networks, and the availability of efficient collaboration tools in general [89] [90], poses a set of questions with regard to how the e-learning platforms should be related or integrated with the rest of the information systems of an organization [91]. The above means that some LMS services could be shared with the rest of the organization; collaboration platforms can be integrated with e-learning services to provide and integrate collaboration, communication, accounting, authentication, recording, document sharing, etc. [92][93]. Software solutions for many of these "needs" already exist and are well-established on the market: collaboration tools, videoconferencing systems, document management systems, single sign-on infrastructures, ERPs, records management, attendance certification management, trouble ticketing, etc.

All these software solutions have their markets and are not part of LMSs. Problems may arise when single solutions (from different manufacturers and not integrated) grow and force relevant learning and re-learning costs on users and IT departments. An integrated solution in which all the services needed are available in a unique, consistent software platform is a better perspective. Integrated solutions offer benefits, such as speed of execution, quality of results, and user interface uniformity [94].

Few studies have investigated the integration between e-learning platforms with (other) information systems of an organization [95] to maximize the positive effects of such integration between systems for educational activities. The advantages organizations can derive from ICT use in education (accessibility, flexibility, efficiency, effectiveness, economies of scale, customization, and measurability) can be consolidated [96]. Other researchers have focused on the successful aspects of LMS. In [97] we can find a literature review related to the aspects of success and failure of LMSs. The authors identify seven key factors: single sign-on, learning management, content management, integration, security, tracking, and group management. As we can see, most of these success factors are related to integrating the rest of the information system in the most transparent way possible. The aspects of failure in LMSs are condensed into eight factors: content creation and sharing, communicative features, structure, learning engagement, assessment, user interfaces, social and informal learning, and mobile features. To improve the impact of LMSs on institutions, both pedagogical and technological improvements are suggested [98].

The evolution towards a collaborative environment is natural for e-learning, according to the nature of learning processes and the tools needed in both environments. Recent years have seen the widespread usage of LMSs in managing and operating e-learning courses in different contexts. Nevertheless, in LMSs, we find minimal support for tasks unrelated to the "classroom" metaphor, i.e., part of training processes but not necessarily limited to slides, videos, or other educational media. The primary usage has been the distribution of learning objects, and during the pandemic, videoconferencing took the primary role, but many other functionalities and features are unrelated to educational aspects. These functionalities, such as the enrolment of students, public tenders and concourses management, support for group decision-making, or project management tasks, usually are not available in an LMS[99].

2.3 LMSs and social media

Another interesting evolution of LMSs faced by this theses is the extension of provided services with collaboration and cooperation services. Research results worldwide demonstrate that collaboration and cooperation in e-learning, even if classified in different ways[100], can greatly benefit the educational process [101]. Guidelines for designing and implementing online cooperative learning are also available, which evidence the adaptation that a traditional LMS should undergo to enforce and support higher education institutions [102].

Online Cooperative Learning (OCoL) tools provide web-based access to services supporting cooperative learning beyond face-to-face interaction [103]. Research results worldwide have demonstrated the value of collaboration and cooperation in e-learning [104], from simple methods to virtual reality applications [105]. In terms of collaboration, there are many features that LMSs could provide to users that are not necessarily related to educational processes: document repositories, forums, wikis, FAQs, video conferencing, and glossaries have been reported as tools and services available inside the LMS platform that could be very useful in collaboration tasks [106][107].

While the proliferation of LMSs has provided learners with many opportunities for traditional learning, few studies have explored the role of social media in creating virtual learning communities [108] [109]. When social media started to take the market and attract students' interest in their private lives, social media quickly became a solid external competitor to LMSs. The introduction of collaboration tools has implied a request for the most needed services in e-learning settings and are already available in most LMSs. Technologies and software platforms used in e-learning share metaphors and tools with collaboration platforms. Wikis and forums are frequent in blended e-learning courses, FAQs are regularly used as the output of training sessions, and social networks are sometimes used to substitute the LMS.

Today's dominance of social networks in computer-mediated communication has heavily influenced the approaches to teaching, learning, and collaborating [110] [111]. Online Cooperative Learning (OCoL) tools provide web-based access to services supporting cooperative Learning that go beyond face-to-face interaction [112]. Social elements like tagging, community creation, networking, multimedia file sharing, microblogging, etc. witness the contamination of e-learning with social media to create working spaces and collaborative learning environments [113].

We can find consolidated research on social aspects of virtual communities in e-learning contexts [114][115] [116]. The recent pandemic has reinforced the idea of virtual communities as educational virtual places. Online communities have proven beneficial to online learning, mainly because of their ability to remove (at least partially) the sense of isolation present in traditional e-learning classrooms [117]. The benefits from online communities positively influence learners' knowledge creation, i.e., an overall satisfaction that overcomes objective difficulties and the absence of human relationships. Being a virtual community member means giving the learner added value compared to individual learning.[118]

The advent of mobile technologies in our life has opened the door to the use of social media in areas not necessarily related to education. The widespread use of mobile devices among learners of any kind, not only students from the education system, has transformed educational environments [119], which has increased the use of mobile technologies in many learning and teaching environments. According to this, to demonstrate the value of their usage, LMSs must provide services that users are familiar with, such as social networks, virtual communities, and other Web 2.0 tools like blogs, wiki, FAQs, forums, chats, etc. [120]. The fundamental paradigm of these environments shifts the focus to cooperation and collaboration rather than pure training [99]. Training tasks involve collaboration between students and teachers at different levels, from a less interactive collaboration level in traditional training where the role of the learner is mainly passive to more collaborative environments where we can find cooperation and knowledge creation mediated by technology[121].

Another factor comes from the pervasiveness of Web 2.0 tools today and, in general, the use of ICT in business interactions between individuals. This element is present primarily in business settings, where the division between "teacher" and "learner" is often unrealistic, and collaboration between a coach and a participant is more suitable[122]. Broadening the business horizon from pure training to supporting organizations with collaborative, social media-enabled features is an excellent opportunity for the e-learning field to earn a stable role inside information systems[123].

2.4 LMS and decision making

Decision-making pervades our daily working tasks, and information systems should provide adequate support for this. Many studies have been done, and tools have been created, from specific Decision Support Systems (DSS) to business intelligence tools to various services provided by software platforms that initially had another scope and objective. There are trivial examples of usage of DSS tools inside learning contexts, like the evaluation processes performed for educational purposes [124]. However, other usages of DSS-based tools are less trivial, although advantageous, like when the virtual learning environment supports educational tasks and collaborative and community-based processes. Examples of this integration between DSS-based tools and e-learning systems are[125][126][127]:

- evaluating the various candidates for a job position
- supporting evaluators in a public tender
- evaluating project proposals that have been uploaded to the platform
- assigning prize respect to documents uploaded in a forum
- evaluating the best contribution for a wiki item.

Supporting decision-making in an e-learning environment has been proposed through different approaches. One of these approaches is multi-criteria decision-making, which has a large bibliography [128]. We find different mathematical approaches like the one presented in [129], where a fuzzy multicriteria group decision support software was developed. This software allows users to choose between two fuzzy inference methods and three different membership functions describing linguistic terms. The decision-makers helped determine each criterion's primary criteria, sub-criteria, weights, and alternatives performance. The software module can be applied to multi-purpose decision-making processes, such as evaluating the performance of students, teachers, journals, employees, or assessing projects, journals, etc.

In e-learning settings, the evaluation of different alternatives is widespread. It relates to different contexts, with much research on methods supporting soft computing evaluation but less generalizing this application to other contexts contiguous to education. Some examples include:

- the evaluation process typical of many educational paths, such as student performance evaluations [130][131];
- the evaluation of educational materials [132] ;
- the evaluation of teacher training; [133];
- the agreement on learning strategies [134];
- evaluation of institutions' educational performance and services [135];
- learning objects' recommendation based on experts' (teachers and tutors) evaluation [136] [137] [138][139], or the wider field of adaptive e-learning [140][141][142];
- the ranking of candidates in a selection process, such as candidates to a doctoral school or a master's degree with a limited number of participants [143][144][145][146];
- the evaluation of users' contributions to social media discussions in terms of quality and quantity of posts on forums, blogs, etc. [147][148].

Many techniques have been used in research projects, but they are not very common in LMSs, especially those primarily used in educational institutions. The first technique analyzed and then included in the experimental services presented in this thesis is the Technique for Order

Preference by Similarity to an Ideal Solution (TOPSIS). TOPSIS was developed by Hwang and Yoon [149] and is a popular method when dealing with multiple attribute decision-making problems. TOPSIS simultaneously considers the distances to the positive and negative ideal solution regarding each alternative and selects the closest to the ideal solution and the farthest one from the negative ideal solution. The method is also used for its relative simplicity of calculus: it uses the shortest distance from the ideal solution and the longest distance from the negative ideal solution. The alternatives are compared to the criteria in an evaluation matrix, then weighted and normalized. In this way, ideal and non-ideal solutions are determined. Finally, the distances of each alternative from the ideal and non-ideal solutions are computed, the separation measures are obtained, and the alternatives are ranked. In [150], there is a comprehensive analysis of the application of TOPSIS to different decision-making contexts from 2000 to 2015. Many changes and extensions have been developed since 1981, mainly focusing on the normalization of the evaluation matrix, determining the ideal and non-ideal solutions, and the distance of alternatives from the ideal and non-ideal solutions. Another thread for the TOPSIS extension proposes to deal with multicriteria group decision-making and decision-making in a fuzzy environment. For example, the authors of [151] review the literature on methodologies and applications of the TOPSIS method until 2012 and recommended future research directions for the TOPSIS methodology. Other researchers focused on fuzzy extensions of well-known consensus management techniques, such as Delphi or AHP [152][153].

We have investigated other mathematical extensions inside our LMS besides TOPSIS, specifically the analytic hierarchy process (AHP). This method has received much attention since its development, and nowadays, it is one of the most popular methods applied in multicriteria decision-making. According to this investigation, we have implemented, together with other research groups, a library of functions related to AHP. This library is usable inside the services provided by our LMS, as the services for managing evaluation committees, defining a joint agreement on the project’s duration, and deciding between the best candidates for any application the LMS can manage.

Like for TOPSIS, we can find a significant amount of research proposing extensions and modifications to AHP [154][155]. Many papers proposing mathematical models for evaluating e-learning products and their components involve AHP, and one of the main threads of research refers to fuzzy extensions[156]. The AHP solution is to structure a problem into a hierarchy, proceeding with pairwise comparison matrices of objects from one hierarchy level concerning an object from the upper hierarchy level. Pairwise comparison matrices of objects are checked in terms of consistency (i.e., consistency of the expert’s preferences), and priorities of objects are obtained from the matrices. Finally, priorities are aggregated into decision-making alternatives, and a ranking process is applied to these. AHP is a highly debated methodology, especially the aspect of consistency of the matrices: for example, in [157], an analysis of proportionality between existing consistency indices in the AHP method is presented, while in [158], a method for achieving matrix consistency in AHP is proposed.

The application of AHP in e-learning settings exists, though in different directions. [159] uses the AHP method to evaluate the criteria affecting e-learning quality and consistent fuzzy preference relations. Similarly, in [160] AHP has been applied to evaluate five teaching platform practices from knowledge management. [151] proposes a model for selecting an e-learning platform suitable for organizations using the AHP method. In [162], a consistent literature review about course website quality has been conducted to generate criteria suitable for measuring course website quality. It is probably not precisely related to the objectives of including mathematical techniques inside a web platform, but it is an interesting application case [163]. An extension of the AHP method with a fuzzy approach and fuzzy triangular numbers has been proposed in [164] to obtain the relative weights of course website quality criteria between high and low online learning experience groups. The authors propose an approach based on the fuzzy AHP method and critical success factors to evaluate e-learning systems by universities and educational institutes.

Fuzzy logic is another promising research area that inspired our development, significantly present in the e-learning research field. Some approaches have been presented in [165], where fuzzy logic has been applied to identify e-learning design requirements and select the most suitable e-learning service provider. Other approaches [166] use fuzzy inference to analyze students' way of working and group behavior, while in [167], fuzzy logic has been used to improve the search capabilities of learning management systems (LMSs). In the field of evaluation, under different perspectives, we find the application of fuzzy logic to the evaluation of students' performances according to their profile [168][169][170][171], or to an evaluation of teaching systems' quality [172], even when teaching in MOOCs contexts [173].

2.5 LMSs and AI

LMSs are extensive knowledge repositories, which is even more evident if we extend the e-learning platform toward collaboration where content is not limited to education. Where we have knowledge repositories, modern ICT proposes to use AI-related techniques for knowledge representation, extraction, and discovery. One of the most frequently used terms in this field is the semantic web and associated technologies. Initially, the aim of building the semantic web was to provide a system representing the information available on the World Wide Web through machine-understandable data, metadata, and other information objects. To achieve this, AI and Natural Language Processing (NLP), ontologies, and knowledge representation have become familiar concepts for researchers dealing with semantic web technologies[174][175].

Regarding the relationship between e-learning and semantic technologies, most educational institutions have recognized e-learning resources as fundamental assets for their training processes, mainly because they deliver educational content to participants anytime and anywhere at competitive costs[176]. In these institutions, we can find many different implementations and customizations of available approaches (from blended to complete online e-learning) and tools (platforms like LMS, technologies like videoconference, standards for learning objects metadata like LOM or SCORM [177][178]). There is a huge expectation on AI, semantic technologies for web-based education: for example, tailored learning material, learning intelligent monitoring and assessment[179], on-the-fly contextual learning objects[180], automatic recommendation of contents [181][182][183][184] etc.

The level of maturity and reliability of educational processes of e-learning is also visible in the increasing amount of material available in various forms and in the availability of many Massive Open Online Courses (MOOCs) involving people around the world [185][186]. The quality of MOOCs is under discussion [187] [188], but we cannot deny that much educational content has been produced and used, and many users have been involved in e-learning. Considering the complexity of learning tasks, any new "intelligent" technology that can help accelerate and improve extracting knowledge from educational content will catch the attention of specialists. Semantic (web) technologies are no exception, providing a landscape where web-based information and services are understood, processed, interlinked, and reused by humans and machines [189][190][191].

Artificial intelligence has also contributed to e-learning from different perspectives, as shown in different surveys [192][193][194]. This emerging topic applies AI principles and techniques in e-learning (AIeL) to improve the effectiveness of teaching and learning in education. Content classification, retrieval, and enrichment through knowledge representation tools, learning analytics, and ontologies for educational content description are AI's most recurrent application fields inside e-learning contexts.

Another perspective sees the semantic web as the possible implementation of a reliable, large-scale environment of machine-understandable and interoperable services that intelligent agents can automatically discover, execute, and compose [195]. Other researchers have used semantic technologies to build a new generation of learning applications from scratch or enrich existing software platforms that deal with educational settings [196][197]. Despite the excellent opportunities of combining e-learning platforms with semantic technologies, there is no magic solution to exploit this integration: spreading the "magic powder" of semantic technologies over an LMS does not guarantee measurable improvements.

Currently, different educational standards for describing the contents in learning resources exist. Several organizations are involved in producing metadata standards specifically for learning technology. SCORM, IEEE LOM, and IMS Learning Resource Meta-data specifications are typical and robust [198]. The IMS Global Learning Consortium (IMS) developed Learning Tools Interoperability (LTI), which aims to provide a single framework that allows integration between any learning application, thus enlarging learning scenarios, scalability of solutions, and flexibility of implementation [199][200].

Standard metadata is used by IEEE-LOM, mainly for interoperability between different LMSs, but unlike RDF-based metadata, the standard only allows for a hierarchical structure. Semi-semantic metadata extends the IEEE-LOM standard with some semantic components, such as extending the relational field with a semantic net to interconnect different learning objects [201] or adding terms associated with some pedagogical or domain ontologies [202]. Semantic metadata is defined as "…the process of attaching semantic descriptions to Web resources by linking them to several classes and properties defined in Ontologies" [203]. Applications using semantic metadata rely on domain ontologies to define their metadata using RDF to express the semantics of a learning resource.

There are several advantages of using RDF over the standard metadata approach [204]: a) an RDF data model starts from the assumption of selecting metadata potentially from heterogeneous ontologies, while standard metadata is taken from a LOM-based, closed-world approach confining metadata to the particular LMS implementation; b) with RDF, a complex statement can be created, thus expressing logical networks, while LOM can express the simple composition of a statement possibly extended through taxonomic classification; c) simple forms of inference (e.g., class inheritance, consistency check, transitivity) can be applied, this way reducing the costs of developing ad hoc solutions to implement the functions which require them [205].

Annotating LO is, therefore, a fundamental task to enhance e-learning usage [206], guaranteeing and facilitating access, sharing, and reuse of learning resources. Various researchers have investigated the complexity related to automatic annotation [207], collaborative annotation[208], or the annotation of multimedia content [209]. Annotation is also a keyword for the semantic world; annotated contents transform a full text to be scanned by keyword into structured, semantically-enabled content. However, some obstacles exist to using structured learning material as a perfect knowledge base for learning activities.

Firstly, most LOs have not been enriched with metadata or with automatic, title-related, or filename-related attributes that are semantically poor and sometimes even counterproductive. Secondly, learning objects are not the only source of knowledge inside an LMS, and LMS platforms are not built just of learning objects. Web 2.0 tools and services, such as blogs, wikis, forums, FAQs, glossaries, questionnaires, etc., are handy for the learning process [210], especially in educational paths with a high degree of interaction between participants and instructors.

As a further element, organizations can replace their tools and platforms over time. However, the investments in LOs should be preserved, so great attention should be paid to content, data interoperability, and migration. For those materials created under some standard's umbrella, the problem should not exist. Still, for other contents like those created with Web 2.0 tools, the availability of an RDF-based representation simplifies the mapping process between data schemas of different e-learning platforms [211][212], thus facilitating content migration between different LMSs. As LOs could be very complex multimedia artifacts, these problems could be frustrating for any interchange of educational material.

Another long-term research line where semantic technologies could play a fundamental role in learning settings is the addition of search capabilities to an LMS [213][214][215]. The integration of semantic technologies is mainly devoted to getting meaningful results from user queries about the knowledge base of the LMS. Parts of such a knowledge base that could be affected by semantic categorization could be contents, course materials, students' profiles, etc. [216].

Another research area where semantic technologies frequently intercept the e-learning field is the connection with the WWW. The Semantic Web extends the categorization of existing WWW resources, allowing "computers to intelligently search, combine, and process Web content based on the meaning that this content has to humans" [217]. Several projects and studies have combined these three factors into e-learning systems, focusing on determining the standard architecture and format for learning environments, which helps integrate Tim Berners-Lee's semantic web stack representation [218]. However, these standards are trying to model the interoperability of educational information relevant to the educational process[217]. IMS and SCORM sequencing models define the educational activities and system implementation, together with the method for representing the intended behavior of an authored learning experience, but not the contents' knowledge in educational activities. Other authors [219] have used the taxonomy of learning resources and stereotypes of teaching models for educational contents and sequences. However, these aspects are heavily platform-dependent and lack standardization and reusability.

A central role is played by ontologies, here intended [220] as conceptualizations of a specific domain regarding concepts, attributes, and relationships. Ontologies enable the representation, processing, sharing, and reuse of knowledge between applications. In e-learning settings, they play a crucial role in several ontology-centered types of research where web technology standards, such as XML and RDF(S), allow sharing and reusing any web-based knowledge system [221].

The impact of the merge of e-learning and semantic technologies is, in our opinion, deep and permanent, for reasons that will shortly be presented but that have been primarily discussed in different research areas [222]. Nevertheless, much of the current research seems to limit how the semantic web will enable instructors to construct elegant ontology-based annotations for existing web-based resources and further expand metadata schemes[223]. The direction followed in this research is focused on content by using semantic technologies to manage the unique identification of entities, thus increasing the information extraction from the e-learning knowledge base.

2.6 LMSs and big data

Besides being a buzzword for the last five years or more, big data represents a radical change in the viewpoint of any information system concerning data volumes, velocity, and variety. E-learning made no exception, primarily when we deal with collecting large, real-time datasets[224]. We consider, in this case, "learning" in a broad sense, not only limited to classrooms but also in the field of contextual learning, experience learning, training on the job, and other various situations where we increase our knowledge with technologies mediating our learning processes.

From an application perspective, big data poses essential issues on the architecture of the application, specifically the persistence layer where the data is stored. On the other hand, if we look at other application fields that imply significant data approaches, there is great attention paid to these tools and techniques due to the issues generated by the famous "Vs" of big data (7 "Vs" for some observers [225]). In particular, of the different "Vs", at least the following three are relevant for our argumentation:

- "Volume". It sounds like the incredible amount of data collected worldwide in different application scenarios, from social media to flight data, from the Internet of Things and its sensors to the tasks of wholesalers.
- "Variety". It deals with the various forms data can take, from structured tabular data to unstructured data containing texts, images, emails, videos, spreadsheets, streaming media, complex BLOB objects like SCORM packages, etc.
- "Velocity". It refers to the speed of data collection inside the platform, which is another severe issue for applications in big data.

These characteristics have demonstrated that traditional persistence layers based on RDBMS are outdated and probably not scalable enough. The phrase "Too big, too fast, too hard" perfectly represents the difficulties that the relational model and the respective implementation in RDBMS suffer from [226]. Most of the current LMSs are based on relational databases, which becomes an issue when we face big data-enabled e-learning contexts [227].

Looking at the research field of big data and e-learning, the focus of researchers seems to ignore (to our knowledge) the architectural implications of big data on software platforms that face big data scenarios. The focus is mainly on big data analytics in e-learning [228][229][230] and the support of AI-based, machine learning techniques applied to e-learning [231], [232].

One of the most significant problems is importing raw data from big data sources into the native representation in the relational schema before querying data. This limit affects the ability to handle some types of data, for example, streaming data. Even if the database community has widely studied these specific issues, it is clear that streaming data does not fit well into the relational approach. If we translate this for the e-learning field, as said, most of the current learning management systems (if not all) based on a relational persistence layer will suffer when involved in big data-enabled contexts [233][234][235]. Analytical tools such as SAS, R, or Matlab can support analysts with sophisticated functionalities. Still, again we have a scalability problem because these tools are often limited to the working memory of the user's machine, and persistence tools do not have these analysis methods out of the box [236]. In general, big data has stimulated a profound change in persistence architectures and tools, giving the floor to NoSQL technologies such as columnar or graph databases or frameworks like the Apache™ Hadoop® ecosystem. TEL's fundamental question is: do we need big data technologies for e-learning settings, or is it just a way of climbing on the current ICT buzzword bandwagon? From an overview of the bibliography in the field, the focus of the current research in big data for TEL is still in its infancy. Most of the approaches and research focus on collecting learners' performance (whatever this could mean) and on feeding them into an analytical tool for educational decision-makers at any level (from tutors to directors). In [237], the author highlights five benefits of using big data inside e-learning contexts:

- Evaluation of the efficiency of courses: data analysis allows for identifying more effective types of teaching for the course's objectives.
- Identification of areas for improvement of the educational activity: imagine having a detailed log of uses of SCORM learning objects to see why many students are taking too long to complete a module or task and the implication of the re-design of the educational content according to these results. Large masses of users (as in Massive Open Online Courses) that use many SCORM objects and a system that records every mouse move, click, and action on the object (for example, for a medical course) could quickly generate big data compatible data streams.
- Analysis of Web 2.0/Learning 2.0 interaction of users in social learning activities, with all the analytics deriving from this interaction.
- Information (detailed or aggregated) about the educational path is immediately available, thus having a real-time (or nearly real-time) dashboard to control the situation on the courses without waiting for the results of assessment tests where it is typically too late for remedies.
- Based on these analyses, course designers could personalize courses according to the students' performance, utilizing a sort of prediction about the successes and failures of learners.

We have started investigating the collection and analysis of big data in e-learning to customize the learning experience based on learners' needs and learning styles. Most of the bibliography of big data and TEL can therefore be labeled "big data for learning analytics"[235].

Learning analytics analyzes data from educational tasks the learner performs for teachers, course designers, and administrators of virtual learning environments to find unobserved and unpredicted patterns and infer new information to improve learning processes. So the main aim of learning analytics is to improve the learning experience and performance in blended or fully online courses. In [237], where the authors explain learning analytics, the most basic unit of data for learning analytics is considered the "interaction", even though the authors correctly report the different definitions available and the lack of consensus on which interactions are relevant for effective learning. The similarity of this research to our approach is that standard logs available from any web application are not enough to have significant data for learning analytics. Data extraction and analysis required developing a specific tool based on the authors' idea to test as we did in our experience.

In [238], the focus is mainly on learners' interaction with social media, thus relying on advanced artificial intelligence mechanisms to infer knowledge and interest. The idea is to assess the learner's knowledge level on different topics and recommend additional education related to his/her former studies to get a better/desired job. Big data is a keyword when dealing with social media analysis and actions logs. Other approaches [239] involve collecting biophysical signals during learning processes regarding emotion detection. This approach is a sort of "humanization" of the Internet of Things (IoT), with IoT being "one of the most promising fuels for big data expansion" [240].

In [241], other than recognizing learning analytics as a significant area of TEL, the author proposes an interesting analysis of "the technological, educational and political factors that have driven the development of analytics in educational settings". The emergence of learning analytics originated in the 20th century is associated with the development of data-driven analytics, the rise of learning-focused perspectives, and the influence of national economic concerns. The relationships between learning analytics, educational data mining, and academic analytics are presented, thus assigning a central role to learning analytics even for the future challenges of the education field.

[242] presents another source for big data in TEL, i.e., the services of LMSs that fall under the label of e-learning 2.0, which is nowadays well established and widely accepted. Comparing the different generations of e-learning (1.0 and 2.0) and looking at the perspectives of Web 3.0/e-learning 3.0, the authors survey some existing predictions for e-learning 3.0 and finally provide their own. In particular, Machine Learning and Data Mining are significant driving forces for Web 3.0, and, therefore, for the development of e-learning 3.0. Many LMSs platforms have traditional services such as synchronous/asynchronous communications or file repositories and other e-learning 2.0 services such as forums, blogs, wikis, FAQs, etc. These services constitute an essential part of the interaction with students and, therefore, could be an interesting place to extract information about learning behaviors. According to the impressive volumes of data collected every minute, Web 2.0 interaction analysis is another field of application for big data tools and techniques.

To conclude, the potential recognized for learning analytics [243] [244] is to track students' learning, reveal patterns in their learning behaviors, or identify patterns that put students at risk of failure. Learning analytics have another significant end-user, the decision-makers of educational institutions. This important group of users could use analytics to reform and support educational programs and activities to improve teaching and learning processes and even the organizations' educational strategies [245] [246]. Besides, there is increasing attention on learning analytics as an instrument to improve learning processes, with the respective pedagogically implications and inputs [247]. Many LMSs have adopted learning analytics tools at the classroom level, thus providing teachers and learners with some benefits from learning analytics data [248][249].

2.7 LMSs and project management

According to what is considered the reference book for project management, the "Project Management Body of Knowledge"© authored by the Project Management Institute™, a project is "a temporary endeavor undertaken to create a unique product, service, or result" [250]. At the same time, project Management is "the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. Project management is accomplished through processes, using project management knowledge, skills, tools, and techniques that receive inputs and generate outputs." According to the definition from [251], project management is the application of a collection of tools and techniques (such as the CPM and matrix organization) to direct the use of diverse resources toward the accomplishment of a unique, complex, one-time task within time, cost and quality constraints. Each task requires a particular mix of these tools and techniques structured to the task environment and life cycle (from conception to completion).

Project Management is as old as the needs of human society to complete complex tasks [215], such as building the pyramids in ancient Egypt or launching a rocket on the moon. Project management is more recent and considered vital in many different production fields, involving various disciplines from management to computer science, mathematics, anthropology, and soft skills. Nevertheless, its application has not been pervasive, and indeed, projects have not been successful without its application. According to [253], 60% to 80% of projects are not on time or within budget, and the average delay is 40% of the estimated duration [254]. These poor results in terms of successful performance could have many interpretations. The most common are summarized as [251]: "project management continues to fail because included in the definition are a limited set of criteria for measuring success, cost, time and quality, which even if these criteria are achieved simply demonstrate the chance of matching two best guesses and a phenomenon correctly".

The issue of time management, linked to the discipline of PM, is historically a problematic theme for the computing world in terms of cultural, technical, organizational, and not least social perspectives. It becomes even more complicated when applied to collaborative environments present in social networks (sharing files, messages, lists), what is called project management 2.0 or social project management [255][256]. Integrating e-learning platforms, project management, and social media is closely related to the world of collaboration mediated by ICT (CSCW), a recurring topic even in project management. Thanks to the social earthquake represented by the various social media, the world of e-learning and PM needs to consider users' expectations.

The theme of Computer-Supported Collaborative Work has been widely debated [257][258][259], especially in the last decade and following project management systems. This area studies the idea of using ICT tools to perform and coordinate (collaborative) workgroup activities. Instead, applications and technological tools to support collaborative work are called groupware or technology cooperation. One of the variations of this approach focuses on training, especially in e-learning; in this case, we speak of Computer-Supported Collaborative Learning (CSCL). The need for training in many areas of organizing the teaching approaches of learning by doing, learning by project, etc., requires e-learning systems to incorporate collaborative technologies.

Over the last 40 years, PM has been a very efficient tool for handling complex activities [260]. It has evolved from just being an accessory for a good-looking project manager to become mandatory if a company wants to participate in specific, large-scale projects, especially in those fields with high-risk levels or which are highly competitive. This dramatic change can be traced back to the diffusion of the personal computer in the early 1980s, from when information technology reshaped all forms of work. However, the early versions of software supporting project managers have been very immature. In the early 1970s, the project management Institute launched a top-down style of project management that allowed planners to develop a project plan by establishing a baseline that could be as long and valid as possible for the duration, even in case of complex or lengthy projects. Project management was also designed to assist relatively large teams [261].

Project managers today can choose from many techniques and software to plan and manage their projects. The widespread usage of network approaches, like Gantt charts, the critical path method (CPM), or the critical chain method (CCM), have simplified the planning and controlling steps. In contrast, project management software has reached a solid maturity level. A Work Breakdown Structure is a (graphical) tool that defines the project's scope and delimits things that should be done, separating them from unwanted or unpaid requests. WBS is the hierarchical decomposition of the work executed by the project team to fulfill the project's objectives and make deliverables. It organizes and evaluates the overall scope of the project. Information for the WBS is taken from project objective statements, historical files of previous projects, and project performance reports. An appropriate WBS encourages a systematic planning process, reduces the possibility of omitting key project elements, and simplifies the project by dividing it into manageable units. Other techniques allow controlling resources, costs, and tasks, and following the project from the initiating phase to the closing tasks through planning, executing, and monitoring. Reporting is straightforward once all the project-related data has been collected, so computers and software could greatly help project managers.

Another area that, over the years, has been contiguous and interlaced with PM is collaboration. Collaboration is the heart of PM: collaborative spaces are made available for everyone within the project team to contribute to the success of the project's objectives. A new generation of PM tools enables this functionality. The whole team leads and develops the project, and each member has complete information about the project, with all the related documents. The project's progress is visible to everyone anytime, according to the permissions granted to the subject. When project managers are free from routine tasks, they can put more effort into the project vision and choose the direction for the project development. [262] discusses methods and tools for collaborative project management. Project alignment ensures that key stakeholders share a common understanding of project work processes, operational procedures, objectives, and plans. The collaborative management of projects is devoted to fulfilling this objective: (a) shared project management, (b) delegated management responsibility, (c) self-organized and trusted approach, (d) non-hierarchical (and participative) management organization, and (e) results-based assessment of progress. The management of collaborative projects means: (a) management of projects in a networked and distributed environment, (b) distributed processes, (c) participants and organizations in different locations, countries, cultures, etc., and (d) either primary project responsibility and tracking or collaborative management.[263]

The key issues with social project management and project management 2.0 are substantially the same. The project manager has the role of a leader more than a project manager. Her/His main task is to ensure communication and collaboration within the project and with the stakeholders for the project work in distributed virtual teams. Continuous communication between the stakeholders ensures good collaboration within the project. Social media is a powerful collaboration tool within the project: in large organizations, the software used for social project management is embedded into the social network. This element enables communication over the project boundaries and allows project stakeholders to discuss with specialists outside and inside the organization [264]. The software is organized according to the project's schedule linking all activities and collaborative functionalities[265]. An activity stream application keeps project stakeholders aware of the project activity and status. Charles Seybold, CEO of LiquidPlanner.com, states five laws of social project management that need to be fulfilled:

- Collaboration and projects are inseparable—a project is a way to do something. A project consists of goals, objectives, deliverables, resources, plans, promises, and purposes, and it is very similar to what is happening in project-based learning and other collaborative approaches to education [263];
- Every participant must benefit from participating. The value must be created not only for the team managers but also for the members. Every team member must be engaged with the project process and its tools.
- Transparency must be maximized. Transparency enables communication and connections, motivating, engaging, and innovating people.
- Autonomy must be maximized. Team members benefit from autonomy, as they control their work. Audit the contributions of the team members to ensure the quality of work.
- Estimating and scheduling must be realistic. The main issue within organizations is honesty, integrity, and trust. In order to keep these values, people need to manage uncertainty, balance workloads and make justifiable promises.

A social project management tool must support project management with all its complex methods and controls. It should allow teams to collaborate fully without making it too complicated. This means that the tools should allow the project members to collaborate, share information, and work in the project effortlessly and transparently. Even if the project plan, documents, and other information should be available for all the stakeholders and others in the organization, these still need to be managed and controlled by the project manager. Somebody needs to be the person who holds the rope in his hand. A social project management system should assist in completing and maintaining project tasks. All the plans, documents, and other information should be updated and visible to all stakeholders. The project members write comments, add files with information, update their tasks, and mark them done.[256]

The three most typical and popular applications enterprises can adopt while using PM 2.0 for their projects are wikis, blogs, and collaborative planning tools. Together with file sharing (documents, reports, agendas, comments, etc.), these tools represent an evident stimulus to consider an e-learning platform as a possible provider of support and services for PM. These services, like many others, are widespread both in collaborative environments and in e-learning platforms, as presented in [265]. Likewise, many situations in educational settings could take advantage of PM services. Some examples can be the following:

- the management of a thesis assigned to a student is an actual project with tasks, milestones, deliverables, and costs (even if not directly sustained by somebody);

- a research project led by a teacher or researcher is, by definition, a project involving again different resources, costs, deliverables, and milestones;
- an educational path and all the tasks that any participant has to manage is another example of a "project";
- a complex training path providing professionals with certification at the end of the activities with the assistance of external resources and tutors is a project from the perspective of the organizing institution. Here we have a typical mix of educational needs (the LMS's most traditional services) and PM tasks;
- a Massive Open Online Course (MOOC), with all the tasks connected to the various phases for the creation, marketing deployment, execution, support, and final certification of the course. It is undoubtedly a project for the institution that delivers the MOOC and for the participant who must perform tasks, pay attention to milestones, and respect deadlines.

The possibilities of using these tools and services inside LMSs are more robust if we imagine using a Virtual Communities system not only for managing "communities" devoted to educational purposes. We have these advantages also in larger contexts typical of collaboration, like a research group, a recreation organization, a secretariat, a board of directors, a club, a sports team, etc. These "communities" need services inside LMSs (like document sharing, forums, wikis, FAQs, synchronous/asynchronous communication, etc.).

3. Methodological Framework

Even though the topic is strongly related to software engineering and computer science, the underlying methodological framework of this thesis follows a more general path. This research can be understood as a framework for constructing (information) system artifacts illustrated in Figure 8, proposed by Mitroff, Betz, Pondy, & Sagasti in 1974 [266].

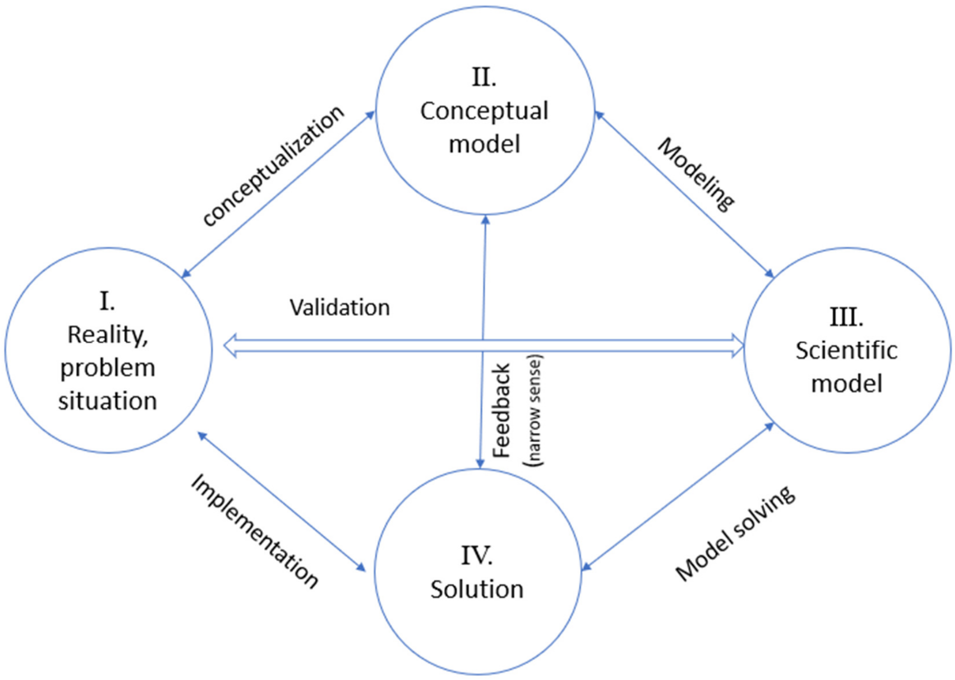

Fig.9: The Mitroff & al. methodology for constructing solution-bearing artefacts.

This approach is based on a "systems point of view for science", which adequately represents the methodology followed in this long-term research project. This model is general enough to describe scientific processes such as the creation/re-engineering of a software platform. However, in this research, the block sequence has been modified. Generally speaking, traditional software engineering processes are composed of five steps:

- investigate activities about the unsatisfied needs for service and investigate the presence of these services inside the most widespread solutions on the market (I. Reality, problem situation);
- conceptualize the users' and system's needs in a conceptual model, such as software architecture, a data model, a class model, a service model etc. (II. Conceptual model);
- transform the conceptual model of the system into a scientific model that can be implemented with the current technological solutions (III. Scientific model);
- create a solution for the scientific model by implementing a computerized system (IV. Solution).

The approach is not purely sequential but iterative with interactions and feedback if needed between the various steps, providing repetitions to improve and better test the final results. Therefore, this general model can encapsulate many software engineering methodologies, from traditional waterfall models to iterative and agile methodologies. However, we decided to stay at a higher level and use this methodology considering the context of operations with not the same "starting" point for scientific inquiry. Indeed, we started our research in a completely different context. An already-existing solution, a well-consolidated product, was already available on the market with hundreds of million users, i.e., LMSs.

Using the framework illustrated in Figure 9, we, therefore, changed the initial order of the methodological path, following a more empirically-driven approach to creating an LMS, presented in Figure 10. The different steps are numbered and refer to the arrows in the figure.

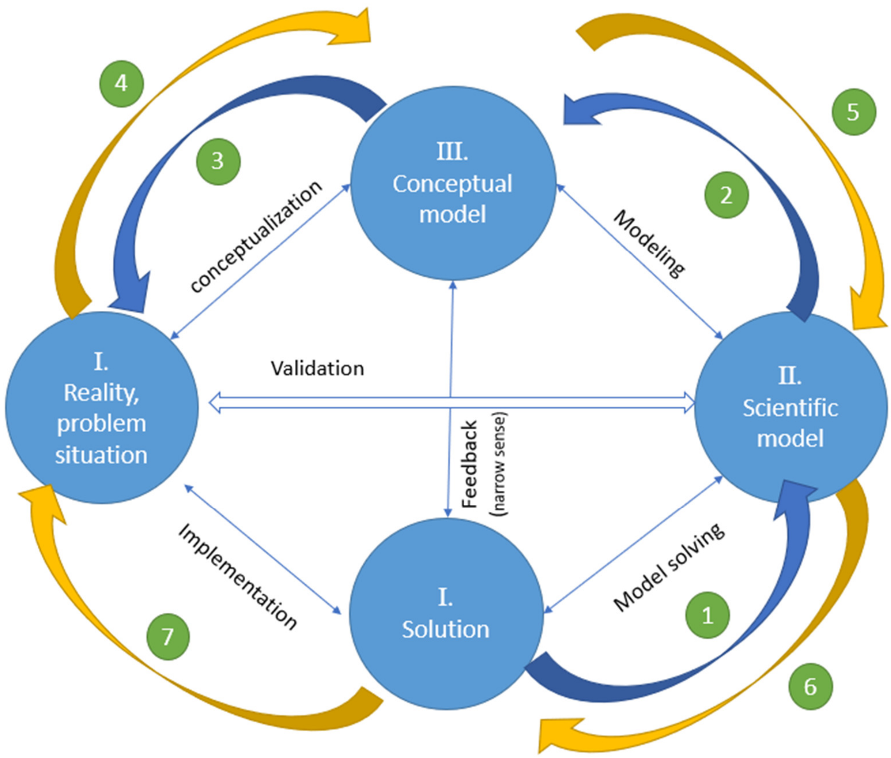

Fig.10: The adaption of the Mitroff & al. methodology for this thesis.

1. We started from an already-available solution, the model of the original paper, , solved into a real solution. As "model" solved, we took the best of the solutions in the field of e-learning, i.e., Moodle™ and FormaLMS™ (I. solution). We analyzed the data/service/class model and general architecture of these state-of-the-art systems (II – scientific model);

2. we went back to the conceptual model that these systems were materializing in the software (III. Conceptual Model), trying to determine if these concepts were representative enough for educational needs and for the evolutions we wanted to implement;
3. we substantiated our research hypothesis through a set of prototypes created to test if our intuitions corresponded to real educational needs from real users (IV. Reality, problem situation)
4. finally, by considering the reality, the problem situation of e-learning, a new educational service/platform concept was studied;
5. through (software) modeling, we created the architecture for a new solution as the model for a new generation of LMSs;
6. after the modeling, a new solution was created from scratch and applied to various application scenarios and contexts;
7. Finally, as the following sections explain, we have validated our platform through experimentations with real customers and projects.

Substantially we have used the methodology proposed in [266]:

- starting from original step IV, instead of step I;
- we moved through the different steps in an anti-clockwise direction;
- having reached the last step (in the original model, the first one), we started a new iteration clockwise, regenerating the various steps through a) conceptualization (a new concept of container for educational and collaborative tasks called a virtual community), b) modeling (a completely new data model for structured data based on new entities such as a "community", "agent"; "role", "community type" etc.), c) model solving (the design of the new LMS), and d) implementation.

All the steps have been followed by the feedback mechanisms identified by the methodology, specifically validation and feedback. The solution found after these iterations was "fed back" to the original problem (the construction of a software platform that facilitates collaboration, service provisioning, and integration with the rest of the information system) to evaluate the results and, if needed, to activate a new iteration. In terms of real-world effects, several projects have used the so-created platform (and is still used). It has generated a spin-off company and is now sold on the market through different channels, other than being used by different educational institutions.

The first consideration related to this methodological choice concerns the first period of the platform's development, which was not research-driven but rather customer-driven. The original idea was to create a software platform similar to the LMSs available at the time (in the late 90s), namely Blackboard™ and WebCT™, trying to overcome those solutions' conceptual and practical limitations. In 1998 there were no Moodle or similar FOSS platforms, so the early years were very experimental and perfectly suitable for the proposed methodology. The used model highlights various research approaches, styles, and attitudes towards science to guide the research. After 2003, we started to work on the idea of virtual communities as a new metaphor for re-engineering the platform. Consequently, the research project started to be supported by the proposed methodology.

The methodology is iterative, with no predefined beginning or end, so it was suitable at a high level to support iterative software development processes. Our research did, however, have a starting point. This iterative process has been used since 1998 to create the platform at the University of Trento. We played the initial role of developer and, after 2003 software designer and architect. The platform, whose structure will be presented in the following chapters, has been used as a testbed to apply new services and integration mechanisms. It is quite a unique situation to have the possibility of experimenting with new services on a platform completely developed from scratch, with all the source code available for research and development, used by different Universities for approximately 8,000 different courses over the last 20 years, with more than 250,000 users in different contexts. We must be grateful to all the institutions that sponsored the creation of these approximately 2.5 million lines of code, with more than 700 tables of five relational databases that support the system and various collaboration activities performed. Thus, the methodology for this research has been partially conditioned by these very favorable conditions. It was possible to fund the design, implementation, and testing of a vast range of new collaboration services on real users mainly developed for educational purposes but then available for any kind of collaboration.

Over the years, the research methodology has been enriched by software engineering and project management integrations from their respective disciplines, specifically KanBan agile methodology, throw-away prototyping, and predictive project management. The tools taken from these consolidated methodologies have been integrated to provide consistency with the present research and the overall system development results. This research spans over more than 20 years and provides an excellent viewpoint to look at how software architectures and software development methodologies have changed.

In conclusion, the research methodology was chosen and then adapted because of its applicability as a super-set of all the research methodologies in the different disciplines involved. The methodology has been used to keep track of the macro evolutions of the project. In contrast, single methodologies have been applied for managing time, scope, and budget aspects of the different research projects with partners (PMI™ project management methodology) and for the specific development of software components/services (Agile Kanban). The details of the application of these methodologies are beyond the scope of this research.

4. The publications and a review of the results

In this chapter, we present the publications that support this thesis. Concerning the seven research topics, the twelve papers presented are somewhat transversal. Thus, to avoid repetition, we will present the respective objectives, main findings, and contributions for each of the twelve papers. Therefore, we will follow the same order used for the literature review, presenting for each topic the paper(s) related to it, the objective of the paper(s), and the main findings and contributions.

4.1 Paper 1: Molinari A. (2021) Project Management and Learning Environment: A Case Study

Objective

This publication analyzes the addition of project management features of an LMS, a topic that LMSs and collaboration platforms have entirely ignored. Many project-management-like platforms are available today, especially riding the media wave of agile methodologies, but there is no trace of the availability of these features in educational contexts. The problem becomes even more complex if applied to the management of learning projects, where we have time, constraints, deadlines, costs, and resources like in any other project. The lack of these features forces users to link external platforms or adapt existing features (like simple to-do lists) to more complex project management tasks. This aspect is another example of how integration between LMSs (providing these features) and an information system would be beneficial from different viewpoints: users, educators, IT managers etc.

Main findings and contributions

The paper presents the tests conducted in a collaborative platform based on the metaphor of virtual learning communities. These tests were on a component developed explicitly for managing projects, activities, and resources, integrated inside an LMS with other services like blogs, forums, file sharing, calendars, and reminders. The introduction of this new component within the system addresses the need to manage collaborative activities between learners, providing a tool for managing and controlling the progress of the activities assigned to the various community members. These tools and techniques made available for any user inside the platform allowed the idea to be implemented for managing a project inside a collaborative and educational environment. This approach revealed two positive aspects: a) the appropriateness of project management concepts within educational contexts because many of the activities we perform during educational tasks can be seen as part of a project; and b) the advantage of implementing these services inside a virtual community environment to provide a natural and fertile ground for the development of these services, and to provide integration with other already-available services, and improve their availability to community members. A qualitative investigation was performed using professional project managers and comparing their user experience in planning (educational) projects with a top-ranked project management software and with the services provided by "Online Communities". The results are surprisingly encouraging, paradoxically because "Online Communities" has not implemented many "not very useful" or "rarely used" services, as considered by project managers.

On the contrary, complete and up-to-date project management services integrated into a collaborative platform seem to help users in daily operations, with a higher usefulness level than trivial to-do lists or simple task managers. The results cannot be interpreted as extensive research. However, we consider these results very interesting due to the experience and professional quality of the involved project managers both from the project and educational side. They validate our original hypothesis substantially, even if not numerically. The educational world and LMSs need to incorporate project management services into the offered services. The next evolutionary steps will be the completion of some project management services with specific features (overallocation management, budgeting details, cost-type resources, charting, and reporting) and greater integration with the other services provided by "Online Communities", such as calendar management, resource booking, grade assignment for assigned tasks, etc.

4.2 Paper 2: Coccoli M., Maresca P., Molinari A. (2020) Big data, Cognitive Computing, and the Future of Learning Management Systems

Objective

This paper is the foundational paper for the special issue "Smart Learning in Smart Cities" (2020), published by the author on the Journal of e-learning and Knowledge Society, Volume 16, No 1 (2020). The concept of smart learning and smart cities was initially examined with a specific focus on the impact of big data and cognitive computing on LMSs. Since they entered the market in the early years, learning management systems (LMSs) have demonstrated their utility inside learning environments, especially in institutions with a low budget or no internal knowledge for developing e-learning initiatives. The paper's objective is to explore two essential evolutions that should profoundly change the architecture of these pillar software tools. Firstly, LMSs could acquire enormous data related to educational tasks. This would be very interesting data for all the actors involved in educational processes (teachers, students, researchers, and administrative personnel). The second investigation line is the application of machine learning, deep learning, cognitive computing, and similar technologies that give computers a more active role in educational processes. It will entail aspects related to exponential learning, a process of exponential growth in training demand. New knowledge and skills must be delivered at speeds never seen before and where big data contexts are fundamental. This paper presents an analysis of how LMSs should evolve in the future, in our opinion and according to our experience, regarding functionalities and services provided to users. Currently, LMS software architecture is mainly based on traditional multi-tier, relational database-oriented architectures and will not be enough to stand the impact of these two new paradigms for modern learning environments.

Both technology and society are living a continuous process of evolution, driving innovation and the development of novel solutions in almost every field of application. In reference to the specific scenario of Technology Enhanced Learning (TEL), we observe significant steps ahead in techniques and methodology. Consequently, we envisage that technological solutions will undergo a continuous upgrade to cope with these to improve the quality of services, as well as the usability, overall performance, and effectiveness of education, and will provide a more pervasive experience for learners. Accordingly, e-learning environments and the related tools have been growing in complexity (Bouquet & Molinari, 2016) i.e., from learning management systems (LMS) based on centralized software architecture to clusters of Massive Open Online Courses (MOOCs) with platforms in cloud-based distributed architectures. The importance of technology as a driver for the future of education has been recognized in prior studies (e.g., Schuck, Aubusson, Burden, & Brindley, 2018), and TEL also seems to absorb the general current trends in IT, specifically disruptive technologies

Main findings and contributions

The main findings of this paper confirmed the research line of this dissertation. We are in need of a profound re-design of LMSs. The investigation outlines the main lines of evolution and structural changes of e-learning platforms conditioned by these new technologies. Some software architectural changes and evolutions according to the advent of big data and cognitive computing are presented together with the importance of having a platform able to integrate adaptive technologies that understand the context, usage of language, expectations, and background of learners, and consequently adapt from the interaction style to the material provided, from the pace of the lectures to the interaction with trainers.

We can now see examples in our lives, such as cognitive computing services present in interactions with websites, using interfaces and assistants such as chatbots, building, connecting, deploying, and managing intelligent bots to interact naturally with various educational environments. We interact with machinery that apply sophisticated decision-making processes with very low time constraints and high accuracy. E-learning is one of the fields of application that can most benefit from this due to its complexity and the variety of disciplines that must be adopted concurrently to achieve good learning outcomes. The use of big data strongly empowers the process of personalization and individualization of learning processes. These aspects strengthen the research question about the need for a new generation of TEL platforms. The paper introduces the vision of a self-made, highly customizable virtual community platform, integrated with scalable, state of the art cloud platforms and cognitive algorithms applied to the different parts of learning processes, from material selection to educational path suggestions, from peer evaluation to big data discovery for decision-makers. The process is still in its infancy, mainly because these worlds (TEL platforms, Cloud services, and cognitive computing) are still separated and focused on their respective scopes. The authors are trying to merge the three disciplines/areas into one research area with precise objectives and deliverables, thus allowing e-learning to maximize the advantages of fusion. The paper presents some early ideas to work on and briefly summarizes the role of the Italian Cognitive Computing association as a driver of innovation, collector of chances, and stimulator of new research.

4.3 Paper 3: Coccoli M., Maresca P., Molinari A. (2019). Collaborative E-Learning Environments with Cognitive Computing and Big Data.

Objective

The paper aims to analyze the actual scenario of e-learning environments and techniques, a fast-changing environment, from both the technology side and the users' perspective. Methodologies, applications, and services are evolving rapidly after recent innovations, thus adopting distributed cloud architectures to provide the most advanced solutions. Two influential technological factors are emerging from this scenario. The first scenario is cognitive computing, which can provide learners and teachers with innovative services that enhance learning and introduce improvements in human-machine interactions. The second scenario analyzed in this paper is a new wave of big data derived from heterogeneous sources, impacting educational tasks and enabling new analytics-based models for both management activities and education tasks. Concurrently, for learning techniques, these phenomena are revamping collaborative models, thus providing further evidence to one pillar of this dissertation, i.e., the need to change the foundational metaphor of LMSs from classrooms to communities and to redesign them profoundly. The paper outlines the evolutionary trends of Technology-Enhanced Learning (TEL) environments and presents the results achieved based on the experiences carried of two Italian universities.

Main findings and contributions

The paper finds evidence about the turning point we are at today in e-learning. Cognitive-computing-based approaches significantly transform many aspects of our lives, and e-learning platforms are not immune to this change. We can notice this crossover in professional applications and high-end software and legacy systems: cognitive computing services applying sophisticated decision-making processes with shallow time constraints and high accuracy. E-learning is one of the fields of application that can most benefit from this situation, due to its complexity and to the variety of disciplines that must be adopted concurrently to achieve good learning outcomes. The bibliography analysis and several proof-of-concepts documented in the paper demonstrate how the use of big data could strongly empower the process of personalization and individualization of the learning process.

Moreover, e-learning is also called upon to provide suitable solutions for learning to use and exploit such new technologies, which cannot be achieved in environments designed for generic purposes. This conclusion raises (again) the problem highlighted in this dissertation, i.e., the need for a new generation of TEL platforms. The two experiences presented in the paper can be regarded as an embryo for developing future, unpredictable e-learning solutions. To this aim, the results achieved while using the integrated environment for exponential learning which we deployed, convinced us to scale the process up on a broader and even younger audience to test the true simplicity of such a TEL environment. Other findings relate to the fact that the surrounding world has become so complex and rapid changes that educational stakeholders will never waste precious time installing software, configuring applications, customizing solutions, tuning databases, maintaining laboratories, etc. Students and teachers must devote their intellectual power to more creative and less repetitive activities. Accordingly, LMSs will have to provide more advanced cognitive services and the best available information, mixing data from different online sources.

4.4 Paper 4: Molinari, A. (2015). Designing Learning Objects for Italian Public Administration: A Case Study

Objective

The objective of this paper was to present the application of a virtual community-based LMS as a real case through a long-term project (5 years) that dealt primarily with problems related to educational materials production and the standards needed for producing educational content in public administrations. This aspect is relevant because competencies and courses for public employees must be certified for their carriers' progressions. There has undoubtedly been some reluctance towards e-Learning because of low trust in this means of education with respect to fake certification of attendance. Specifically, this research aims to analyze the effectiveness of SCORM-based e-learning material as this has recently become mandatory in the Italian Public Administration, thus forcing innovation through dematerialization processes. This innovation involves millions of Italian citizens and companies that now have the opportunity to interact with public bodies more efficiently and effectively. Nevertheless, neither the public administration nor most companies (especially small and medium-sized enterprises) were ready for this radical change in e-learning. A significant effort in producing educational materials and integrating the LMS has been made to allow end-users to absorb concepts, tools, methods, and procedures that take advantage of citizen-to-government and business-to-government communication.

Main findings and contributions

The research demonstrated the centrality of integrating an LMS with the rest of an information system, in this case, a Human Resource Management and Identity Management System. Furthermore, it presents a successful experience of designing, creating, and delivering distance learning materials designed for these purposes, together with the best practices and lessons learned. As the main findings of the research, there are clear indications about best practices to be used in conducting these projects for pervasive e-learning applied to public administrations and in building the respective learning objects for contexts. A first recommendation is that particular attention should be applied to the micro-design of the contents, scheduling single items in a very fine-grained way instead of providing non-specific, long sequences of concepts and contents. A second element relates to the positive effects of using a virtual community that was shown to be a better container for eLearning tasks. This result is similar to other successful experiences, like other authors mentioned in the paper. A virtual community was created for each edition of a set of courses (50 companies at the time), limiting access to members and key stakeholders to increase the quality of the final results. The study found that a platform structurally designed to implement the idea of a virtual community is recommended outside traditional academic contexts rather than simply managing a classroom or training event. Another crucial result refers to how the remuneration of the actors involved (teachers, content experts, e-tutors) should be calculated not to depress the interest of these actors in the e-learning market. The experience led to creating a cost model designed explicitly for eLearning by evaluating the time spent producing learning objects. The production of learning objects has encountered a great deal of resistance from teachers. Finally, the paper provided clear evidence of the role of lifelong learning, providing companies with a perspective of permanent training helping them follow the pace of innovation that the Italian public administration has started. This result implies the need to design a path that includes migration of many of the training, information and updating activities of the main stakeholder of the project towards e-learning materials and virtual community platform, thus guaranteeing companies the possibility of staying up to date.

4.5 Paper 5: Bouquet P., Molinari A. (2016). A New Approach to the Use of Semantic Technologies on E-Learning Platforms

Objective

This paper explores the possible integration of semantic technologies with e-learning platforms. Semantic technologies have been studied and used in different areas of computer science. E-learning has been one of these, but the most frequent semantic technologies in this discipline has been extracting and indexing contents such as forums, blogs, learning objects, etc. The research aims to take advantage of semantic technologies differently from the mainstream use done in the past. This new approach refers to using semantic technologies to manage the persistence layer of learning management systems (LMS), i.e. where all the contents are stored. The idea of is to use semantics technologies as a support, if not an entire replacement, for the backend and persistence mechanisms of LMSs. The testbed has been the design and the application of this approach to the persistence layer of a Virtual Communities System, where these technologies address two fundamental issues: a) entities disambiguation and identification inside the persisted objects b) adding new features to the platform without refactoring it.

Main findings and contributions

The paper presents some experiments on how semantic technologies could be coupled with e-learning software, with some final considerations about the application of semantic technologies on our collaboration platform that, thanks to the metaphor of virtual communities, facilitated this kind of integration and evolution. The early implementation revealed two of the most interesting aspects we wanted to test, i.e., the ease of implementing and/or new functionalities of a software platform when semantic technologies are wisely integrated with them. A partial objective was to identify issues that could be generalized to any initiative to extend a software platform. The idea was to put semantic technologies aside from traditional development technologies, identify content entities, and use persistent identifiers to store their unique ID from an entities' central repository called an ENS. Some further investigations emerged as necessary to achieve a clear vision of the pros and cons of this approach, specifically regarding sustainability and investments in re-factoring e-learning applications and general software applications. A second aspect that emerged from this research was semantic persistence layers' performance. Intensive tests were conducted using the same big data-oriented technologies (Hadoop, Hbase, Flink etc.) but in different contexts where a big data range of operation is required. As the results were encouraging, we conducted some preliminary tests with the knowledge base in the virtual community platform. Another item regarded the exact moment to align the database and the semantic store if some management operations are available to the public. Finally, the potential that semantic technologies could provide for e-learning and collaboration is vast, but the problem here is the usability of content and services. Enriched by these semantic functionalities and contents, the risk is that they could become too complex to be understood and, therefore, unusable. A great help will come from semantic tools for data visualization and navigation.

4.6 Paper 6: Casagranda, M. , Colazzo, L. , Molinari, A. (2014). Estimating the Effort in the Development of Distance Learning Paths

Objective

This paper is devoted to supporting the ecosystem of LMSs with a model for better understanding the ratio between costs, production of didactic material, and the activity of monitoring and facilitating e-learning tasks. The quantification of the effort required to produce e-learning material has always been subject to the proposal of some "magic numbers" not supported by a method or analytical data. This paper proposes a method for calculating the effort required to design and develop e-learning paths, which is an essential contribution to the development of the e-learning sector. Qualified teachers and tutors may be put off participating in e-learning initiatives, given a) the number of hours to be dedicated to the various activities; b) the loss of income upon the repetition of the e-learning editions; and c) the complications linked to the use of unknown instruments and technologies. The proposed model aimed to be a reference point for professionals working on developing content in their estimation of costs linked to the design and development of learning materials, providing a calculation basis that considers several methodological approaches and educational objectives.

Main findings and contributions

The model is based on systematically gathering data regarding the three main actors involved: teachers, tutors, and instructional designers. Data was collected from a series of e-learning projects carried out over five years using the LMS at the center of this dissertation. In the first two years, ex-post data on design and development times was collected, including various teaching methodologies. In the following years, critical variables which allowed a possible costing model to be abstracted and generalized were monitored.

We attempted to address the problem of calculating the total number of hours worked by all the actors, providing a general framework for this complex calculation (regarding the number of variables and situations to be considered). The encouraging outcomes of this research primarily result from the lack of an adequate model for standardizing the measurement of the effort required to create online material. This lack of models leads instructors to receive inadequate compensation for their work. We believe that the lack of this calculation could be one of the possible factors that could slow the spread of distance learning. Using multipliers and reference tables that have been trialed in the field in some revealing projects, our model calculates the number of hours worked by the creators of distance learning courses to be recognized against the number of hours scheduled for the online course. Most of the trials/experiments with this model were carried out under the auspices of the DL program of the Autonomous Province of Trento and the University of Trento, where we applied the model to a set of 37 editions of different courses. The model, even if subject to improvements and integrations that followed this research, has shown a few advantages that encourage us to carry on the research:

- the clarity in calculating the acknowledged hours: the teacher “undergoes” the parametrization of the model yet contributes to their evaluation and has a direct match after the production phase
- predictability of costs in the yearly budget phase: the organization can classify “ex-ante” the courses that it intends to offer, categorize them according to the parameters of the model, and precisely estimate the cost of the various e-learning initiatives without having to resort to less “stimulating” models for the actors and while having a precise idea of the expenditure
- comparability of costs regarding course editions that end up in the same boxes of the model
- the clarity in the temporal engagements taken on and the implementation modality on behalf of the actors. Roles of teacher/tutor can be precisely defined, as well as instruments to be used and time needed to dedicate to these activities
- more profitability for teacher and tutor compared to traditional costing models: doubtlessly an element of motivation for the same to participate in e-learning initiatives

Our results were highly encouraging and showed a deviation of about 10% between the “ex-ante” calculation based on the a priori application of the suggested parameters and the “ex-post” statement of accounts (allowing an a posteriori evaluation of the hypothesis) based on the systematic gathering of data from the roles involved (teachers, tutors, instructional designers, etc.). Further experiments are needed to confirm or adjust the multipliers stated in the model, especially regarding new media and educational models and approaches.

4.7 Paper 7: Bouquet P., Molinari A. (2019). Sport, Dual Carriers and Education: The E-Learning Way

Objective

This paper presents another extended project in which the use of a virtual community system has been of help in maximizing the effects of e-learning tasks, demonstrating much higher flexibility and adaption to different needs compared to those addressed by traditional LMSs. Athletes involved in professional sports often face challenges combining their sporting ambitions with education. Very demanding, intensive training sessions and competitions at home or abroad cannot easily be combined with sufficient involvement in academic activities, not only in terms of results but especially in terms of levels of motivation, commitment, resilience, and responsibility from the athlete. A possible solution could be the support provided by e-learning services, which most universities have in operation today. Unfortunately, standard e-learning services are forged for “regular” students and not for people never attending courses, never participating in the university’s social life, never reading push or pull information coming from the institution, or never living an academic life and never having contact with respective course mates. This paper presents the results of a project that used an LMS based on virtual communities to answer the needs of this category of students. The aim was to support and stimulate their academic careers through innovative services to solve the above problems. On this basis, the project aimed to design and deliver the same services for a broader category of users, i.e. working students with very similar (if not identical) problems and whose university support is not as high as it should be.

Main findings and contributions

The three-year project did not only produce results to fulfill its objectives. It has also produced or improved many new services inside the virtual community LMS. It, therefore, summarized the results from almost a decade of research and investments in extending the platform and applying it to real-world contexts. This project witnessed how vital it is to have an idea of a community behind an LMS, thus allowing a long list of services for the specific target (athletes) to be reused in many other contexts unrelated to sports. The platform has benefitted from these services, with all the other communities and community members in different contexts and in other installations available for institutions that have adopted this platform.

This long-term research has added value to the research field. The services can be devoted to users who cannot be at the same time/place of the event, such as a) Erasmus students; b) participants in exchange activities abroad; c) students who take part in business games, marketing games etc.; d) people participating in workgroups, or local laboratories; and e) teams related to evaluation tasks. The pandemic demonstrated the usefulness of these services. It is not strange to see non-educational tools such as Microsoft Teams ™ becoming a pillar inside educational institutions, where the concept of “team” totally resembles the idea of “community”.

Here is the list of services reinforcing the idea of an LMS based on a “community” rather than a “class”:

- Online student registration for exams, events, and meetings with the contemporary creation of a videoconferencing session with all and only the participants to that event;
- Adaptation of existing services for delivering MOOCs specifically created for these students. It implied the provision of support services, such as the organization of shifts for MOOC tutors, the possibility of booking direct assistance sessions, or the semi-automatic composition of FAQs based on the questions entered in the forums;
- Services to allow remote examinations together with the related administrative processes, such as remote student identification, visual check of the absence of any auxiliary material in a remote room, and any other element (for example, double webcam) able to provide legal validity for a remote (or otherwise) exam session. These services became fairly standard during the pandemic but were not available at the time, and not all of them

were explicitly organized for remote examination inside the videoconferencing tools; Information on regulations, schedules, appointments, examinations, administrative deadlines, etc. is taken from an RSS feed available from certified sources, other platforms, or applications (for example, the ERP where all grades and exams' dates are recorded);

- Self-organizing study communities to support remote students, without any intermediation by teachers, where students are allowed to manage any aspect and where most of the services are focused on providing educational material to the participants;
- Online tutoring with the possibility (similar to the remote exam) to book the service, see the tutor's agenda, share materials only for that session, etc. This service has been the most challenging component of the project but probably the one that will solve most of the practical problems of student-athletes;
- Services available to registered users for conducting remote exercises with some other member of the same community, collecting results and comments or personalized feedback from other community members;
- Services that support students in complying with administrative obligations through a personalized agenda are updated in push mode with appropriate reminders. These reminders will be delivered through social extensions that exploit virtual communities and related services (doodle, reservations, VC, sharing documents, forums, bulletin boards, messaging, etc.).
- Delivering innovative training practices (e.g., serious games, business games) in order to run the game in an environment and acquire the analytics necessary for the trainers;

Due to the number of services added to the platform and their re-use inside other contexts, this project well represents the practical achievements of this dissertation.

4.8 Paper 8: P. Bouquet, A. Molinari (2019. E-learning and Project Management: Adding New Features to Learning Management Systems

Objective

This paper pertains to the research area of adding project management services to LMSs. Frequently, educational tasks are mixed with project management tasks: from managing educational paths to following a thesis student, from preparing an exam to organizing a team of students working on a project. Nevertheless, no project management services can be found in most modern LMSs. The paper aims to demonstrate how virtual communities implemented inside an LMS can provide an advantage for its users. For example, managing appointments, deadlines, milestones, etc. for a particular case of a university student inspired some unique features of mobile applications associated with the LMS. The paper describes how our software platform, traditionally used for e-learning activities, was equipped with a fully-fledged set of tools compatible with the most used project management standards, including task planning, costs, and resource management functionalities.

Main findings and contributions

The paper describes the results of implementing project management functionalities for users of learning management systems. Managing tasks within an educational environment show a series of constraints and issues that need to be managed with appropriate tools, like those supplied by project management. Virtual communities provide participants with a set of features to a) manage the entire lifecycle of a project; b) create tasks using the Work Breakdown Structure and Critical Path Method tools to define scope and plan tasks' sequences; c) assign resources and control costs associated to a project, with a combination of role-permission to a level that can properly administer the security, confidentiality and privacy of the activities; d) extract any needed report from the platform; and e) including people in the project by simply enrolling them into the community associated with the project. The integration of these features within a typical e-learning platform guarantees the enlargement of the application fields of LMSs, allowing them to be used not only for traditional educational activities but also for more collaboration and cooperation-oriented tasks. Another contribution is the idea that project management is heavily based on collaboration and shared services, so an LMS, if properly adapted, could be a very positive integration for project managers.

4.9 Paper 9: Maresca A., Molinari A. (2018). Implications of learning Environments on the Information Systems of Educational institutions.

Objective

The paper summarizes the evolution of LMSs, focusing on their capabilities to react to new stimuli from end-users which may require deeper integration with the hosting information system. The focus is on customized platforms and their capabilities to perform better in a collaboration context rather than as a general-purpose LMS. The research wanted to collect empirical evidence that when learning processes are not isolated islands inside the information system but core components of internal processes, LMSs provide much higher rigidity and total cost of ownership. The objective was to support the idea that, in contrast, a customized platform, where the source code has been developed internally, could make an ROI precisely in these situations, furthermore providing extra advantages such as a) seamless integration with the rest of the information system; b) more outstanding customization capabilities; and c) much higher flexibility in adapting educational processes to the changing organizational needs.

Main findings and contributions

The paper uses the virtual community platform created and developed as a reference point over the years, compared with the different current solutions to support educational processes. The platform is oriented towards supporting collaborative processes, where e-learning is one of the most important but not the only process. New services supporting collaboration in different ways are constantly added. From our experimentation, it is clear that an e-learning platform is not an external system concerning the rest of the information system. It is a crucial component for any organization, providing appropriate and valuable services to a plethora of diversified users that bring different needs and expectations. When such a platform enters an organization, its effects is immediately visible:

- Needs for integration with sub-systems existing in the organization: for instance, integration with the single-sign-on system implemented in the company;
- Overlapping platform functionalities with pre-existing functionalities in the organization's information system. Examples include document repository, mailing distribution, virtual room management, forum, etc.;
- Competition with possible new systems entering the organization, mainly due to the Web

2.0 functionalities that nowadays most of the companies intend to implement, and that usually, any (serious) LMS can supply;
- They are partially overlapping and in competition with some functionalities already present, somewhere in some software.

The paper examines these radical changes in technology and business needs for an educational institution. The answer is an extension of the foundational paradigm of the platform, shifting from classrooms to communities. The paper also presents some arguments about an element of standard LMSs that we label “boring uniformity”. Most institutions that adopt mainstream LMS such as Moodle™ are stuck with the LMS’s layout in the default installation. Any deeper customization of the layout finds the same roadblocks seen before. This leads to a “boring” uniformity of most of the LMS’s installations. The argumentation deals with the empty spaces left by the approach carried out by LMSs for a significant part of the TEL market, where new customized services for new educational processes and approaches are needed, well-integrated with the rest of the information system.

Finally, the paper analyzes the over-emphasis on the capabilities of customization of free/open-source LMSs. LMSs are a considerable software effort, and anyone who has written a single line of code knows the possibility for an external person to safely and consciously put their hands inside this mass of code. Therefore, when people claim “we have customized our LMS”, they often refer to some CSS style changes of visual aspects, labels, logos, menus, and very few other things. Real customization means, for example, changing the structure of a database table to add information coming from another component of the organization’s information system, connecting the two systems and creating this connection bi-directionally. Virtual community-based LMSs are much more flexible for adding features or integrating with the rest of the information system. Indeed, it is widely known and comprehensible from the LMS maintenance team’s perspective that many roadblocks to (even) modest customization must be placed to avoid instability and incompatibility situations. This forces ICT teams to consider the forking of the entire platform as an alternative. Forking is the last resort for any institution, and the main reason the presented virtual community platform found some believers is mainly due to this element.

4.10 Paper 10: Molinari A (2017). Learning Management Systems and the Integration with Social Media Services: A Case study

Objective

LMSs have reached a very high level of maturity, providing professional solutions to mostly any educational need for distance collaboration. This paper analyzes how LMSs should evolve in terms of functionalities and services provided to users in the future. Specifically, the paper wants to foresee the extension of virtual communities to the natural terrain, i.e., the collaboration services, where virtual learning environments should be mixed with typical Computer Supported Collaborative Work (CSCW) tools and approaches that put collaboration at the heart of the system. Nevertheless, traditional e-learning services should also be improved with additions coming exactly from this integration with cooperative/collaborative services. The services provided by the platform have been tested in various learning settings, from high-school students to university students, to professional participants to blended courses and finally to public servants changing their traditional way of having learning sessions. In the paper, the role of social media-related services in the platform is analyzed, and some practical results were derived from the comparison between educational services provided by social media and social media services provided by an e-learning platform.

Main findings and contributions

With empirical evidence, the main findings presented in the paper relate to how a modern LMS should provide features inherited or simply copied by social media interaction style and should customize and actualize these features into educational contexts. The contribution is analyzing services provided in the virtual community platform, a forefather of modern social media. Over the years, interesting suggestions have been collected through various implementations in academic and industrial contexts and (at the time of writing) 150,000+ users. First of all, it seems that for educational settings, LMSs enriched with specific features from social media are better than adaptions/customizations of social media. Second, services on social media platforms are by far better and more usable than those available in LMSs, but less profitable for educational purposes. A very nice service such as the wall (in Facebook) is undoubtedly more charming for personal/recreational usage. However, more effective and attractive service for educational stakeholders be a specific "educational path", especially for learners. Third, LMSs should not delegate social tasks inside educational contexts to external platforms like social media. An integrated educational setting seems more efficient (even though less attractive) for learners, who probably do not want to be distracted by many disturbing elements working on their training tasks.

4.11 Paper 11: Molinari A, Bouquet P (2016). Big data and the Impact on an E-Learning Platform: A Case Study

Objective

The paper presents a re-design proposal and mechanisms to refactor the persistence of an LMS layer to collect volumes of data compatible with big data tools and technologies. The focus is on the virtual community platform used in this dissertation as a testbed. The objectives are the analysis and experimentation of architectural and software solutions to start moving towards the big data field, with an explanation a) of the technologies chosen; b) the changes in the architecture of the application; and c) the (big data) analytic tool for the real-time analysis of users performances while highlighting some related issues.

Main findings and contributions

The main findings are related to the analysis of several elements of data gathering and manipulation that push any virtual learning environment toward big data, and that increase the need for a structural change of LMS architecture:

a) Traditional weblogs, when the application is a web-based software
b) Internal logs of usage of the platform, the so-called "digital breadcrumbs", that track the learner's journey throughout the entire learning experience;
c) Mobile logs, where data about mobile learning actions are collected;
d) Service logs of users' actions on the different elements of the platform such as documents, forums, blogs, FAQs etc.;
e) Logs from the SCORM player and the records of the execution of SCORM objects;
f) Tin-CAN API calls, in case the platform is connected or acting as a Learning Record Store (LRS);
g) Massive Open Online Courses (MOOCs), by definition generators of high volumes of data;
h) Life-long learning, an old buzzword of e-learning that is still valid and interesting

and, most of all, is another generator of big data, specifically along time;

i) Serious games that use materials inside the platform thus generating a relevant dataset related to the users' performance.

These areas reveal a dramatic need for a structural change in LMS architecture towards approaches and technologies connected with big data. The paper presents some ideas and proof-of-concept prototypes, where the adoption of an entity-centric vision of persistence, the use of ontologies as domain descriptors, and the shift from traditional DBMSs to NOSQL, graph-based storage systems have been foreseen.

4.12 Paper 12: Molinari A. (2015). Supporting Decision-Making Processes in Virtual Learning Environments

Objective

The paper aimed to introduce decision-making tools and techniques inside e-learning settings. Compared to the traditional Decision Support Systems (DSS) area, a different perspective of integrating DSS-based tools and the organization's information system is proposed. There are trivial examples of usage of DSS tools inside learning contexts, like the evaluation processes performed for educational purposes. However, other uses of DSS-based tools are less trivial, although advantageous. This usefulness is evident when the learning environment supports educational tasks and collaborative and community-based processes. Examples of this integration are evaluating the candidates for a job position, supporting evaluators in a public tender, evaluating project proposals uploaded in the platform, assigning prize respect to documents uploaded in a forum, evaluating the best contribution for a wiki item etc. The paper wanted to analyze how these advanced decision-making processes could be integrated inside e-learning settings to support educational processes and how a virtual community approach could allow users to switch from traditional learning/training tasks to decision-supported tasks.

Main findings and contributions

This paper contributed to the discipline with several ideas where a single DSS-related topic has not been proposed in a collaborative, virtual community environment. The virtual community platform has been used and experimented with in various collaboration contexts, not only academic ones. These DSS-based tools have been extensively used in the Local Development Agency's multi-expert, multi-criteria decision-making process to evaluate projects' proposals. Various tools have been provided to the end-user (the expert/evaluator) in order to help them:

a) to aggregate grades/votes/likes and any other form of evaluation expression using a richer set of mathematical tools, even when these grades were expressed using linguistic operators;
b) to aggregate evaluations from experts with different backgrounds and initial positions, using a consensus management tool that provided a more shared evaluation process.

The most remarkable novelty is a mixed procedure that combines individual ranking (as carried in a multi-attribute setting by each member of a group of experts) with a linear-constrained optimization process, whose purpose is to determine a distance-based group consensual ranking. This approach could be reused and applied in our platform's different collaborative contexts and services, thus extending LMS's possibilities outside the strict learning environment. This approach allowed us to integrate the platform inside institutions' information systems not just as a tool supporting e-learning but as an integrated tool supporting collaboration and cooperation processes

4.13 Summary of Publications 1-12

The contribution of the individual papers are summarized in Table 2.

Paper N.	**Objective**	**Main Results**
1	Designing, implementing, and testing an advanced version of project management services and complex, real-world projects.	Successful design, implementation, and test of a new set of professional project management services for an LMS. Tested with professional project managers on complex, real-world projects
2	Introduces the vision of integrating a self-made, highly customizable virtual community platform with scalable cloud platforms and congruent cognitive algorithms applied to the different parts of learning processes.	Results of this exploration are still preliminary, mainly because the three investigated worlds (TEL platforms, cloud services, and cognitive computing) are still separated and primarily focus on their scope. Accordingly, the paper presents some early ideas on where to work. However, all these elements go in the direction foreseen in this thesis, i.e., it raises the problem of developing a new generation of TEL platforms.
3	Analyzing the compatibility of a Virtual Community System with new trends in e-learning, specifically exponential learning and life-long learning.	Test with groups of students of an innovative learning environment based on cognitive computing to implement exponential learning, reverting the typical master-slave approach that sees software platforms as masters and end-users as slaves.
4	Verifying the effectiveness and the costs related to an extensive use of SCORM-based learning objects in order to reach a wider audience using a virtual communities-based LMS.	Extensive delivery of e-learning materials to more than 70,000 users and excellent results obtained not only using e-learning as a substitute for traditional classroom activities, but also involving and motivating public servants directly in the creation of learning objects.
5	Exploring the use of semantic technologies in the management of the persistence layer of LMSs.	Design an application ontology related to the LMS domain, implementation of a proof of concept for applying a semantic persistence layer using top-notch technologies and solutions, creation of a knowledge graph for a few sub-domains of the whole LMS domain.
6	Creating a model for the quantification of the effort required to produce and deliver e-learning	The model has been adopted in practical projects to determine the appropriate payment for teachers and content producers, being

	materials. E-learning material.	substantially one of the very few models currently existing. For the validation of the actual costs, the LMS used during this thesis was successfully and quickly adapted, thus demonstrating the need for integration, customization, and re-engineering of an LMS.
7	Presentation of a special project that customized the existing Virtual Community System to the needs of special categories of students that are not constantly involved in academic tasks.	New specific services for special categories of students have been designed, implemented, and tested. The outcome is particularly relevant because a) it involved dual-carriers students and b) services can be easily extended to working students, a much larger audience interested in following academic studies.
8	Demonstrating the validity of equipping an LMS with high quality project management services	Successful design and implementation of a fully-fledged, professional set of project management services, in line with mainstream applications, create a sort of unicum for the LMS market of LMSs. Tested with professional project managers
9	Analysis of how LMSs should evolve in terms of functionalities, services, and in terms of integration with the hosting information system	Presentation of the (primary) services that could be provided by an (extended) LMS based on virtual community management to the rest of the information system's users and platforms
10	Recap of a long-term experience in the integration of social media services within an LMS.	Design, implementation, and tests with approx. 150,000 users of social media services, and a comparison of their usage and their validity with major social media platforms (Facebook).
11	Designing and implementing a big data enabled LMS.	Successful design and implementation of a proof-of-concept that tested the feasibility of a big data enabled persistence layer and the integration of big data system software with the LMS
12	Extending LMSs with decision-making tools and techniques	Design, creation, and integration of various DSS tools inside the LMS. Tested in a real-world scenario, specifically public tenders, students admission to degrees, evaluation of offers.

5. Discussion and Conclusions

This research focuses on the evolution of learning management systems. The main objective has been to design, create and test a more collaborative environment with respect to mainstream LMSs, more integrated inside the information system, providing and receiving a more extensive set of integrated services to a broader audience than the pure-educational interested one. A literature review was conducted, a profound re-design and refactoring of an in-house LMS was carried out, and long-term experimentation with different groups of users, information systems, and stakeholders was implemented. This implied collecting many results across eight years for this dissertation and more than 20 years of field projects.

This long-term experience presents some results that could be useful for the three research fields involved, i.e., software engineering, information systems and technology-enhanced learning. In a sense, the analysis of these three fields combined in a single study is to our knowledge, unique. Not many studies have attempted to re-think the foundational principles and software architecture of one of the most used (especially due to the pandemic) software platforms included in an organization's information system, i.e., an LMS.

There is a sort of assumption of the LMS market, solutions, and vendors that what is available today represents the needs of the educational sector. The research in TEL focuses on experimenting with new ideas on existing platforms (mainly Moodle™ and Sakai™) but without proposing any foundational re-engineering. They are "satisfied" by what these (excellent) platforms provide, probably because, in terms of research, the myth of software reuse is sometimes stopping innovation. Especially in educational contexts, it is much easier and cheaper to adopt consolidated platforms like Moodle™, rather than creating a new one, due to the significant investments needed. In the end, many chief educational officers (or any Education decision maker) consider software platforms like Moodle™ to be "good enough" for most of educational needs. Teachers and students mainly need the platform, it is solid and well-known, which does not stimulate the exploration of new software for new educational tasks. This fact, combined with the availability of other free tools for the most common collaboration tasks (such as sharing files, micro-blogging, and content delivery), stops any stimulus to extend LMS use outside purely educational contexts. It was the author's situation for more than 20 years of research in the TEL field. This lack of a boost in research was emphasized during the pandemic due to the activities of software giants like Microsoft ™ and Google™ that provide their all-in-one solutions (Teams™ and Meet/Classroom™) to the educational world for everything related to computer-mediated communication (education included).

The author objectively found himself in a fortunate situation: a) being a first mover in the direction of new TEL platforms; b) having vast public sponsorship for the creation from scratch of a new, multi-purpose platform for collaboration; and c) riding the idea of not succumbing to the dictatorship of Moodle™. This advantageous position probably allowed to explore new multi-research territories that others did not have the opportunity to do.

We want to clarify that this claim is not á presumption but a mere analysis of the history that happened to the research team that the author had the burden and the honor of directing. As said, it is not very common to have the opportunity to manage a software team of approximately fifty developers entirely focused on (re)engineering a new platform based on the idea of a virtual community. Therefore, these findings could be considered original and relevant not necessarily because of the author's merits but also because of the context in which this research has been conducted.

Having clarified the anomalous characteristics of the work that generated its uniqueness, it is not surprising that the author found himself in the strange position of being "out of the pack" when discussing TEL and software engineering in educational contexts. In many conferences, the research presentation was preceded by the affirmation of wanting to "de-Moodleize" the world. This provocation well represents the idea that due to a) the need for optimizing IT investments; b) the need for collaboration tools; and c) the increasing role of education inside organizations, LMSs should play a central role in corporate information systems, and that, at the same time, this has not been recognized and achieved because of the purely educational nature of state-of-the-art LMSs.

Platforms like Moodle™, Docebo™, Dokeus™, Sakay™, Webct™ have proven to be ineffective in contexts disconnected from education, raising the issue of the evolution of software platforms towards services that are not necessarily related to traditional academic tasks. No relevant literature has been found that goes in the same direction as the present research. Probably after the pandemic, the awareness of the potential of re-founded LMSs as providers of collaboration services to the whole corporate information system will appear as evidence. So hopefully more researchers will create a debate about a new generation of LMSs.

5.1 Answering the research questions

In addition to the practical objectives of redesigning and experimenting a new generation of LMSs based on the metaphor of a virtual community, three research questions were posed, whose answers are in the twelve publications presented in this dissertation.

The first research question was formulated: "Should an LMS be re-engineered to facilitate an advantageous integration with the rest of the information system, thus allowing a more significant and quicker ROI ?" This question was answered by the constant research, design, implementation, and testing of the "Online Community" software platform integrated with the information systems of a few customers of various projects that had this platform as the technological backend of collaboration activities. Most of the time, the potential integrable functionalities were available separately in other systems, thus generating two main concerns for ICT managers:

- The availability of duplicate functionalities, with respective problems of budget justification or removal of one of the duplicated systems;
- The integration of the different systems and the consequential costs of development and maintenance: single sign-on issues, data exchange, alignment, software compatibility, hardware, and software requirements.

The achieved integration proved efficient and improved the general satisfaction in the various projects. The market success of the platform confirmed this research intuition. The platform has been adopted outside educational and (even) academic contexts, so becoming an alternative to the mainstream, free, open source LMSs.

In the various papers on this area, different aspects have been analyzed. From various perspectives, when an LMS enters organizations, its effects are immediately visible:

- There is an evident need for integration with sub-systems existing in the organization: to mention the simplest ones, integration with the single-sign-on system implemented in the company;
- There are some overlapping functionalities between LMSs and pre-existing functionalities in the organization's information system. Examples include document repositories, mailing distribution, virtual room management, forums, etc.;
- We have found the evident competition of the LMS with possible new systems entering the organization, mainly because most of the companies intend to implement these functionalities and these functionalities are usually, already available in any (professional) LMS;
- There is a partial overlap and competition with some functionalities already present in some software. These are the most insidious aspects because none of the systems (LMSs and other information systems) can completely satisfy specific needs.

Integration is therefore needed in order to solve these conflicts and overlaps. Most if not all, services needed for collaboration are already available in an LMS. A typical example found is document sharing for groups. System administrators do not commonly appreciate this fact, and most of the time not accessible via the web. In this case, virtual communities are better candidates. The on-the-fly creation of a virtual community with a set of services available for the members is a perfect solution for many of these situations, not necessarily related to educational activities and so available to the rest of the information system.

The second research question was: "Which is the best conceptual and software architecture of an LMS to facilitate and improve collaboration and integration mechanisms with the rest of the information system?" The answer to this question has been tested not only during the year of the present research. It is based on more comprehensive research that was started back in 1998 by the author of this research inside the Laboratory of Maieutics at the University of Trento, where the author was responsible for the research and software development team.

The answer is that a radical change in the foundational architecture of an LMS is needed to achieve a profitable and extensible integration with the corporate information system. This software architecture change deals with the entire re-design of the persistence layer of the platform, where concepts like "teacher", "class", "course" etc. should be removed and substituted by structures that facilitate the creation of a more generalized collaboration environment. The pure adding of new services or rebranding them in a more collaborative direction was not possible because of the dependencies of these services on these foundational structures. At the same time, competition with other collaboration platforms is very tough nowadays, so adding educational services to an LMS has proved inefficient and insufficient.

In our vision, a virtual community is an enormous facilitator of this integration, supporting cooperative activities between users instead of just learning activities. This transformation requires a profound re-engineering of an LMS to prevent the risk of LMSs being progressively marginalized and non-specialistic, non-appropriated solutions replacing them and governing educational processes. The main, long-term, challenging research area has been the virtual community concept to validate this research direction. What concerns the idea of community, what a “community” represents for humans in our society, and the best way to transpose the concept of a “community” into the virtual world provided by software platforms has been a difficult challenge. Secondly, comprehending the phenomenon of social media related to educational environments and how to implement services of these platforms inside our LMS, to open the possibility of using it in more collaborative contexts, has been the other investigation area in answer to this research question. Again, the final users’ appreciation, especially from the IT departments that adopted this platform by sharing the idea of a virtual community outside the pure learning context, witnesses the positive results achieved in this research.

The last research question was: “What services should be added to an LMS to promote this integration, demonstrating the advantages of adopting an enriched LMS based on the virtual community metaphor as a pillar for any collaboration task? The answer to this question has been found through the extensive efforts of the research team towards implementing software services devoted to improving the appreciation of the virtual community platform by their stakeholders at any level, from students to team managers. The contribution of the author of this dissertation to this answer has been a) the analysis of user needs; b) the redesign of the architecture of the software; c) the management of the software team (composed by more than 30 developers during the period); and finally d) the management of user feedback. The author has directly made only a few contributions to the software writing process.

Many user requests about adding new services to the platform and ideas inside the research group have been implemented. Some of them have been wholly implemented for this research. In contrast, others have been implemented due to customer requests and are irrelevant to the research questions. The services that have been analyzed in this research touch various areas, but mainly they can be classified as follows:

- Time management services, specifically devoted to community members in order to facilitate their collaboration inside the boundaries of the community: post-it, to-do lists, schedule reminders, shared agenda among community members;
- Project management services, provided through a full-fledged project management platform for tasks, resources, and cost management, completely integrated with the rest of the virtual community services;
- Decision support services devoted to supporting educational services inside the platform: evaluation services, multi-criteria decision-making services, fuzzy evaluation methods, integration of linguistic operators inside evaluation services, consensual ranking tools for decision making;
- Social media-, community-oriented services mostly added as natural extensions of a “virtual community: blogs, forums, FAQs, curriculum sharing, community wall, self-assessment tools, questionnaires, surveys, and opinion polls;
- Integration services, where services available in the virtual community platform are at the disposal of users through a single-sign-on mechanism with: integrated communication, preservation of hierarchical relationships among corporate rules and communities’ relationships, file sharing, automatic enrollment to communities and sub-communities, community members’ management, propagation of community rights and roles management, integration with student management systems and grading systems;
- Purely educational services taking advantage of the virtual community metaphor, including a teacher and student register of tasks, community-based voting, educational

events booking, SCORM seamlessly integrated with community tasks, study plan management, credit management, educational path management with iterations and branches;
- Massive Open Online Course services, allowing the involvement and especially the management of the large volume of users, certification delivery, dashboards to control course progress, booking and agendas of the various events, and community members' special services (due to the potentially large number of participants);
- AI-related services, through experimentation with an entity-centric, ontology-based persistence layer where inference processes of (supervised) machine-learning have been tested.

5.2 Implications for the future generation of LMSs

This research's findings can have various implications for the software architectures of learning management systems. The first implication is of an architectural type. Implementing the software system to support educational processes has proved insufficient to expand the use of educational systems within an information system. It is precisely the architecture of modern LMSs based only on structural metaphors dedicated to education, limiting the architectural extension of these platforms.

The implication is that an LMS should radically change its architecture, introducing the idea of a virtual community to allow a significant expansion of the services that could be provided both for the educational field and for the collaboration of subjects mediated by technologies.

A second implication concerns integrating learning management systems within the corporate information system. The many experiments carried out in real projects with tens of thousands of users show a profitable integration between the two worlds that benefits both the educational processes and the processes of collaboration and integration within the information system itself.

A third implication concerns the technology-enhanced learning market. LMSs have dominated this market sector for a long time, but the advent of social media and mainstream videoconferencing platforms are seriously endangering this predominance. These alternatives to LMSs probably are not entirely inclusive of educational needs. However, they provide "good-enough" services of decidedly lower quality, overlapping (if not wholly substituting) LMSs. In the past, videoconferencing platforms were encapsulated within the LMS as a particular service. Now video conferencing platforms such as Microsoft Teams ™ or Zoom ™ have added a series of generic services that can also be used in simple educational contexts, thus determining substantial disuse of the e-learning platforms.

The radical change hypothesized as a conclusion of this research could contribute to a rebirth of LMSs and a cost optimization sustained by the organization for education and collaboration processes by increasing their ROI by providing educational and collaborative services. Indeed, it will not be easy for the e-learning platforms consolidated on the market to carry out such a technological reconversion and complex rethink of their software architecture. We refer to platforms used by hundreds of thousands or millions of users worldwide with substantial investments also made in their customization concerning corporate image or the specific needs of individual organizations. It is unrealistic to modify what is already consolidated today in the LMS arena. Thanks to the vast availability of open-source modules, today's software creation processes will not be so complex.

5.3 Limitations of the research

This research covers different technical and functional aspects of the vast area of technology-enhanced learning, spanning from foundational issues of LMSs to collaborative services to very technical aspects like the persistence layer of a modern, collaborative application. Even with the large set of research areas touched by this thesis, the duration of the research and the number of real-world users actively and daily using the implementation of the ideas presented reduces the limitations compared to the potential uncovered areas.

Nevertheless, this thesis has several limitations. One severe first limitation is the lack of complete experimentation of using AI-enabled services inside LMSs. Only a few proof-of-concept experiments have been conducted that have given interesting preliminary results but must be deepened with more extensive and comprehensive research, especially combining this research with the big data scenario.

The profound experimentation of big data scenarios in e-learning is a second limitation of the research done, not because of tools and techniques put in action during the research but because of the possibility of collecting real-world data that could contribute to simulating a big data scenario. Therefore, the potential for using big data in e-learning contexts has been explored only from a theoretical point of view. Only some experiments on tools and techniques have been conducted facing an amount of data in the order of half a terabyte, no more than this.

A third limitation relates to the DSS tools. What has been studied, designed, implemented, and tested in supporting multi-criteria, multi-expert decision makings has been highly appreciated and put into real-world usage by our end users. However, it has been tested only in academic and public contexts. Interesting evolutions of these services could have been outside these contexts, i.e., private contexts where these services could be used for many activities other than educational tasks: idea evaluation, product comparison, internal process evaluation, curriculum screening etc..

A final limitation of this research is the project management services. Even if the level of implementation largely satisfied the education project, this successful service is used mainly by people with no professional experience in managing projects. Tests revealed a high level of satisfaction but related to the previous absence of project management tools, mainly from users with no project management background. Due to this, we should further test the service with professionals who have certification in project management to increase the features of the part of the platform, specifically the cost and resource management features.

5.4 Suggestions for future research

This research demonstrates that extending LMSs with appropriate, generalized services focused on organizational aspects of collaboration rather than purely education can benefit an information system and its users. We can provide many different suggestions to proceed in this evolution of LMSs that we consider vital for the discipline of e-learning.

Expanding LMSs towards more collaborative services is a priority because it can benefit educational processes. Many valuable services typical of social media should be provided inside an LMS, and peer collaboration without specific educational roles (teacher, student, etc.) should be improved and institutionalized inside educational contexts. Removing the idea that state-of-the-art LMSs should mediate collaboration between educational and non-educational institutions' stakeholders is crucial.

Secondly, we had to explore better the internal structure of an educational platform, particularly the characteristics of its services and tools, especially looking at the structure of the persistence layer where data is stored following 20-year-old principles related only to educational contexts. Just to mention a few, from the first LMSs, we had so many revolutionary events and evolutions that demonstrated their limitations.

In this research, we have followed one possible path, starting from rethinking the platform's founding pillars and then re-writing the software components related to the research findings. Achieving this objective was not only a technical endeavor; it meant stimulating users to use the LMSs in different contexts and interactions, not only in education. Many educational institutions, especially single teachers, have relegated the LMS to a secondary role, implementing all their teaching activity on social media such as Facebook, WhatsApp, Instagram, or, recently, the leading video conferencing platforms like Teams™, Zoom™ or Meet™.

We witnessed the emersion of new phenomena not always under the control of educational stakeholders and not even of ICT researchers and managers: a) new educational models (MOOCs and flipped classrooms, just to mention two examples); b) new collaboration tools and languages (social media); c) new competitors for LMSs (social media tools, videoconferencing platforms, cloud services); and d) new roles of technologies in our lives (due to the pandemic). These all are terrific stimuli for any researcher in e-learning as these themes are multi-disciplinary and inter-disciplinary questions. The common ground is the centrality of technologies in human life, an aspect that any researcher, instructor, and ICT manager should be concerned about.

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6. Appendix A: List of Publications not included in this thesis but published within this research

The paper **in bold** are classified in the Publications Forum (JUFO) rating system.

Publications in Journals

1. **Turchet L., Bouquet P., Molinari A., Fazekas G., The Smart Musical Instruments Ontology, Journal of Web Semantics, Volume 72, 2022, 100687, ISSN 1570-8268, https://doi.org/10.1016/j.websem.2021.100687.**
2. **Nikou S., Molinari A. Widén G.(2020) The interplay between literacy and digital technology: A fuzzy-set qualitative comparative analysis approach, Information Research Vol.25 No.4, 2020**
3. **Coccoli M., Maresca P., Molinari A. (2020) Smart Learning in Smart Cities, Journal of e-learning and Knowledge Society, Special Issue on "Smart Learning in Smart Cities" Volume 16, No 1 (2020), Published: May 15, 2020**
4. **Casagranda, M. , Colazzo, L. , Molinari, A. (2016), Using E-learning in the digital transformation of an Italian Public Administration, International Journal of Advancements in Mechanical and Aeronautical Engineering, Vol. 3, pp. 114-120 Issue 1 - ISSN 2372-4153**
5. Casagranda M, Colazzo L, Molinari A (2014). Distance Learning, public administration and business innovation: A case study. MONDO DIGITALE, ISSN: 1720-898X

Publications in Conference Proceedings

1. Molinari A., Towards a Project Management-Enabled Learning Environment: A Case Study (2021), in 27th International DMS Conference on Visualization and Visual Languages, pp. 104-110

2. Molinari A. (2019) Learning Environments and Social Applications: what's next?, Proceeding of International Conference on Psychology, Language and Teaching (ICPLT 2019) – DOI IIER.04042019.15253

3. Coccoli M., Maresca P., Molinari A. (2019) When e-learning Meets Cognitive Computing and Collaborative Environments, DMSVIVA 2019 -25th International DMS Conference on Visualization and Visual Languages, ISBN: 978-1-5108-9148-7, ISSN 2326-3318, July 8 - 9, 2019

4. Molinari A. (2018), Users involvement in Learning Communities: a case study, Proceedings of E-learn World Conference on E-learning, Las Vegas, NV October 15-18, 2018, pp. 1508–1516 ISBN: #978-1-939797-35-3

5. Westera W., Fernandez-Manjon B., Prada R., Star K., Molinari A., Heutelbeck D., Hollins P., Riestra R., Stefanov K. Kluijfhout E. (2018), The RAGE software portal: toward a serious game technologies marketplace, Proceeding of the International Games and Learning Alliance conference Conference (GALA 2018), Palermo, Italy, 5-7 December 2018, pp 277-286

6. Molinari A. (2018), The use of MOOCs (Massive Open Online Courses) in business education: an analysis of the state-of-the-art between myths and failures, Proceedings of the 2018 SIEC-ISBE internation conference, Reykjavik, June 2018, ISSN 2164-2877

7. Molinari A. (2017), Opportunities for Technology-Enhanced Learning in modern Public Administrations: between myth and reality, MARGI 2017, 3rd international conference on "Multidisciplinary academic research & global innovation", Beijing, 25-26 August 2017, ISBN: 978-969-9948-86-2

8. Maresca P., Molinari A., Stanganelli L. (2017), Smart Health And The Role Of Technology-Enhanced Learning: A Case Study, Proceedings of 10th annual International Conference of Education, Research and Innovation, Seville Nov. 2017, DOI: 10.21125/iceri.2017.0532, ISSN 2340-1095

9. Bouquet P., Molinari A. (2016) Using Semantic Technologies In e-learning Platforms: A Case Study. In Proceedings of the Eighth International Conference on e-learning in the Workplace (ICELW 2016). ISBN: 978-0-9827670-6-1, Columbia University, New York, 15-17 June 2016

10. Bortoli S., Bouquet P., Pompermaier F., Molinari A. (2016). Semantic big-data for tax assessment. In: SBD '16 Proceedings of the International Workshop on Semantic Big-data. New York, NY, USA:ACM New York, NY, USA, ISBN: 978-1-4503-4299-5, San Francisco, CA, USA, 01/07/2016, doi: 10.1145/2928294.2928297

11. Maresca P., Molinari A. (2016) Is e-learning ready for big-data? And how big-data would be useful to e-learning?. In: Proceedings - DMS 2016: 22nd International Conference on Distributed Multimedia Systems . ISBN: 9781510841284, Salerno, 25-26 Novembre 2106

12. Molinari A. (2016) Integrating Project Management Services And e-learning Platforms: Implications For Software Architectures, INTED 2016 - 10th annual International Technology, Education and Development Conference, Valencia,. 7 - 9 March 2016, ISBN: 978-84-608-5617-7 / ISSN: 2340-1079 Doi: 10.21125/inted.2016

13. Molinari A. (2015), Learning Management Systems To Support University Programmes: A Case Study. In: Eduvision 2015 - Modern approaches to teaching coming generation. ISBN: 9789619366240, Ljubijana, Slovenja, 3-4 december 2015

14. Molinari A. (2015), Collaboration Services As A New Perspective For e-learning Systems. In: Proceedings of MAC-ETL 2015 - Multidisciplinary Academic Conference on Education, Teaching and Learning . ISBN: 9788088085041, Prague, 4-6 december 2015

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Project Management and Learning Environments: a Case Study

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A B S T R A C T

The paper analyses the addition of project management features of an LMS, a topic that LMSs and collaboration platforms have entirely ignored. Many project management-like platforms are available today, especially riding the media wave of agile methodologies. The question is not surprising in itself, as managing time, costs, and resources linked to the discipline of Project Management, is historically a problematic issue for the IT world from a cultural, technical, and organizational point of view. The problem becomes even more complex if applied to the management of learning projects, where we have time, constraints, deadlines, costs, resources like in any other project. LMSs and, in general, collaboration platforms do not include these features, forcing users to link external platforms or adapt existing features (like simple to-do lists) to more complex Project Management tasks. In this work, we will present the tests conducted in a collaborative platform based on the metaphor of virtual learning communities. These tests were on a component developed explicitly for managing projects, activities, and resources, integrated inside the LMS with all the other services (blog, forum, file sharing, calendar, reminders, etc.). The introduction of this new component within the system addresses the need to manage collaborative activities between learners, providing a tool for managing and controlling the progress of the activities assigned to the various community members.

1 INTRODUCTION

This paper presents some services provided inside a virtual community platform as extensions towards managing the users' time, specifically teachers, students, and administrative personnel involved in educational tasks. These services are rarely available (if any) inside Learning Management Systems (LMS) or are simple tasks lists, to-do lists, or academic tasks scheduled in some workflow systems. Functionalities that provide support to (education) projects are something significantly different. Project Management is a well-established discipline, where we can find additional standards, guidelines, and certification processes provided by worldwide organizations. The advent of web platforms claiming to provide Project Management services has changed the scenario, with a lot of competition in Project Management services. If we aim to provide a Project Management approach to the conduction of educational activities, we find different solutions: a) "traditional" Project Management platforms, fully equipped with standardized services for scope, time, cost, and resource management, but with a lack of support to collaboration and social processes inside project teams b) a lot of web platforms that support collaboration processes [1] and claim to support Project Management processes but that are not very efficient in this sense, lacking basic mechanisms like critical path method (CPM), timesheet cost and resource management, milestones, constraints, deadlines, etc. [2]

This paper explores what should be needed, in the author's opinion, inside a Learning Management System and inside educational contexts to support the many activities that fall into the definition of "project" [3]. We designed and realized a set of services oriented explicitly towards the Project Management concepts and methodological tool and added them to a virtual community platform (with all essential collaboration, social media-oriented services). From providing

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traditional collaboration, education-oriented services, the platform has been extended to a fully-fledged set of tools compatible with the most used Project Management standards, including task planning, costs, and resource management functionalities.

Since the advent of open-source LMSs, Technology-Enhanced Learning (TEL) is a consolidated research topic. A lot of tools and techniques are available for creating, delivering, and managing online educational paths with plenty of solutions for every educational institution. What is less known in the technological solutions that support our daily educational tasks is integrating with Project Management tools and techniques to manage tasks, resources, and costs within educational settings. We can find a plethora of platforms and cloud services available today, even for free, that support at different level activities related to a project. Implementing Project Management suggestions inside educational processes forces teachers or students to exit from the learning environment (for example, Moodle, Forma.LMS or Sakai LMSs), and use an external platform. This implementation, in turn, could be problematic as most of the items that are the subject of the educational project are inside the LMS, so the user is forced to duplicate the material. Then, if we consider the aforementioned trivial problem of document sharing, but we extend the analysis to other typical Project Management tasks (like checking deadlines), the situation is again complex: the educational platform and the Project Management platform are entirely disconnected.

We can mainly find inside LMS under the label "project" or "Project Management" is a sort of task-list or to-do list service that the user must manage directly. In a few other cases, the idea of managing projects is implemented with a set of steps of a predefined workflow, in some way linked to each other, but this is very limited even concerning elementary Project Management tools. Let's consider the world of education in its full complexity and what educators do every day. We can find plenty of activities that can be fully defined as a 'project'. Still, strangely software platforms that are so useful for educational purposes are not providing adequate support for this. We have decided to add a set of Project Management functionalities to our "Online Communities" system. "Online Communities" is a software platform created from scratch by our team, constantly updated with new services that our research group considers engaging in educational and, more generally, in collaborative contexts. The organization of the paper is the following: in Chapter 2, we will analyze the idea of projects in educational contexts, presenting how and where education and project management disciplines could intersect. Chapter 3 will briefly introduce "Online Communities", the collaboration platform where we added the services to support project management activities in educational contexts. In Chapter 4, an overview of the different services for project managers will be presented. Finally, Chapter 5 will explain a qualitative analysis with six experienced project managers who used our platform's various features and compared them with top project management software.

2. PROJECTS IN EDUCATIONAL CONTEXTS

The de-facto standard in the Project Management discipline [3] identifies what a "project" is: "a temporary endeavor undertaken to create a unique product, service, or result" [3], The discipline of Project Management [4] applies a set of different tools and techniques taken from different disciplines (CPM, breakdown structures, network techniques etc) to improve the use of various resources toward the accomplishment of a unique, complex, unique task, taking into consideration time, cost and quality constraints. After many years of mostly being ignored by the software industry (with some notable exceptions), nowadays, we can find on the market many different tools that project managers can choose to plan and manage their projects. Nevertheless, the application of tools and techniques derived from the standards is rare inside these platforms. Here the focus is mainly on extended functionalities of Agile and in general collaboration services, rather than focusing first on core services like critical path method (CPM), Critical Chain Method (CCM), PERT, etc. The perspective of using a collaborative platform as a Project Management tool is fascinating, but this should happen without compromises concerning what Project Management methods provide to millions of skilled project managers around the globe, thus limiting the power of Project Management concepts. Deadlines, cost management, task duration, resources, and many others are problems that everyone involved in project-related activities faces.

The next consideration relates to the presence of these tools inside another kind of collaboration software, i.e., LMS. If we look at educational contexts, there are plenty of academic tasks that are part of a "project" in the plain sense of the definition, enriched with many other aspects typically managed in project contexts. The many relations among students, between students and teachers, between students and the educational institution or external organizations (like stages), can be efficiently and profitably managed as projects. Moreover, using Project Management concepts and tools for students of any course would be a real growth in any direction their future professions will lead them.

Everybody talks about team working, tasks, milestones, deliverables, scope, risks, i.e., uses the typical jargon of Project Management Nevertheless, the application of this complex discipline has not been so widespread and is undoubtedly not applied extensively in education. According to several studies [5], even today, we have a wide range of tools and techniques available, projects are frequently out of time and out of budget [6]. The poor results shown by these (and other) researches in terms of success are subject to different interpretations. Among them, we can mention "Project Management continues to fail because included in the definition are a limited set of criteria for measuring success, cost, time and quality, which even if these criteria are achieved simply demonstrate the chance of matching two best guesses and a phenomenon correctly" [6].

Project Managers, today, can choose among many techniques and software to plan and manage their projects. The widespread usage of network approaches, like Gantt charts, critical path method (CPM), etc., have simplified the planning and controlling steps. In contrast, Project Management software has reached a solid maturity level. The Work Breakdown Structure (WBS) has been adopted as a (graphical) tool to define the project's scope and delimit what should be done in the project, separating them by unwanted or unpaid requests. WBS is the hierarchical decomposition of the work to be executed by the project team to fulfill the project's objectives and make deliverables. It organizes and evaluates the overall scope of the project. Information for a WBS is taken from project objective statements, historical files of previous projects, and project performance reports. An appropriate WBS encourages a systematic planning process, reduces the possibility of omission of key project elements, and simplifies the project by dividing it into manageable units.

Another area heavily interlaced with Project Management and relevant for our argumentation is collaboration. Collaborative spaces are available within the project team to contribute to the success of the project's objectives. New generation tools of Project Management enable this functionality. The project is led and developed by the whole team, and each member has complete information about the project, with all the related documents. The project's progress is visible to everyone anytime, according to permissions granted to the subject. When the project manager is free from the routine tasks; s/he can put more effort into project vision and choose the direction for the project development. The authors of [7] discuss methods and tools for collaborative Project Management; if these elements are coped with the widely recognized collaborative nature of educational processes, we should expect a convergence of these two disciplines and the relative tools.

On the contrary, the only field where we have found the application of Project Management tools and techniques inside educational contexts is the production of learning objects [8]. Here the concept of Project Management is not focused on providing tools inside the LMS for the management of activities as a project, but rather on managing the creation of learning objects with the typical five phases of the lifecycle of a project (initiation, planning, executing, monitoring and controlling, closing). This means treating the production of learning objects using the project's lifecycle as stated in [3], but the LMS remains in the background with the traditional set of functionalities not equipped with Project Management functionalities.

In our opinion, educational processes in general (and not only the production of educational material) can profitably use the pillars of the discipline. Following this idea, we have integrated into our self-made LMS an entire set of Project Management functionalities. The management of tasks within an educational environment shows a series of constraints and issues that need to be managed with appropriate tools, like those supplied by Project Management. The pandemic we live in demonstrates that it is very important to provide a precise work plan for students who are not allowed to follow physical lectures. Our "Virtual communities" platform provides affiliated users a set of features strictly related to Project Management tools and techniques: a) define and manage projects and their scope b) prepare a fully-functional Work Breakdown Structure with predecessors and constraints c) implement the Critical Path Method in the calculation of start/finished dates and free/total slack d) assign resources to tasks and check their allocation e) assign and control costs associated to a project, with a combination of role-permission to a level that can adequately administer the security, confidentiality, and privacy of the activities.

The integration of these features inside a Learning Management system guarantees the increase of application fields for these platforms, allowing them to be used for traditional educational activities and more collaboration and cooperation-oriented tasks. The problem we see in today's collaboration platforms that claim to be Project Management-enabled platforms is precisely the approximation and imprecision of implementation of Project Management services. In our experience, this incompleteness causes users to start using the service and then abandoning it (and the platform consequently), or on the contrary, considering Project Management as the discipline of the colored sticky notes attached on a Kanban board. The world of education is impoverished in terms of Project Management tools and techniques. The proposed one could be an excellent way to improve the awareness of educational actors about how to manage their interaction with the institution. We use words like "educational projects", "educational tasks", "learning milestone", "educational deliverable" very frequently in our focused discussions. On the contrary, even inside modern LMSs, there are no accurate, native, theoretically-grounded services that could support educational actors in exerting their tasks under the umbrella of Project Management theories and tools.

3. PROJECT MANAGEMENT FUNCTIONALITIES IN LMS

The typical collaboration services available in enterprise platforms (like wikis, blogs, and collaborative planning tools. Together with file sharing (documents, reports, agendas, comments, etc. all these tools represent an apparent stimulus to consider an e-learning platform as a possible provider of support and services to PM. These services, like many others, are widespread both in collaborative environments and in e-learning platforms, as presented in [9][10]. Likewise, many different situations in educational settings could take advantage of PM services. Some examples can be the following:

- the management of a thesis assigned to a student is an actual project with tasks, milestones, deliverables, and costs (even if not directly sustained by somebody);
- a research project led by a teacher or researcher is, by definition, a project, involving again different resources, costs, deliverables, and milestones;
- an educational path and all the tasks that any participant has to manage is another example of a "project."
- a complex training path providing professionals with a certification at the end of the activities, with the respective assistance of external resources and tutors, is a project from the perspective of the organizing institution. Here we have a typical mix of educational needs (the LMS's most traditional services) and PM tasks
- we can certainly consider as a project the massive open online course (MOOC) initiative, with all tasks related to various phases of creation, marketing deployment, execution, support, and final certification. Both the institution that delivers the MOOC and the participant that has to perform tasks, in any case, must pay attention to milestones to respect deadlines.

The possibilities of using these tools and services inside LMSs is even stronger if we imagine using a Virtual Communities system not only for managing educational "communities", but also in larger collaboration contexts. Examples of this can be a research group, a recreation organization, a secretariat, a board of directors, a club, a sports team, etc. All these "communities" need services available inside LMSs (like document sharing, forums, wikis, FAQ, sync, and async communication, etc.). E-learning became so popular thanks to many factors, like network availability, multimedia, increased power of client workstations, flexibility, low costs, etc.. Still, the role of software platforms like Moodle™, Docebo™, Dokeus™, Sakay™, Webct™ is central. These platforms have proven to be effective in contexts not necessarily connected to academic education, posing the issue of the evolution of software platforms towards services that are not necessarily related to traditional academic tasks. Last but not least, the integration of e-learning (or collaborative) software platforms with the rest of the information system of the hosting organization represents clear evidence of the role of software platforms today in education.

From a meta-architectural point of view, e-learning platforms have based their pillars on the idea of "course" or "class". The meaning of this choice is that the primary container for relationships among users of the platform is a virtual place that resembles in some way what happens in any educational organization: collecting people in a (virtual) classroom. What emerged in past studies [9] and from our preliminary experiments is a need for a different funding paradigm for software platforms: the "community" or "virtual community". The virtual community is a container ready for didactic processes, but not only: research teams, recreation groups, friends, secretariats, the board of directors, colleagues, anything that could be an aggregation of people around the scope using virtual spaces on the Web. The application's core comprises some abstract entities, i.e., virtual communities as an aggregation of people to which some communication services are available to obtain specific objectives. "Online Communities" [10] is a space on the Web devoted to a collaboration objective, populated by people who communicate with each other using a series of communication systems. This approach could represent all the hierarchical relationships between different types of communities (such as faculties, didactic paths, master degrees, courses, etc.). The main characteristics of a virtual community could be the following:

- a community is a composition of services for a virtual space of interaction involving end-users for that community;
- the services are general applications that enable the users to communicate synchronously and asynchronously, to publish contents, exchange files, coordinate events, etc.;
- a manager of the community activates the potential services of a community according to the needs, and the users of a community can use them with different rights and duties;
- communities can be aggregated into larger communities with hierarchic mechanisms and infinite nesting levels;
- the communities can be aggregated arbitrarily into larger communities disregarding the possible position of a hierarchical structure;
- all users are recognized.

The addition of Project Management services inside e-learning came mainly from the experience of the team in the techniques of Project Management, on the one hand, but also from everyday tasks: consider, for example, as part of learning community college, the need for a teacher to coordinate several undergraduates involved in the long task of drawing up their thesis. The individual, the professor, or those shared between them have often intertwined/ associates and impose the need to manage time, deadlines, relationships, and mutual dependencies. More complicated is the situation on the teacher's side, where s/he could have more thesis to follow, so more projects of this type to manage. We, therefore, believe that the lack of a tool of this kind can be solved naturally with valuable tools for planning and managing existing projects, but these:

- do not integrate platforms
- on average, they are complex
- they are much more appropriate for people with specific expertise in the complex and multifaceted discipline of Project Management

The approach we have followed in the elicitation of requirements wanted to incorporate functional needs very different from one another so that you can create many services with them, most of the time very similar but individually functional on their own for the end-user:

- Personal To-Do List: in this case, the list of tasks of the project is not shared with other users, but is personal reminders of the activities to be carried out in a given period. Tasks can include everything, from social activities to complex projects.
- Brainstorming: here, we can use the list of tasks for brainstorming with people who do not have the chance to meet either physically or through video conferencing. Indeed, given the opportunity to participate in forums, contribute to wikis and glossaries, write a FAQ, attach files, etc., users can add their opinion in various ways to the single tasks, simply reusing the mentioned services that are already available inside the platform. This integration with many services already available is not completed for all services. It will be developed within the service task list/project management evolution roadmap in the following months. We implemented the integration with file management services, which is a crucial service transversal to everything inside the platform. We will provide some examples of this integration in the following pages.
- Organization of meeting: planning a meeting, sending invitations to participants, defining the date, assigning documents to the meeting, all this can be easily implemented inside "Online Communities) via the use of one task named, for example, "Meeting". Subsequently, participants can attach their feedback or materials to this. Then, another simple integration is the "online presence" service, to see in the moment of the conference call, if the person is available or not.
- Bulletin-board system: the services related to task management can be used as a simple bulletin-board system, also shared by multiple users. You can share files and exchange messages with the planning of tasks. In the bulletin boards, tasks can be set by the task leader, updated by the users that have the proper permissions
- Project planning, execution, and monitoring: this is a full-fledged service where you can create and redefine the structure of the task gradually. The inspiration of this service is the category of software devoted explicitly to implementing PM tools and techniques like WBS, Gantt, PERT, CPM, milestones, constraints, deliverables, etc. With this service, it is possible to assign responsibilities to users, and then associate them with each task. During the project's execution, the resource's contribution is updated with a % of completion. This indicates whether the job is completed or not and to what extend. Aggregating all this information, the project manager can check the degree of progress of each activity under the project. For every task of the project, there is the possibility of attaching files

The shortlist just given is not intended to analyze all the possible scenarios of use of the PM services but can show only some examples. As can be seen from the list, the proposed uses have entirely different nature and are not targeted to manage activities with a rigid structure defined as "a-priori". We can even note how the examples discussed above can be transformed with extreme simplicity from case to case. For example, a To-Do List can change very simply into brainstorming or even into more sophisticated projects. Everything happens through the simple assignment of some users to a given Task and the addition of some files.

4. IMPLEMENTING PROJECT MANAGEMENT SERVICES INSIDE AN LMS

The idea of implementing Project Management services inside learning contexts benefitted a lot from the availability of "Online Communities", the virtual space dedicated to each community (what we call the virtual community). This collaboration space provided services to the users, so it was simply a matter of creating new Project Management (PM) discipline services. However, being aware of all the platform provides and integrating the PM services with this. Another fundamental factor from the virtual community concept that we used in assembling the new services was the concepts of 'roles', 'rights', and 'permissions'. Those are assigned to each user for each separated community, allowing a fine-grained, sophisticated way of managing and controlling "who does what" on a specific task.

One of the implementation choices was how to consider the project and its component activities. A project is created as a tree of tasks with arbitrary depth, whose nodes and leaves represent tasks, milestones, or deliverables. To manage the structure mentioned above, we decided to implement a Work Breakdown Structure (WBS), the standard project management tool used for the analytical breakdown of a project at different levels of detail. Each activity has a numerical index that determines the level, composition, or membership hierarchy.

The Project Management services contain some sophisticated features typical of top software solutions, strictly related to the critical path method (CPM) and its calculation mechanisms. These options have been added in the recent version on the platform as a substantial improvement requested specifically by skilled users complaining about the lack of these options. These options (fig.1) allow us to obtain the same results we can get, in terms of calculation of time, start, finish, etc., with Project Management professional tools.

The options are:

- defining a project calendar with working and non-working days
- specifying the start date of the project from which the CPM will start to calculate all start/finish dates according to the predecessors
- default resources: this allows you to set the resources you want to automatically assign when a new task is created
- Milestone: allows the project to use "Milestone", i.e., tasks that have a duration equal to zero days and represent crucial moments in the project to be highlighted to stakeholders.
- Project visibility: this option sets the project visibility

for the involved resources. It can be limited only to the assigned tasks to those resources or when tasks are complete.

- Task completion: this option sets the possibility for the created project to have task completion confirmed by a manager. Therefore, a task will be completed when all its resources set completion to 100%, or when verification by a manager is required.
- Summary task: this allows the project to have the robust feature typical of the WBS, i.e., tasks that summarized all data (start, finish, costs, etc.) of the subtasks. If you are using the project in the CPM mode, it will not be possible to create dependencies from and towards summary tasks. This is a simplification compared to full-fledged software, as these platforms implement the CPM also for the summary tasks. In this situation, the calculus is more complicated for the calculation engine, and we have decided to skip this version.
- Estimated duration: this is instead an exciting niche feature available only in the most advanced software, but we consider it very important. This option allows to set the duration of tasks in estimated days, i.e., days of duration considering a linear calendar of 365/366 days per year without non-working days. For example, a task with a duration "6?d", is a task with 6 days estimated duration.

Another professional feature of the PM service is the possibility of setting, on each task or project, constraints and deadlines. A task has the following features:

- Status: The status indicates at what stage of development the project is. Son provided the states active (the task is in progress), inactive (the task is still in progress), pending, and completed.
- Priority: can be low, standard, and high. It is an indicator of the urgency of the execution of a task.
- Temporal constraints: An activity has three dates that mark its production cycle: start date (the start of the task), end date, deadline (maximum limit for completing the task). To allow the creation of milestones (used to indicate the achievement of the objectives set at the design stage) we let the three abovementioned dates to coincide.
- Percentage of completion;
  - Category: allow a subdivision of projects according to the subject
  - Description;
  - Attachment: you can attach any file that is available inside the file repository of the community.

Tasks and users can also be shared among different communities with the exact inheritance mechanism. On the one hand, users have an institutional role inside the organization and one or more functional roles in each community in which they participate. Examples of institutional roles are those of the classic academic institution (student, teacher, etc.) As examples of functional roles, we have a community administrator, participant, moderator, blogger, secretary, member, dean, writer, etc. Administrators can create roles freely, assign users with individual permissions to each service available in the platform and PM services.

We, therefore, decided to add an extra feature that takes advantage of the possibilities of the creation of a project inside a virtual community: a member of the virtual community can be a resource of the project (fig.3). In educational communities, this is the case very frequently, where the community itself exists because of the need to manage a project. A workgroup, for example, created with some students that have to perform a common educational task, with milestones, deadlines, and detailed WBS perfectly fits as an application scenario of the illustrated feature. We can also add external users, so avoiding limiting the management of the project to people enrolled in the community.

This feature, natural as it may seem, has been very complicated to implement because of the need to validate the users' actions inside the different parts of the portal. In this perspective, external users typically have minimal actions to perform inside the platform. At the same time, in educational projects, they can act as an essential stakeholder and thus need different permissions on the project. For example, imagine an enterprise tutor following a workgroup to support her ideas. S/he can be an external person, with supervisory tasks to perform on what the workgroup is doing. Still, at the same time, her high-level permission on that specific workgroup should be isolated from the rest of the portal.

The Project Management service provides the user a general activity for the project at level zero of the WBS, thus providing a consistent approach to creating both complex projects and simple reminder/to-do lists and following standard planning procedures commonly available in scheduling software. This particular task indicates the project's root, distinguishing it from the others only by the absence of a parent.

Starting from this summary task, the user can manage the rest of the WBS, together with the rest of the inputs (duration and predecessors) for the CPM engine (Fig. 4). This feature implies a set of best practices in planning a project, starting from a) the definition of a calendar, b) the start date of the project c) the tasks and their dependencies. With these inputs, our system can produce as output a) the start and finish date of all the tasks, b) the critical path, i.e., the tasks that have a total float equal to zero c) the finish date of the project. What we expect in a Project Management context is not so "normal" in educational contexts. For example, forcing thesis students to think about their thesis as a "project" with tasks, deadlines, constraints, etc. has dramatically improved both students' and supervisors' daily work.

As a further implementation, we have improved the previous version of our services, adding for each task or project the possibility of adding constraints and deadlines. A task has several other features, like a status (indicates at what stage of development is the project), priority, temporal constraints, and the creation of milestones (used to indicate the achievement of the objectives set at the design stage).

From a security and protection perspective, the community where the project is created/managed guarantees a "sandbox" for the permissions' management. A user holding the appropriate permissions is allowed to create a project with an arbitrary number of sub-tasks to which different resources can be assigned (Fig.5). The roles that we have decided to support are:

- Owner of the project: role assigned when creating the project. The owner is the user with total control over the project and has no limit in respect to assignment of roles, cancellation of tasks, attachment, etc.
- Manager: this role will have the same potential as the project owner, with some restrictions on the tasks created by other managers. A manager may appoint other managers or simple resources, and this appointment can be made only on tasks whose owner is the creator of the task itself. The same goes for the cancellation and modification of activities. Note how the role of the project owner is separated from the others because of the control on every part of the task list regardless of the assignments. The task manager and the owner will also be asked to indicate the status of a task or project, thus introducing control over the work of other users.
- Resources or executors of the project: these users will have a limited subset of actions since their primary purpose is to perform the task and inform the manager through a report.
- Guest: this role is for those users who want to enable you to view a project without, however, afford to interact with it in any way.

You can create three different types of projects or task lists on the platform depending on confidentiality and the context required. You can create personal and public projects within a community or personal projects at the portal level, i.e., outside any specific community. A task list is visible only to the creator of the same and to the assigned people. However, a public project provides the necessary permissions for users with admin rights within the community to view and interact with all users involved, inviting external people from other communities or even not enrolled in the platform. We get more flexibility in a portal task list, conceptually associated with a super-community, where all subscribers to the portal (here we are at the highest level of the communities' hierarchy) are considered within the same context. We, therefore, can potentially engage all people registered with the platform in a single project, regardless of the inclusion in any community.

Another example of beneficial integration of Project Management services into a collaboration platform is attachments' management. Every task of a project can have some interesting documents attached with it to explain/clarify/deepen what the task has to do. In educational projects, this feature can be even more important if not indispensable, for example, if we consider a task as educational homework and the attachment as the instructions and content of the task to be performed. So in educational usage of project management tasks, attachments should be almost considered as a requirement rather than simply a desired feature. The interesting thing is that this feature, considering the concept of community that protects the visibility of documents and limits access to the members with appropriate authorizations, is substantially already available. In an educational project, we can add documents to the file repository of the community, then create the tasks list, and finally attach the appropriate documents to the relative tasks. The cost of implementing this feature has been minimal compared to the benefits brought to the Project Management service. (Fig.6)

Budgeting is another relevant feature, even if in educational contexts it is not so common. The implementation has been oriented to the maximum easiness because we knew that a certain level of complexity and project management knowledge is needed when dealing with the budget. The feature allows classifying resources in work or material resources. According to how the relative fees will be charged on the project, it assigns them an hourly or quantity cost. Users can then allocate resources to tasks, and the engine will calculate the budget for the different tasks using a sort of OLAP cube (Fig.7). Availability for every resource, of the day-by-day assignment plan on each task of the project is a direct consequence of the assignments. This availability, in turn, provides allocation charts, resources' overloading information, and other double-checking tools commonly available in full-fledged software tools.

Finally, to summarize the most important features of this new service, we have to mention the reporting facilities provided to selected users. This service "simply" presents all data deriving from the previous planning activities, providing some primary reporting mechanism. In the current version of the platform, this feature is still in its preliminary steps, not because of lack of data, but mainly because of three different reasons: a) need to implement core features before this; b) test the feature extensively to ask users which kind of reports, among the many possible, they would like to have, also considering the possible crossing with data not necessarily related to project management but rather, with educational aspects of the community; c) the possibility of exporting data and creating reporting with external BI/reporting tools, rather than implement them internally.

Figure 8 shows an example of reporting obtained from a project planned inside a community. We can see details about the WBS with its tasks, completion level, and associated costs to any single task.

5. DISCUSSION AND RESULTS

To test the above-presented services, we asked the collaboration of six project managers with a tested experience in the educational field, asking them to plan their project using our platform's contemporarily Microsoft Project and services. The projects were of different sizes, different complexity, and a different number of involved resources, so they were not perfectly comparable. Our interest was to test the functionalities of the services created inside "Online Communities", and especially have feedback from those users, particularly experts in Microsoft Project. This constructive input was helpful to understand if our services could be a valuable contribution to what they were usually doing with their favorite software.

It is not easy to compete with an established software since the 80s like Microsoft Project, with millions of users and a development team that can extend the platform towards the desired features. Our aim was mainly to understand the appreciation for what we included, especially the advantages of being integrated with a web platform that provides different services concerning pure project management services.

We asked our testers to implement their educational projects using both the services presented in this paper and Microsoft Project. The PMs involved in the experimentation have a medium to a high level of experience in using MS Project, so their judgment could have been very severe concerning our platform. The educational projects were different but substantially falling into these macro-categories: bachelor/master theses, long-term assignments, planning new Master's and bachelor degrees, educational materials, software development. Each Project Manager plans over three months from 3 to 5 projects in both versions, replicating the same tasks, duration, predecessors, and the rest of the requirements of the critical path method. We then collected their quantitative feedback about some analytical dimensions. The dimensions of analysis have the following characteristics and features offered by the two platforms:

- Project settings Definition
- Calendar exceptions management
- Work breakdown structure creation
- Predecessors, Leads, and lags
- Milestones
- Constraints
- Assigning resources to tasks
- Attachments
- Reporting functions

For each of these investigation areas and for each of the above-listed features of the platforms, subjects have expressed an appreciation score, an overall judgment on the production of a project plan, and the user experience with them. Finally, we asked to give a qualitative suggestion for our platform in a final "desired area of improvements" answer. As a qualitative integration, a forum for general discussion has been created and made available to the community participants where the test took place. The final results also consider the valuable comments for the final analysis, so we excluded all the requests of clarification and bugs notification. We kept the judgments useful for our research. Here follows a summary of the questions and the quantitative results expressed on a Likert scale of 1 to 5, with 5 being an excellent evaluation. (Fig.9).

From the results emerges a strong appreciation of the MS Project features (as primarily expected), but some exceptions are notable and can be an interesting field of improvements and promotion for the use of our platform. The first notable exception regards the assignment of resources to tasks. This task is notoriously uncomfortable in any project management software. Still, from qualitative comments, we have noticed that the evident appreciation in favor of "Online Communities" derives from the availability of resources from the community members. This availability lets the project manager understand the project team, assign it to the various tasks, control them in the sense of "members of a community", not unknown resources listed in the software.

The second feature that received higher appreciation compared to MS Project has been attachment management. This result is another expected one, both because of the lack of web availability for the Microsoft solution and for the beneficial idea of having a file repository, organized in folders and protected with authentication/authorization mechanisms, from where to pick up the file that I want to attach to that specific task. All comments from our users converged on this helpful feature, paradoxically a feature recommended for MS Project. Finally, the overall judgments on the user experience and the applicability of the project management tool in educational contexts. Here the comments have been richer of comments and appreciation, even if we must consider that MS Project is a desktop application, full of functionalities that most users don't know. That creates a sometimes clumsy and poorly efficient user experience. More important for us is the positive results compared to the usability and usefulness of project management tools, which confirms our initial research question about the needs of these services for whoever is involved in educational processes.

Other comments on the forum that could be relevant for the research follow:

- web-based features of "Online Communities" have been very appreciated compared to MS Project: a web-based software tool, even if not very equipped with lots of functionalities, is much more helpful for today's project managers than a desktop, Windows-only tools, especially in an educational context where limited budget and low expertise on project management create an entry-barrier to the usage of these services;
- a particularly appreciated feature is the community-based management of resources, which certainly need many improvements (like some cost features, profile management internal to the platform, skills portfolio management, etc.), but even in the current

version could be very useful. Consider again that other services of the platform, apparently disconnected from Project Management services and not created for that purpose, have revealed their utility when the project management services have been added to the platform. A typical example is the "Curriculum" service, implemented for teachers to know the CV of the community members. In a Project Management context, this could be used by the project manager to understand skills and competencies of the project's resources;

- The forum has been helpful for users to communicate some minor bugs related to screen refresh and CPM incoherences
- All the users have reported the lack of some functionalities that available in MS Project, mainly advanced features not related to the CPM implementation (custom fields, total slack, recurring tasks, timesheet management): excellent suggestions for future improvements;
- Few user-experience suggestions were related to the assignment of resources and management of the CPM. All the users, being project managers with long experience, were aware of the many improvements on one side and the complexity of the needs in Project Management. Not everything in Project Management is simple or can be simplified.
- A few comments were about several features of "Online Communities" that have been considered even better than stand-alone MS Project. These comments are not surprising, and it's not a significant element of proudness because it is straightforward to propose something better when somebody else already opened the path. What we consider instead a valid argument is the availability of non-predictive project management features inside e-learning contexts.

6. CONCLUSIONS

In this paper, we presented a new set of features of our LMS called "Online Communities" that extend the platform's services towards the use of Project Management tools and techniques inside educational and collaborative contexts. These tools and techniques, made available for any user inside the platform, allowed to implement the idea of managing a project inside a collaborative and educational environment. This approach revealed two positive aspects: a) the appropriateness of Project Management concepts inside educational contexts, because many of the activities we perform during educational tasks can be seen as part of a project b) the advantage of implementing these services inside a virtual communities' environments, that provides a natural and fertile ground for the development of these services, the integration with other already-available services, and their availability to community members. A qualitative investigation has been performed using professional Project Managers and comparing their user experience in planning (educational) projects with a top-ranked project management software and with the services provided by "Online Communities". Results are surprisingly encouraging, paradoxically because "Online Communities" has not implemented many services mostly considered "not very useful" or "rarely used" by project managers.

On the contrary, complete and up-to-date services of Project Management integrated into a collaborative platform seem to help users in daily operations, with a higher level of usefulness compared to trivial to-do lists or simple task managers. Results can not be interpreted as extensive research, but due to the experience and professional quality of the involved project managers both from the project and educational side, we consider these results very interesting. They validate our original hypothesis substantially, even if not numerically. Educational world and LMSs in particular, need to incapsulate project management services into the offered services. The next evolutionary steps are the completion of some project management services with specific features (overallocation management, budgeting details, cost-type resources, charting, and reporting) and greater integration with the other services provided by "Online Communities", like calendar management, resource booking, grade assignments to assigned tasks, etc.

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FIGURES

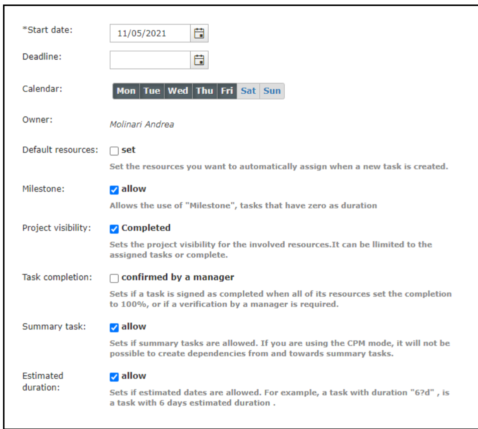

Fig.1 – Options for advanced settings of an educational project

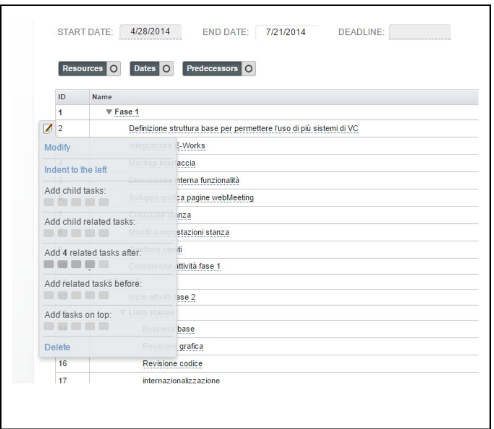

Fig.2 Structuring a WBS with child tasks and predecessors

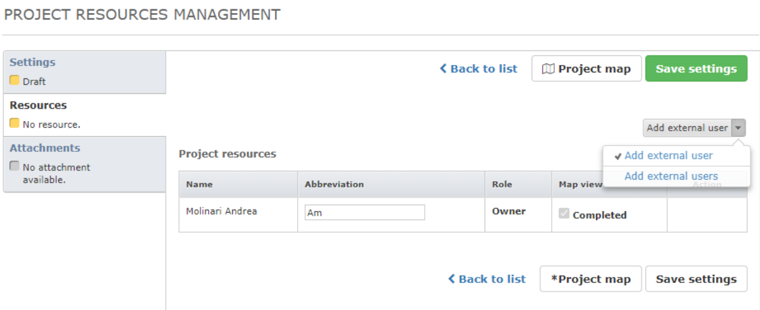

Fig.3 Managing resources and roles inside the project

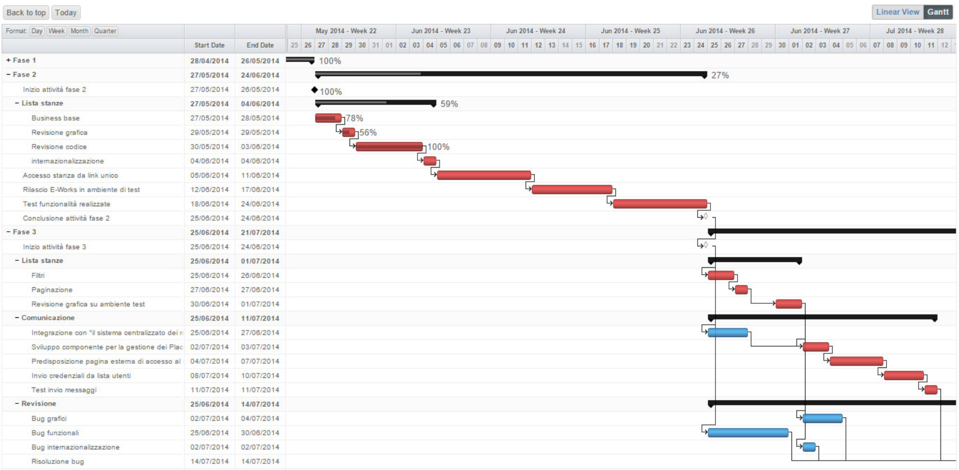

Fig.4: the WBS with critical path, predecessors, and completion percentage

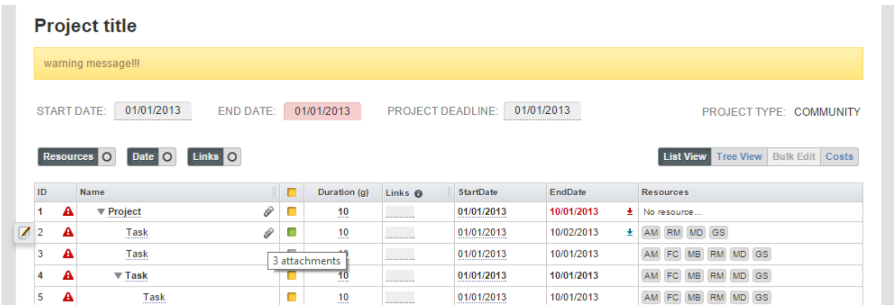

Fig.5: WBS with assignments of resources taken from the community's users

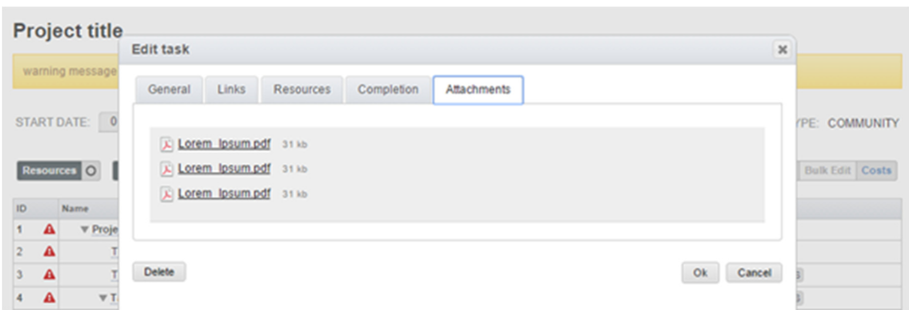

Fig.6: Property of a task with the possibility of attaching files taken from the community's repository

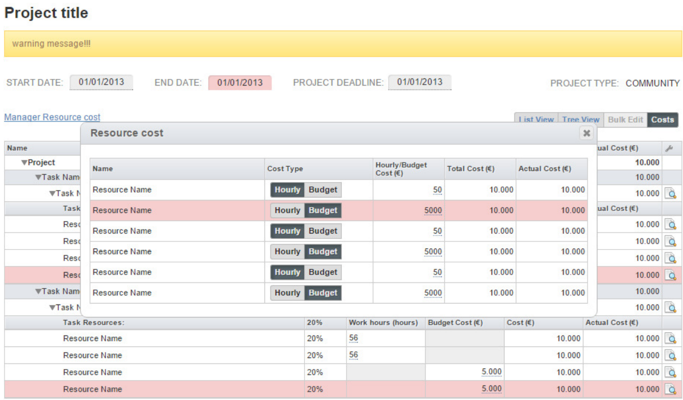

Fig.7 Resource Management with costs and allocation availability for each resource.

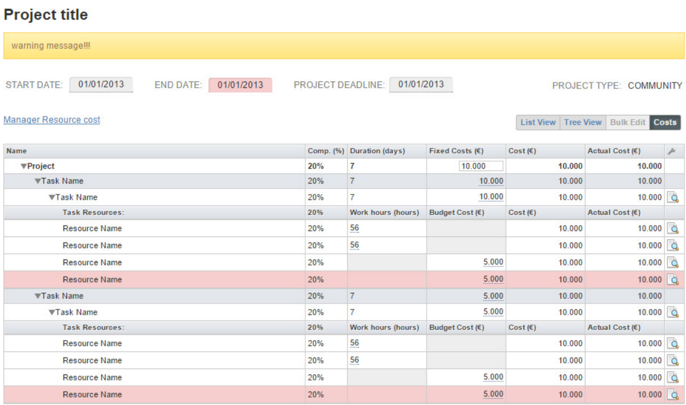

Fig.8 WBS, tasks, completion, and associated costs to any single tasks

	Online Communities							MS Project							
	PM1	PM2	PM3	PM4	PM5	PM6	AVG	PM1	PM2	PM3	PM4	PM5	PM6	AVG	
Project settings Definition	4	5	3	4	4	3	3,83	5	5	4	5	5	5	4,83	1,00
Calendar exceptions management	2	2	3	2	2	2	2,17	4	5	4	4	4	5	4,33	2,17
Work breakdown structure creation	3	3	4	3	3	3	3,17	4	3	4	4	3	4	3,67	0,50
Predecessors, Leads and lags	4	4	3	4	5	4	4,00	5	5	4	5	5	5	4,83	0,83
Milestones	3	3	4	3	4	3	3,33	5	4	5	5	5	5	4,83	1,50
Constraints	3	2	2	1	2	1	1,83	4	5	5	5	4	5	4,67	2,83
Assigning resources to tasks	5	4	4	4	5	5	4,50	3	4	3	3	2	3	3,00	-1,50
Attachments	4	5	4	4	4	5	4,33	1	2	1	1	2	1	1,33	-3,00
Reporting functions	2	3	2	3	3	2	2,50	4	4	5	4	4	5	4,33	1,83
Overall judgement on the production of a product plan	3	3	4	3	3	4	3,33	4	4	5	4	5	4	4,33	1,00
Overall judgement on the user experience	4	4	3	4	3	4	3,67	3	4	2	3	4	3	3,17	-0,50
Overall judgement on using the tool in edu contexts	4	5	4	4	4	3	4,00	3	4	2	2	3	2	2,67	-1,33

Fig.9 The results of the experiment of the new PM services on 6 users

Publication II

Coccoli, M., Maresca, P., & Molinari, A.

Big Data, Cognitive Computing, and the Future of Learning Management Systems

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Big Data, Cognitive Computing, and the Future of Learning Management Systems

Mauro Coccoli, Paolo Maresca, and Andrea Molinari

Introduction

Both technology and society are living a continuous evolution process, driving innovation and the development of novel solutions in almost any field of application. Making reference to the specific scenario of Technology Enhanced Learning (TEL), we observe significant steps ahead in techniques and methodology and, consequently, technological solutions undergo a continuous upgrade to cope with these, to the aim of improving the quality of services, the usability, the overall performances, the effectiveness of education, and to provide a more pervasive experience for learners. Accordingly, e-learning environments and the related tools have been growing in complexity (Bouquet & Molinari, 2016) i.e., from Learning Management Systems (LMS) based on a centralized software architecture toward clusters of Massive Open Online Courses (MOOCs) platforms in cloud-based distributed architectures. The importance of technology as a driver for the future of education is recognized in prior studies (e.g., Schuck, Aubusson, Burden, & Brindley, 2018), and TEL seems also to absorb the general current trends in IT, specifically disruptive technologies

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that include ubiquitous and pervasive computing: Learning Analytics, Big Data, and Mixed Realities.

Many things are dramatically evolving, with contaminations coming from different sectors, most of them are mainly owing to the rise of big data and cloud computing. In this line, we believe that one of the most promising directions to be explored in TEL is related to the adoption of cognitive computing solutions (Coccoli, Maresca, & Stanganelli, 2016). These complex set of approaches and technologies is an enabler for a number of new functionalities. Moreover, the introduction of the cognitive computing paradigm also impacts on the learning process, as schools and universities must face with new jobs and new training demands, where big data contexts are fundamental, since new knowledge and skills should be delivered at a speed never seen before (Coccoli, Maresca, & Stanganelli, 2017). In this paper, we will present our vision about the adoption of cognitive computing inside TEL, depicting the impact on new platforms and services for the future of this discipline.

The paper is organized as follows. Section "Related Works" reviews related works to outline the current situation and guess trends for LMSs. Section "From Classroom to Communities" considers the users' perspective of cognitive computing and investigates the process that is transforming classrooms in communities. Section "Next Generation TEL Platform" highlights what we consider as mandatory characteristics of TEL platforms. Section "The Italian Cognitive Computing Community" reports the inherent activity that is carried on by a group of Italian researchers within the newborn Italian Cognitive Computing Community (ICCC).[1]

Related Works

The possibility of gathering big data from a wide number of heterogeneous sources, combined with the unprecedented opportunities of exploiting such data with cognitive computing techniques, is reshaping the technological scenario of many fields of applications. E-learning is overwhelmed by such a sudden change, which allows improving existing methodologies as well as imagining new ones. In this respect, modern LMSs are evolving and they offer new functionalities so that many researchers are investigating this trend. In the following, we report briefly a variety of works focussing on e-learning systems and related services, based on the exploitation of big data through artificial intelligence and cognitive computing techniques (Coccoli et al., 2016). From a quick analysis of the relevant literature, a lot of scientific work is related to learning analytics. Recording, storing, and aggregating information is a fundamental tool for improving feedback to students and improvements of educational paths (Fedrizzi & Molinari, 2013), big data analytics must be done within the LMS, to the aim of improving learning performances of both students and teachers.

Banica and Radulescu (2015) analyze the impact of big data on education focussing their attention on the academic environment, which has a large scope

[1] http://it-cogcom.com.

and some specific peculiarities. Their expectation is a change in the way e-learning is approached by students and teachers. Based on the currently available software solutions, they propose a system architecture for a consortium of universities to analyze, organize, and access huge data sets in a cloud-based environment. Exploring the large amount of data available on the Web, e.g., online communities, messaging services, social network sites, social media, Dietz-Uhler and Hurn (2013) showcase learning analytics techniques allowing to derive knowledge from large blobs of information. Specifically, in their work they focus on tracking students' data, to help them succeed. They survey learning analytics tools adopted in different universities and institutions and how faculty can make use of data in their courses to monitor and predict students' performance.

Following the same current, Yu and Jo (2014) also show an example of how to fruitfully exploit big data for the prediction of the students' performances, to the aim of optimizing their careers. Moreover, Kolekar, Pai, and Pai (2017) are observing the large amount of information freely available over the Web investigating the opportunity of using such data to get enhancements in all the phases of the learning process. It is pointed out that social media play a vital role with respect to e-learning system (Colazzo, Molinari, & Villa, 2009) and the effective use of information totally lies with the way we utilize these data. In this respect, also Sheshasaayee and Malathi (2017) believe that the application of big data with e-learning is a hot topic, which has the potential for creating a huge impact on the whole education system. All of these can provide useful hints on how to reshape existing LMSs.

Besides, from the methodology perspective, Cen, Ruta, and Ng (2015) introduce the idea of "big education" applying the paradigm of big data to the whole education process to predict students' performances, based on individuals' learning attitudes and their after-school activities. This seems a promising vein, since also Gudivad (2017) theorizes about cognitive analytics-driven personalized learning, which can be achieved owing to the advances in cognitive computing for analyzing unstructured data, e.g., blogs, discussions, e-mail, and course messages, to gain insights into student learning at an individual level.

New functionalities are tied to new technologies, like, for example, the mix of learning and semantic technologies through the use of ontologies for the description of the domain(s) (Bouquet & Molinari, 2012), and, in this specific case, the availability of sophisticated cloud infrastructures is required to handle properly such a huge quantity of information, as well as the design and development of new learning environments, supporting suited machine learning technologies. We observe that when considering big-data-capable learning applications, a paramount item emerges, i.e., the students' data protection. In fact, personal information in the e-learning frameworks can be very detailed, thus very precise profiling can be obtained and maliciously used for different scopes, such as remarketing. This topic was faced by Habegger et al. (2014), which clearly present possible threats of considering big data within e-learning platforms, as well as privacy and security cannot be neglected (Caviglione & Coccoli, 2018).

From Classroom to Communities

E-learning has become a very competitive world, with a lot of public and private Institutions that provide a lot of possibilities for our professional growth. From personal to professional needs, from private sector to public administrations (Casagranda, Colazzo, Molinari, Tomasini, & Villa, 2011), the perspective of lifelong learning is our present and our future, and the formal education activities should expand their boundaries also involving industries and the labor market (Colazzo, Molinari, & Villa, 2011). In this perspective, defining the location where the education processes take places as a “classroom” (whether real or virtual) is limiting the perspective of what today a smart education could and should be. This requires a paradigm shift to transform classrooms into organized virtual places where people use educational tools and services, where we can speak of men *and* machines, rather than men *or* machines, to empower humans’ transformation of their skills.

This virtual place where education can take place, in a physical room or through a mobile device, together with people that you regularly meet or together with people that you will never meet in person is a “virtual community”. This (virtual) place, so important for our present and future learning processes, should condition in our opinion not only the educational processes, but also the way software platforms should be built. Many years ago we started to follow this new approach to education through “Online Communities” (OLC), a collaborative environment totally designed and developed without referring to any existing LMS paradigm or software architecture.

Starting since 1998, when neither Facebook nor Moodle or Sakay were even existing, we decided to develop from scratch a virtual community platform called “Online Communities”, as an alternative to proprietary platforms like WebCT™ or Blackboard™. The decision to create this platform was a consequence of various reasons: principally, the use of commercial software would have been possible at too high a cost (acquisition, maintenance, management and training) when compared to budget limits. This is the same reason why so many small–medium educational institutions (like high schools) are using Moodle without even understanding the impact of it on their educational processes: uniformity, flattening of services, complexity in connecting the LMS with the rest of the organization’s information system (Colazzo et al., 2009).

Many administrators of the information system, especially in the educational sector, are adapting their needs to the software system that, somehow, is able to solve most of their problems, and they mostly are resistant if not reluctant to develop an internal solution. Money, availability of qualified resources, short time to implement the solution, these all are comprehensible reasons for choosing the easy way of acquiring a pre-cooked solution.

To support those trainers willing to experience the use of computer technologies in their educational processes, we developed a completely new platform that moved from a mere LMS to a more structured set of services that support collaboration among members of the virtual community. Organizing educational tasks inside a "classroom" or "my courses" metaphor (what you find behind the LMS available today) means forcing stakeholders of educational processes to adapt much more complex processes to what the platform provides. They normally "adapt" themselves to what the platform supplies out-of-the-box, thus limiting the innovation potential of their ideas, and forcing users to adapt their learning processes to the technological tool.

Collaboration processes are those that mainly suffer this limitation: the idea of (virtual) community allows to extend the usage of the platform to any other environment where collaboration among participants to the community are mediated by ICT (Kimball, 2002). This personalized software is able to supply better and personalized services that ease procedures and processes for the different users (students, professors, administrative personnel). Social media, like Facebook, Twitter, Whatsapp, Instagram or similar media are great tools when applied to the context they have been originally created, mostly exchanging multimedia information among peers. Yet, it is not so easy to integrate them in the educational processes, not only because of technical availability of integration mechanisms and privacy issues, but also because of an educational design problem. How do we cope the style of the lecture with the usage of social media made by our learners? How is changing the role of the teacher and what are the expectations of learners about the use of social media? How do we differentiate the use of social media respect to the target? Using these tools in academic teaching is different respect to their usage in professional business environments.

Probably, we need adaptive technologies that understand context, usage of language, expectations and background of learners, and adapt from the interaction style to the material provided, from the pace of the lectures to the interaction with trainers. This is a typical application of cognitive computing, where the system "understands" the learner interaction profile and adapts itself to this. Posting a photo or retweeting others' comments is a very beneficial aspect for training, especially professional training, but educational processes are more than this. Sometimes, educational processes need the support of other tools and services, that social media can provide through a distorted usage of its services, because they are *not* educational services. The usage of social media in education therefore forces educators to adapt their learning processes to what the platform provides, while it should be exactly the opposite, i.e., the platform should adapt services to users' needs. Last but not the least, the capabilities of expanding social media services to educational needs are simply driven by economic consideration, not necessarily coinciding with educational needs. It is sure that cognitive computing will impact every decision in the following decade, but education seems to be not on the radar of social media.

The innovative aspect that we introduced with "Online Communities," and that now constitutes an extra advantage, is to construct the services considered relevant by educational experts, based on the precise educational needs of the different users: teachers, students, or any other role involved. If we consider cognitive computing and the power provided (and needed) by cognitive computing platform, the idea of using (micro) services provided by external suppliers, and consuming them according to the specific needs is a good starting point for our research. These are very important architectural aspects for our argumentation about a next generation of TEL platforms:

(i) We entirely wrote every line of code of the platform, so we do not depend on different contributors (like in many open source projects) and we do not suffer the "will the new release cover my customization?" syndrome;
(ii) The platform is based on a micro-service architecture, allowing to be easily extended in any direction;
(iii) We added a semantic-enabled extension of the persistence of the platform, i.e., some parts of the platform can be stored as a semantic representation of the knowledge in RDF triples (Bouquet & Molinari, 2016). The triple (or quadruple) format for persisting (part of) data relevant for decision-making and cognitive computing is another component that is not currently available in mainstream LMSs, and that is native into "Online Communities."
(iv) We have also integrated some soft computing, fuzzy logic-based decision support systems (Fedrizzi & Molinari, 2013), to support decision-makers with intelligent tools about educational processes;
(v) The platform is natively equipped with a new storage layer collecting data from all services available in the platform: this big-data-enabled extension of the platform is particularly useful for our cognitive extensions.

Next Generation TEL Platform

According to the above considerations, we consider that as a foundational element for new services in TEL the existence of a new generation of TEL platforms, which must be re-designed respect to the approaches that have been used in the past decade to create most of the current LMS. These new architectures must keep into account the definition, design, and use of novel cognitive services, where big data about training and learning are acquired and historicized, on top of which we foresee the application of a new set of cognitive services that could improve.

(a) The learning processes, providing the users with a much richer set of services personalized for the respective needs;
(b) The teaching processes, providing new suggestions about the best material for the individuals, finally aiming at a "personalized education" that consider what the learner is, what she wants, what is better suited for her needs;
(c) The administrative awareness of how learning processes are conducted, controlling time and kind of resources used, and imagining new business models related to intelligent usage of educational resources;
(d) The decision support processes for the educational institution's decision-makers, which can use cognitive services to intercept trends and formal/informal needs found by cognitive services into the amount of analytical data collected, on forum posts, on teacher–students interactions, etc.

In order to foresee these different scenarios, the fundamental factor of next generation TEL platforms is the presence of cognitive services pervasively integrated inside the core architecture of the system. Here we have two sides of the word "learning": learners that will increase their knowledge, thanks to educational processes; and machines/systems/platforms that will learn about learning processes, thanks to the use of cognitive services. However, thinking that a cognitive service is only the result of an algorithm is a wrong starting point: it is something more because learning does not "come only" from a software algorithm but it is also due to a very complex hardware architecture that implements it. A cognitive algorithm is performed on a parallel architecture and the latter must be dimensioned according to the learning needs of the algorithm itself. In other words, since the algorithm must be trained, we often need substantial memory and computational resources to be implied in educational processes characterized by the cognitive approach.

Precisely for this reason, the personalization of cognitive services will require additional hardware and software resources to be sized to achieve the objectives.

For this reason, when defining a cognitive TEL we have to go beyond a basic hardware machine because personalization will require a system to adapt over time to the use we will make of it, in the perspective of a lifelong learning support to our knowledge growth. This capability is offered by the cloud, from Platform as a Service (PaaS) hardware machines, and from Software as a Service (SaaS) solutions. Furthermore, feedback is needed to improve the effectiveness of this approach, and so we should be able to observe the system by measuring it and updating it in real time. Clearly, these platforms provide to LMS the computational power needed for computing services, but at the same time these computing platforms are not created specifically to supply the whole set of services that a virtual community platform can provide to its users.

These considerations push to build innovative architectures for the platforms that must provide an educational environment whose particularity is to be able to change configuration quickly in order to adapt to the different needs of learners and teachers. In particular, the authors thought that a wise adoption of the best of some services from multiple vendors, within the same platform, could improve the satisfaction of end-users as well as solve the structural problems of the laboratories. Often University laboratories need to be scalable on a different number of students, they need to be used for different educational activities (lessons, exercises, application laboratories, exams, etc.). Sometimes they must even be scaled up to more applicative situations, like some tests for research projects or experiments.

The authors believe that, in this case, an integrated environment is needed, and from our preliminary analysis and tests, Microsoft Azure and IBM Watson could coexist within the cloud in order to realize both the needed PaaS and the SaaS. Figure 1 shows an example of the Azure environment in which the sizing of the hardware machine is offered for the different cases of (i) courses, (ii) laboratories, and (iii) exams.

The common dashboard for the teacher and the student offers the possibility to instantiate a laboratory session or to take part in an exam session. The only requirement is the availability of a PC and a possibly fast connection.

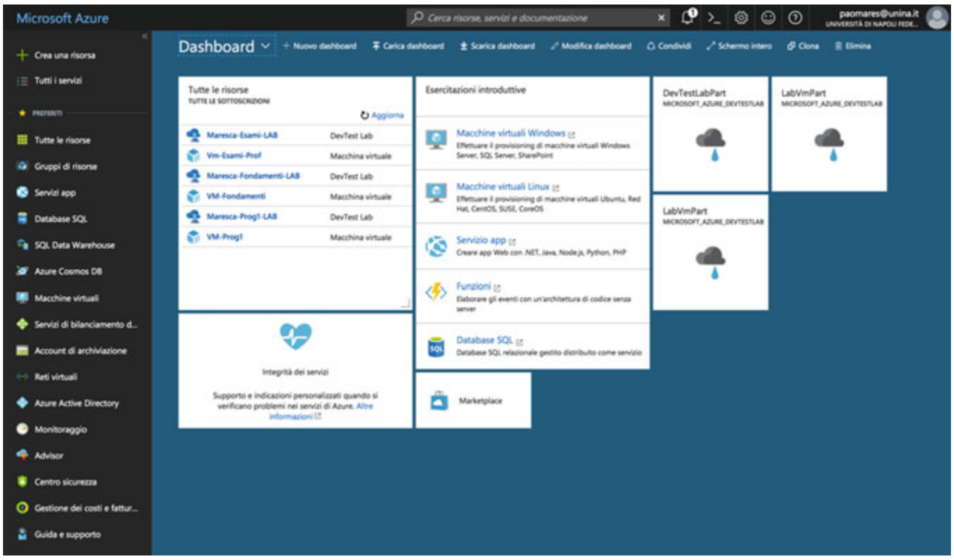


Fig. 1 The Azure dashboard

For example, the teacher can, in a laboratory consisting solely of the PCs that students bring with them, instantiate an exam session on the fly as shown in Fig. 2.

The student after having profiled with his institutional credentials visualizes a dashboard and chooses his activity: laboratory, exams, etc. In the specific case, the student takes an exam but in the same classroom can coexist with students who are doing different activities. For example (Fig. 3), the student is logged into Eclipse where he can decide whether to compile a program or enter the IBM cloud, through the appropriate plug-in, and also use Watson's cognitive services.

At the end of the activities, we can ask students to provide their opinion on the environments used. In particular, students were asked to provide overall feedback on satisfaction and usability. The information gathered, on a random sample of about 50 people, about the overall satisfaction of the platform, are shown in Fig. 4.

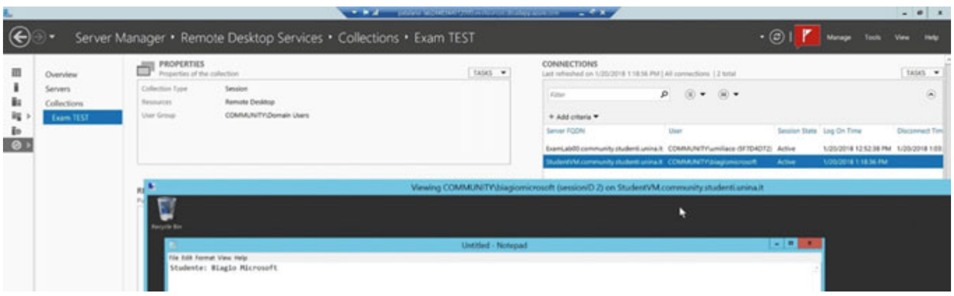


Fig. 2 The Azure server manager

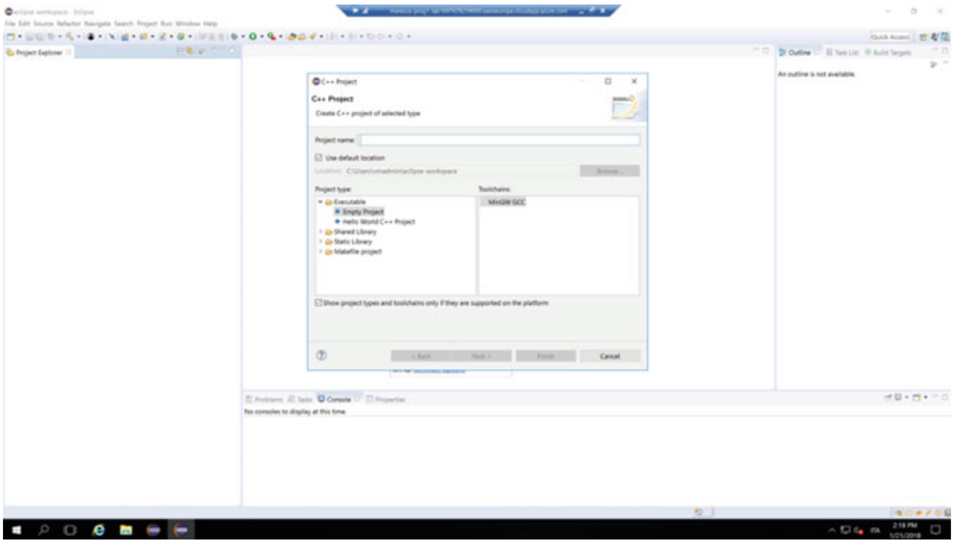
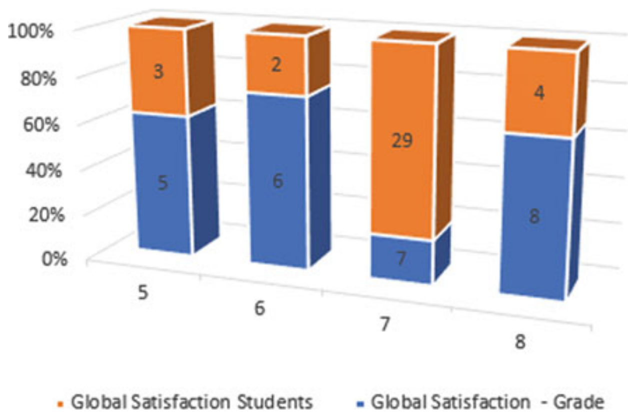


Fig. 3 The eclipse environment used by the Azure SM

Fig. 4 Satisfaction of use for TEL



Since these integrated environments of multiple technologies may be too complex for young students, we have also asked to comment about usability and this is what we have collected (Fig. 5).

It is evident that not only the presence of two different environments but also of concepts that synthesize the existence of functionality often put the students in difficulty. This is the expression of the judgment that they provide to usability which, however, results in an ordinal scale from 5 to 9, quite positive despite the evident complexity. We therefore believe that a common platform, based on a more general metaphor than a classroom, about to provide conventional and non-conventional educational services as a uniform learning environment, is the direction we should move in the next years.

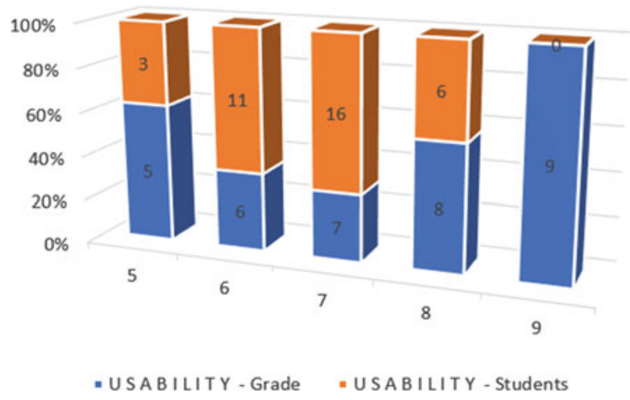


Fig. 5 Usability for TEL

The Italian Cognitive Computing Community

Another component of this vision of cognitive-enabled TEL is the support of the research community in the field of cognitive sciences. In this section, we introduce the idea of being supported by the newborn Italian Cognitive Computing Community, where a big-data-enabled architecture and some prototypes of cognitive services are under experimentation. The idea is to bring this innovation and new services into the architecture of the building cognitive TEL platform.

On May 18, 2018 the Italian Cognitive Computing Community was launched in a public event hosted by the University of Naples, Federico II. After this first step, 4 universities, 16 companies, the Accademia Aeronautica of Pozzuoli, 1 high school joined our community whose goal is to promote the use of cognitive computing technologies and accelerate the relevant research. In addition, the Community will try to become the reference point and contact point in Italy for all professionals, scholars, and researchers within the cognitive computing theme.

In short, the planned activities are the following: (i) set up a users' interest group; (ii) share and exchange experiences and information to grow continuously; (iii) create contacts and relationships between University research, the labor market, and the business world; (iv) publish research and disseminate in international conferences; and (v) support and organize initiatives for the promotion and dissemination of the group activities.

The main actors of this community will be companies, professional organizations and professionals, teachers, researchers, and students. We will pay particular attention to our students who will be among the main actors of this community and collaborate in establishing direct links with the industry. In fact, they are at a crucial turning point in which technologies such as the cognitive computing will completely transform the world of work and will be the key to the emergence of new professions. It will be interesting to think also to define fast and agile methods to update their curriculums in order to make them always current and relevant to the demands of the advanced industry world.

Based on a preliminary poll among the participants, we have identified the following topics of interest: (i) ethics in artificial intelligence; (ii) the use of cognitive technologies in e-health; (iii) the adoption of cognitive computing solutions in the agri-food chain, including the block-chain technology; (iv) the application of cognitive systems in pollution prevention; (v) e-learning; (vi) e-economy; and (vii) social issues. It is worthwhile noticing that people involved in the ICCC are from different areas, i.e., informatics, engineering, economics, robotics, medicine. For the e-learning topics, focus will be concentrated in the application of cognitive scientific advancement in the construction of a new cognitive-enabled TEL.

Conclusions

We are on a turning point of training processes, a very challenging and important moment in which cognitive approaches will transform most parts of our lives. Beside professional applications and high level-specific software systems, we are already experimenting a set of cognitive computing services in everyday activities, for example, using interfaces and assistants like chatbots, where to build, connect, deploy, and manage intelligent bots to interact naturally with the various users of educational environments. In practice, more often than we think, we are interacting with machineries that apply sophisticated decision-making process with very low time constraints and high accuracy.

E-learning is one of the fields of application that can mostly benefit from this, due to its complexity and to the variety of disciplines that must be adopted concurrently to achieve good learning outcomes. Especially, the use of big data strongly empowers the process of personalization and individualization of the learning processes. Moreover, e-learning is also called to provide suited solutions to the problem of learning such new technologies, which cannot be done in environments designed for different purposes. This raises the problem of developing a new generation of TEL platforms. The paper introduces the vision of the authors, where a self-made, highly customizable virtual community platform will be integrated with scalable, top-notch cloud platforms and congruent cognitive algorithms applied to the different parts of learning processes, from material selection to educational path suggestions, from peer evaluation to big data discovery for decision-makers. The process is still in its infancy, mostly because these three worlds (TEL platforms, Cloud services, and cognitive computing) are still separated and mostly focus on their own scope. What we are trying to do is merge the three disciplines/areas into one single research area, with precise objectives and deliverables, thus allowing e-learning to maximize the advantages of the fusion of the three. The paper presented some early ideas where to work on, and quickly summarize the role of the Italian Cognitive Computing association as a driver of innovation, collector of chances, and stimulator of new researches.

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Publication III

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Collaborative E-Learning Environments with Cognitive Computing and Big Data

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Collaborative E-learning Environments with Cognitive Computing and Big Data

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ABSTRACT

The actual scenario of e-learning environments and techniques is fast-changing from both the technology side and the users' perspective. In this vein, applications and services as well as methodologies are evolving rapidly, running after the more recent innovations and thus adopting distributed cloud architectures to provide the most advanced solutions. In this situation, two influential technological factors emerge: the former is cognitive computing, which can provide learners and teachers with innovative services enhancing the whole learning process, also introducing improvements in human-machine interactions; the latter is a new wave of big data derived from heterogeneous sources, which impacts on educational tasks and acts as enabler for the development of new analytics-based models, for both management activities and education tasks. Concurrently, from the side of learning techniques, these phenomena are revamping collaborative models so that we should talk about communities rather than classrooms. In these circumstances, it seems that current Learning Management Systems (LMS) may need a redesign. In this respect, the paper outlines the evolutionary trends of Technology-Enhanced Learning (TEL) environments and presents the results achieved within two experiences carried on in two Italian universities.

1. Introduction

Technology and society are undergoing a continuous evolution process, which is pushing innovation and driving the development of novel solutions in almost any field of application. The wide adoption of such solutions in a plethora of services that are commonly available on the Web for daily operations heavily impacts on users' behaviors and expectations. Specifically, with reference to the Technology-Enhanced Learning (TEL) scenario, we observe significant steps ahead in techniques and methodology. As a consequence, technological solutions are subjected to continuous upgrades to cope with these, to the aim of improving the quality of services, the usability, the overall performances, the effectiveness of education, and to provide learners with a more pervasive experience. Accordingly, e-learning environments and the relevant tools have been growing in complexity, i.e., traditional Learning Management Systems (LMS), based on a centralized architecture, are moving towards clusters of Massive Open Online Courses (MOOC) platforms in cloud-based distributed architectures [1] and Learning Objects (LO) include more and more videos and multimedia interactive artifacts. Concurrently, LMSs have been exploring new spaces of possibilities; among these, we mention the adoption of users' profiling techniques and analytics to the aim of tailoring personalized learning paths and activities as well as to predict students' careers, to achieve a further empowerment of the individual learning model. A clear synthesis of the more significant evolutionary steps of learning solutions is presented in [2] where the changes

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occurred in tools, services, learning strategies, methodologies, and delivery techniques are arranged along a timeline. It is worth noticing that the achieved progresses are not just replacements of the previously adopted solutions, yet they are characterized by one or more of the following: *(i)* extension of capabilities; *(ii)* improvement of performances; *(iii)* promotion of different educational approaches and methodologies; *(iv)* change in the way contents are delivered; *(v)* change in the users' interaction model. Despite the methodology is sound, the analysis concerns the period from 2001 to 2015 and, since then, many changes have occurred, mainly due to the rise of big data and cloud computing.

In this respect, we highlight that the introduction of cognitive computing can enable a number of new functionalities [3] and that the adoption of this new paradigm also reflects on the learning process, as schools and universities must face with new jobs and new training demands since new knowledge and skills should be promptly delivered [4], also pushed by big data. As a result, it seems that LMSs have reached their maturity stage in the innovation adoption curve, since they are pervasively adopted by learning providers at any level, from the primary schools up to higher education institutions, to the aim of guaranteeing the most effective implementation of TEL solutions. Nevertheless, most LMSs hardly can cope with the high degree of interoperability and complexity that novel paradigms require, hence they should expand their boundaries offering new services and rethink the whole design process, considering the labor market and industry needs too. In this respect, the paper discusses the evolutionary trends of e-learning and presents the results achieved within two experiences carried on in two Italian universities: *(i)* an innovative didactic approach to software engineering, adopting advanced technologies and mixed solutions in a cloud infrastructure; *(ii)* a novel collaborative learning environment that surpasses the typical functionalities of the more prominent LMSs.

We highlight that such experiences are driving TEL platforms towards new standards where both learners and teachers, rather than technology, will be at the center.

The remainder of the paper is structured as follows: in Section 2 we present some related works investigating these topics; Section 3 outlines the main drivers for the development of the next generation TEL platforms; in Section 4 we report the experience of a cognitive-computing-based laboratory, while in Section 5 we depict a newly developed e-learning collaborative environment. Section 6 concludes the paper also giving hints on future development directions.

2. Related works

As highlighted in the previous section, we are going to focus on two phenomena: *(a)* big data, and *(b)* cognitive computing. In fact, the possibility of gathering information from a wide number of heterogeneous sources, combined with the unprecedented opportunities of processing such data by means of sophisticated cognitive computing techniques, is reshaping the technological scenario of e-learning applications, allowing the improvement of existing methodologies as well as imagining new ones.

Moreover, the possibility of recording, storing and aggregating information, can significantly improve learning performances of both students and teachers [5]. For these topics, we report a number of related works that illustrate different solutions showing how variedly these two aspects can empower e-learning methodologies and how platforms are evolving with new functionalities. From a quick analysis of the relevant literature, i.e., searching indexing services such as Science Direct, Scopus and Web of Science, we found several publications on these challenging topics, enlightening that, more and more, LMSs offer such services among basic tools or as add-on functionalities.

2.1 The impact of big data on e-learning

Due to the presence of big data, a number of significant changes has occurred in education and in e-learning systems. Their impact on the academic environment is investigated in [6], where the authors' expectation is that a change will suddenly occur in the way e-learning is approached by both students and teachers. In this respect, based on the currently available software solutions, they propose a system architecture fostering universities to constitute consortia to analyze, organize and access huge data sets in common, in a cloud-based environment. A similar approach is also considered in [7], which proposes a strategy to improve outcomes of the education process through the collaboration among universities at an international level, to the aim of supporting the teaching and learning process by means of shared e-learning services. The integrated framework presented links the individual impact with the organizational impact, promoting a collaborative culture model.

As hinted, another key factor for the empowerment of e-learning services, is their integration with information from other platforms and services, given that a large amount of data is accessible in, e.g., online communities, blogs, discussion forum, messaging services, and social network sites. In this respect, [8] showcases some effective learning analytics techniques to derive knowledge from unstructured and large blobs of information. Specifically, the paper focuses on tracking students' data to help them succeed. To this aim, the authors investigate the various types of analytics tools that different universities and institutions adopted, to discuss how faculty can exploit such data to monitor and predict the students' performances, to finally enhance them. Moreover, [9] investigates the same large amount of information freely available over the Web, to explore the opportunities of using such data to get enhancements in all the stages of the learning process, not only in assessments. Following the same current, [10] shows an example of how to fruitfully exploit big data for the prediction of students' performances, to the aim of optimizing their careers.

We point out that, currently, social media can play a vital role with respect to e-learning systems and the effectiveness of information is strongly tied to the way we process these data. In this respect, [11] states that the application of big data with e-learning is a hot topic, which has the potential for creating a huge impact on the whole education system.

We also highlight that processing big data in an effective way is only possible relying on complex cognitive computing solutions implementing suited machine learning techniques. Such techniques allow to cope with data characterized by large volume, different types, high speed, uncertainty and incompleteness, and low value density. Going deep in technical details, algorithms and methods (e.g., representation learning, deep learning, distributed and parallel learning, transfer learning, active learning, and kernel-based learning) is out of the scope of this paper, however the interested readers can find a survey of how machine learning is used for big data processing in [12]. Other references can be found in [13], which showcases a large understanding of past, present and future directions in this domain, made through a mapping of the characteristics of cognitive computing, i.e., observation, interpretation, evaluation and decision, versus the so-called V's of big data, i.e., Volume, Variety, Veracity, Velocity and Value.

2.2 The impact of cognitive computing on e-learning

From the side of cognitive computing, there are only recent works that deal with such advanced techniques used in e-learning applications, for example to serve the instructional design process, helping to find personalized learning assets and improving the definition of individual learning strategies or classifying resources. Among these, [14] focuses on recommendation systems implemented on the basis of cognitive services. The paper envisages the possibility of using the same approach to meet the needs of students and teachers, especially to enable personalized learning strategies and implement recommendation systems for educational resources, based on information derived from the interactions between students. The authors propose the prototype of a platform and survey the approaches to develop advanced TEL solutions, analyzing the state of the art of using cognitive systems in e-learning, identifying paradigms and pedagogical methodologies, techniques, tools and learning objects with respect to the recommendation of pedagogical activities using cognitive computing. In [15], the authors use cognitive systems for the automated classification of learning videos, with special reference to MOOCs, i.e., exploiting the capabilities of Automatic Speech Recognition (ASR) and Optical Character Recognition (OCR) services to extract text from audio and visual frames so to be able to perform classifications based on taxonomies. Further developments of this work led the authors to find a solution overcoming traditional term-based methods, which analyzes the content of large video collections by means of cognitive services such as: *(i)* Speech-to-Text tool to get video transcripts, and *(ii)* the use of Natural Language Processing (NLP) methods to extract semantic concepts and keywords from the above video transcripts [16].

2.3 Empowering e-learning methodologies

Besides, from the methodology perspective, [17] introduces the idea of *big education*, applying the paradigm of big data to the whole education process to predict students' performances, based on individuals' learning attitudes and their after-school activities too. This seems a promising vein, since also [18] theorizes about cognitive analytics driven personalized learning, which can be achieved owing to the advances in cognitive computing for analyzing unstructured data such as, e.g. blogs, discussions, e-mail, and course messages, to gain insights into student learning at an individual level.

New functionalities are strictly connected to new technologies such as, for example, the mix of learning and semantic technologies through the use of ontologies for the description of domains (see, e.g., [19] and references therein) and the availability of sophisticated cloud infrastructures is required to handle properly such a huge quantity of information, as well as the design and development of new learning environments, supporting suited machine learning technologies as reported in [20].

2.4 Privacy and security issues

Finally, we observe that when considering big-data-capable learning applications another paramount item emerges, that is the students' data protection. In fact, personal information in the e-learning frameworks can be very detailed, thus very precise profiling can be obtained and used maliciously for different scopes, such as, e.g., remarketing. As well as privacy, security cannot be neglected and should be considered one of the most important factors in the design of TEL platforms [21]. For example, this topic was faced in [22], which clearly presents possible threats of considering big data within e-learning platforms.

3. Emerging trends in TEL

According to the above considerations, we propose a new point of view on TEL platforms, enlightening the main characteristics they should offer. Their design must consider the new wave of cognitive services for their use in advanced solutions and for their ability to cope with the huge amount of data circulating within the learning frameworks and the connected software environments outside the LMS (e.g., discussion forums and blogs, social network sites, indexing services, digital libraries, etc.). In more detail, personal data about learners, their learning tasks, scores in the assignments, etc. should be stored and historicized to the aim of improving the whole learning and teaching process, also including administrative information to monitor how learning processes are conducted and make an assessment to the aim of predicting performances through suited learning analytics. More precisely, we state that the next-generation TEL platforms will offer pervasive cognitive services.

From the side of the learning process, we have to consider two different aspects: *(i)* learners will acquire new knowledge thanks to the educational strategy and methodology adopted, and *(ii)* at the same time, machines, systems and platforms will acquire information about learners and their individual learning processes, owing to cognitive services. However, thinking of cognitive services merely as the result of an algorithm is not a good starting point: there is something more because learning does not derive from a software algorithm but also from the complex hardware architecture it relies on. In fact, cognitive services can be effective only within a parallel architecture, whose capabilities must be suited to the learning needs of the algorithm itself. In other words, since the algorithm must be trained, we often need substantial memory and computational resources to be implied in educational processes based on a cognitive approach. The personalization of cognitive services may require additional hardware and software resources and thus, for this reason, when defining a cognitive TEL, we have to go beyond a basic hardware configuration to face to possible personalization issues, which may require a system flexible enough to adapt over time its characteristics to the use we will make of it, in the perspective of a lifelong learning support to our knowledge growth. Such features can be achieved through the adoption of cloud architectures, Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) solutions. Furthermore, feedback is needed to improve the effectiveness of this approach, and we should be able to observe the system and get feedback to perform real-time tuning operations.

In the light of the above considerations, it is required to build innovative architectures for the platforms that aim to provide innovative didactics, able to change configuration quickly in order to adapt its functionalities to the different needs of both learners and teachers. In particular, we believe that a wise adoption of the best of some services from multiple vendors, in the same platform, could improve the satisfaction of end users as well as solve some structural problems of the laboratories. In fact, often university laboratories need to be scalable for different number of students attend classes or they may need to serve different educational activities (e.g., quizzes, lessons, exercises, application laboratories, exams, etc.). Sometimes they must even be scaled up to more applicative situations, i.e., performing tests for research projects or experiments. Specifically, Section 4 provides a detailed description of the innovative learning environment that the Federico II University in Naples, Italy, setup, based on the above concepts.

Moreover, we observe that e-learning platforms and applications continuously change together with learning itself and learners' attitude and needs. In many cases, educational paths are designed in collaboration with institutions from other countries, i.e., to promote mobility of both workers and researchers, in other cases a strict interaction with industries and the labor market is required. Consequently, performing educational tasks in a "classroom", whether real of virtual, may be limiting the perspective of what today a smart education should be. Hence, in order to stay competitive, formal education models should expand their boundaries also involving the external world and this can only be achieved through the adoption of suited technological solutions for online collaboration, interoperability, data exchange, and the seamless integration with legacy systems. The implementation of such solutions requires suited machinery and infrastructures as well as a paradigm shift able to drive the transformation of classrooms into communities to enhance humans' faculties and empowering the transformation of their skills so that, in such new "places", we can speak of men *and* machines, rather than men *or* machines. Even in this case a specific example is presented and Section 5 depicts the characteristics of the innovative e-learning platform developed at the University of Trento, Italy. platforms.

4. An integrated environment for exponential learning

This section provides a detailed description of the innovative learning environment setup at the Federico II University in Naples, Italy, based on cognitive computing to implement exponential learning. We recall that cognitive computing was born based on human reasoning models and this special capability can be exploited transversally on, potentially, any domain of application, so that it can be regarded as a real revolution, exponentially accelerating processes. In the past decades, we have been accustomed to a swirling growth, according to the Moore's law (the number of transistors in a dense integrated circuit doubles about every two years) or the analogous Metcalfe's law for the number of nodes of a network that clearly explains the enormous dimensions reached by social networking sites such as, e.g., Facebook. However, we were not prepared to cope with the needed exponential growth of learning caused by the growth of knowledge, which is in turn derived by the growth of data processed with novel Artificial Intelligence (AI) techniques. Consequently, the learning environments should be promptly adapted to this reality.

4.1 The hardware and software setup

According to the above considerations, the Federico II University in Naples, Italy, setup a laboratory with suited hardware and software configurations, providing students of the "Software engineering" class with the possibility to use the most advanced methodologies and tools to develop quite complex projects within their assignments and to share their results with mates. Previously, the authors already carried on didactic activities focusing on computer programming in collaborative environments (see, e.g., [23], [24], and references therein) but cognitive computing has accelerated this need, thus enabling more ambitious projects to be implemented both from the point of view of the hardware resources that can be used and the complexity of the software that can be used. The implemented solution is an integrated environment offering high-level tools for cognitive computing design and programming. Specifically, after a preliminary analysis and a series of stress tests, Microsoft Azure and IBM Cloud have been identified as the best-matching solutions for developing cognitive-computing-based projects. Owing to their cloud-based architecture, both platforms can coexist in the same installation, where they can be used simultaneously if needed, allowing to realize the needed PaaS and SaaS infrastructures.

More precisely, students can use the cognitive e-learning platform from both IBM Cloud and Microsoft Azure with relevant laboratory and customized virtual machines. Taking advantage of such a mixed configuration, enables students to disregard hardware and software issues, focusing on their individual learning tasks. Besides, they can use complex machines simply through a browser, which is a strong point because they may have to use laptops or even personal computers with poor performances. To better clarify, we highlight that the Azure environment offers different profiles for sizing the hardware machine. One can choose one of the following: *(i)* courses, *(ii)* laboratories, and *(iii)* exams. Then, the decision to instantiate a laboratory session or to take part in an exam session is up to the user. The only requirements are the availability of a PC and a network connection. In more detail, the teacher can, in a laboratory consisting solely of the PCs that students bring with them, instantiate an exam session on the fly. Then, the students will have to use their institutional credentials to log into the system, where they can access a personalized dashboard and choose which activity to carry on such as, e.g., laboratory, exams etc. Even if a student is taking an exam, in the same classroom, at the same time, other students can perform different activities. For example, writing and compiling a Java program within the Eclipse IDE as well as entering the IBM Cloud platform, and also use, e.g., the IBM Watson cognitive services.

4.2 Some results

At the end of the activities, the platform allows students to assess the effectiveness and ease-of-use of the environments they used. In particular, they were asked to provide their overall feedback on satisfaction and usability. In order to evaluate the global satisfaction of the platform we considered an ordinal scale with values between 5 and 8. The students were asked to express their opinion after working on the platform for several hours. More precisely, Figure 1 shows that 87% of users gives a medium-high evaluation (scores 7-8), while only 13% believes that the platform has low-sufficient usability (scores 5-6).

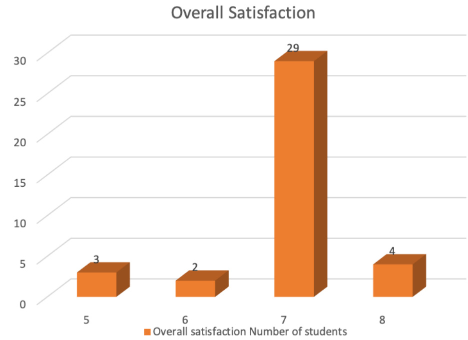

Fig. 1. Results from the questionnaires on users' satisfaction.

Since these integrated environments of multiple technologies may be too complex for young students, we have also asked a feedback on usability whose results are shown in Figure 2. In order to measure the usability of the platform we used an ordinal scale of values between 5 and 9. Students, in a slightly lower number (36 vs. 38), expressed their opinion about the usability of the platform after working on it for the didactic projects they were engaged in. More precisely, Figure 2 shows that the 61% of students gives a medium-high evaluation (scores 7-8-9), while only 39% (scores 5-6) believes that the platform has low-sufficient usability. Besides, students were also asked to express suggestions and possible improvements. From this analysis it emerges that students experienced some difficulties, due to the presence of two different environments but also for the functionalities, rather different from the classical university-laboratory setup they are used to, which offer only basic tools.

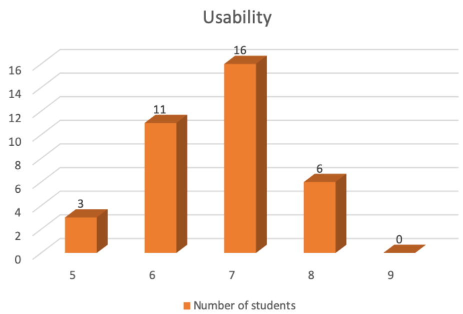

Fig. 2. Results from the questionnaires on usability.

In conclusion, the integrated environment in use was judged satisfactory with respect to the functions it had to perform. Given its apparent complexity, we consider such results quite positive and encouraging for the prosecution of this experiment also in the next academic years, in new classes and with a growing number of students.

5. From classrooms to communities

According to the above considerations, in this section we depict the characteristics of an innovative e-learning platform developed at the University of Trento, Italy. As highlighted in previous sections, classrooms should shift to communities and in such new places both students and teachers will be able to enhance humans' faculties and empowering their skills transformation, also owing to modern technologies and new paradigms for the possible relationships between men and machines. Specifically, we will discuss the Online Community (OLC) project.

5.1 The online community (OLC) project

The project started back in 1998 with the idea of implementing a different approach to educational content management, in contrast to proprietary platforms like WebCT™ and Blackboard™, which were dominant at that time. In this scenario, OLC was created from scratch, after having considered three possible alternative solutions: *(i)* adopting a commercial platform; *(ii)* adapting free-open source software to the needs of educational environments, as Moodle or similar where not existing yet *(iii)* building a brand-new platform. Finally, the third option, despite having the traditional pros and cons of every "make" solution, was chosen for other motivations that now, in the idea of innovating e-learning systems with new cognitive services, revealed to be the right decision. Compared to the adoption of commercial software, the Total Cost of Ownership (TCO) of this kind of solution was probably too high especially in the hypothesis of an extension, not counting the rest of the associated costs for maintenance, management and training, when compared to budget limits. We observed in the following years that this is a very common reason for the adoption of Free and Open Source Software (FOSS) platforms such as, e.g., Moodle by many small-medium educational institutions like high schools and universities. Put simple, being free of charge is the main reason for adopting this solution, without taking care of the side effects on the educational processes that it implies. In fact, a software platform implements processes in a rigid way once they have been coded, so the adoption of this component forces the institution to customize, adapt or even change the way things can be done because "the system does not allow me to do differently". As a secondary effect, the connection of the LMS with the rest of the organization's information system is mostly impossible [25]. As a consequence, many system administrators, are adapting their needs to the software system that, somehow, is able to solve most of their problems, and they mostly are resistant if not reluctant to develop an internal solution. Money, availability of qualified resources, short time to implement the solution, these all are comprehensible reasons for choosing the easy way of acquiring a pre-cooked solution.

We consider much more important to have the possibility of investing in a platform that can be easily extended with new services according to the needs of those trainers willing to experience the use of computer technologies in their educational processes. We therefore decided to develop a completely new platform, and very soon the platform was transformed from a mere LMS to a more structured platform devoted to support collaboration among members of a virtual community. The idea of "classroom" that is lying behind most of the LMS available today is, in our opinion, very restrictive with reference to the more complex processes that normally happen inside educational tasks, and can be extended to any other collaboration environment where collaboration among participants to the community are mediated by technologies. In other words, the idea of a customized LMS that could constitute a competitive advantage for one university versus another one is established [26]. This personalized software is able to supply better and personalized services that ease procedures and processes for the different users such as students, professors, or administrative personnel. Finally, a second decisive item was the need of deep integration with the rest of the legacy information system: authentication with single sign-on, integration with exam records and administrative procedures, possibility of bi-directionally exchange news and messages among people living the university day-by-day routine. Substantially, creating the platform from scratch was related with the rejection of "one-size-fits-all" approach to software components of an information system. Many administrators of the information system, especially in the educational sector, are adapting their needs to the software system that, somehow, is able to solve most of their problems, and they mostly are resistant if not reluctant to develop an internal solution. Money, availability of qualified resources, short time to implement the solution, these all are comprehensible reasons for choosing the easy way of acquiring a pre-cooked solution.

This adaptation of educational tasks to software platforms is a typical situation where many institutions are lying today. Because teams not always have the knowledge and resources to modify existing (open source) software educational platforms (i.e., LMSs like Moodle), they normally "adapt" themselves to what the platform supplies out-of-the-box, thus limiting the innovation potential of their ideas, and forcing users to adapt their learning processes to the improper technological tool. The typical example is the use of social media (the one that is more appreciated by learners in that moment) to support educational tasks. Social media such as, e.g., Facebook, Twitter, WhatsApp and Instagram are great tools when applied to the context they have been originally created, mostly exchanging multimedia information among peers. Yet, it is not so easy to integrate them in the educational processes: it is clearly a technical problem of available software Application Programming Interfaces (API), but it is also an instructional design problem introducing issues on how to cope the style of the lecture, how is changing the role of the teacher and what are the expectations of learners about the use of social media. In fact, an educational process is something wider than posting a photo or retweeting others' comments, even if it can benefit of this situation. Sometimes, educational processes need the support of other tools and services, that Facebook (for example) can provide through a distorted usage of its services. This normally forces users (mainly educators) to adapt their learning processes to what the platform provides, while it should be exactly the opposite, i.e., the platform should be able to adapt its services to the users' needs. The same happens with LMSs: most of the educational organizations have no possibilities of intervention, nor adaptation or modification on software platforms that have the size and complexity of Moodle, and so they adapt their educational processes to what the chosen platform provides as standard services.

5.2 Latest innovation

The innovative aspect that we introduced with OLC, and that now constitutes an extra advantage, is therefore reverting this master-slave approach that sees software platform as masters and end-users as slaves. The approach followed by OLC is to construct from scratch those services identified as relevant by educational experts, based on the precise educational needs of the different users: teachers, students or any other role involved. OLC has some architectural aspects there are very important for our argumentation about a next generation of TEL platforms: *(i)* we own and have created every single line of the source code, so the whole knowledge of the platform architecture and its potential are not scattered among different contributors (like in many open source projects); *(ii)* the platform is equipped with a micro service architecture, thus allowing an easy extension of the platform itself with new parts but taking advantage of the many services that any LMS should provide both to users and to developers that want to extend it; *(iii)* some services have been already developed in the past towards the direction of providing "intelligent" services. Owning and knowing the whole source code of the platform means to have a great advantage if you want to extend it with innovative elements, so the idea of using OLC as a basis for cognitive computing has been straightforward. Nevertheless, some crucial evolutionary changes had to be applied to the platform, and these changes are the key success factors for this shift:

a) stimulate interaction: the platform should encourage users to interact, not just to download files with teacher's slides. Today, the vast majority of LMSs are used solely to download files, while interactive and more participative services are left to the availability in the platform (if any) and/or at the goodwill of the teacher;

b) pervasive and enriched logging: the platform should log actions of users in order to activate cognitive processes: logging is essential for cognitive computing in order to classify users and infer the best service at the best moment. This logging should not be just the web application server logging, but specialized, application-level logging are needed to capture specific actions inside the single page of the LMS;

c) extensible, service-based architecture: the platform must be extensible through a service-by-design approach, in order to add new services whenever new possibilities can be explored. A micro service architecture is highly recommendable;

d) inference-oriented persistence layer: in order to facilitate inference, reasoning and cognitive computing algorithm, the persistence layer of web platform should be updated to more efficient and flexible data structures [20].

On this basis, a set of profound re-engineering operations has been implemented inside OLC. For example, we extended the platform towards a semantic representation of the knowledge inside the contents of the platform. We also integrated some soft computing, fuzzy-logic-based decision support systems [1], to support decision makers with intelligent tools about educational processes. Moreover, we experimented new storage layers, in order to collect data not only from traditional sources inside the educational environment (i.e., files, forums, galleries, posts, photos, etc.), but also collecting a lot of analytical information about the use of the platform and its services by the users. This immediately opens the problem of the size and appropriateness of traditional relational databases. We performed some experiments in substituting some parts normally stored in relational tables into triples available for a semantic knowledge representation. This meant using triple stores in the beginning as a persistence layer, thus facilitating operations like inference, reasoning, machine learning, etc. The triple (or quadruple) format for persisting (part of) data relevant for decision making and cognitive computing is another step that is not currently available in mainstream LMSs.

To better clarify the above concepts, let us consider as an example the diagram sketched in Figure 3, which depicts the preparation process of proper data sources for big data integration and analysis. The first step is the selection of the data from the persistence of OLC. This persistence is a typical big data source, with structured and unstructured information (file, learning objects, blog posts, forum topics, wikis, etc.) created inside the platform itself. The idea is to separate such data from the rest of the platform, to create the background to be able to apply the cognitive algorithms. So, in a sense, this resembles an Extract Transform and Load (ETL) process, typical in any data warehouse as well as OLAP and data mining solution. The most part of information is coming from the first data source we used in our experimentation, due to its affinity with big data sources, that we call "Actions". This service collects all data coming from users' interactions with other OLC objects or services. In practice, it acts like a sensor introduced inside the source code of the platform in any place the software needs to capture an "action" from the user interface. This is a relevant enrichment of the logs recorded by the web application server, and has been used for many different purposes. Due to volume issues, the system at the moment is blocked on collecting only some types of events, to a certain granularity defined by the system administrator. This choice has not been a design choice, but a performance-related one. In fact, it was clear from the early experimentations that the amount of data could have been compromising the capacity of the DBMS to stand with data acquisition pace and volumes: that is a typical "Velocity" an "Volume" big data problem.

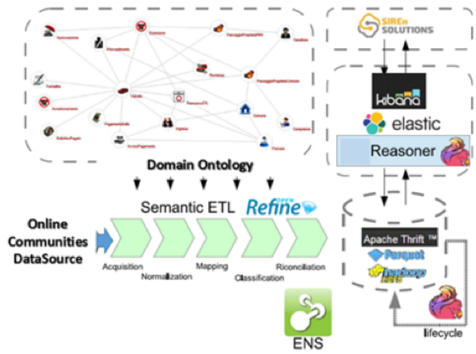

Fig. 3. Overview of the big data preparation process for the analytics tools.

In more detail, there are several elements of data gathering and manipulation pushing our virtual learning environment towards big data, thus increasing the need of a structural change of LMSs architecture, which should adopt new approaches and technologies. Specifically, we mention:

- traditional weblogs, being the application a Web-based software;
- internal logs of usage of the platform, the so-called digital breadcrumbs, that track the learner's journey throughout the entire learning experience;
- mobile logs, where data about mobile learning actions are collected;
- service logs, users' actions on the different elements of the platform like documents, forums, blogs, FAQs etc.;
- logs from the SCORM player, normally an external entity respect to the core services of the platform, with the records of the objects' execution;
- X-API calls, in case the platform is connected or acting as a Learning Record Store (LRS);
- MOOCs, by definition a generator of high volumes of data;

- lifelong learning, an old buzzword of e-learning that is still valid and interesting and, most of all, is another generator of big data, specifically along time;
- serious games that will use materials inside the platform, thus generating a relevant dataset related with users' performances.

The next step in the pipeline is the execution of cognitive tasks which can materialize implicit knowledge to support learning processes. At the moment, this reasoning is limited to basic inference regarding actions performed on certain parts and services of the platform, but the mechanism is ready for larger application scenarios. When the inference process is complete and new knowledge is inferred, a set of administrative routines is executed to load and transform part of the knowledge base to feed applications persistence.

6. Conclusions

As a conclusion, we remark that nowadays we are on a turning point in which cognitive-computing-based approaches are significantly transforming many aspects of our lives. In fact, beside the changes we can notice in professional applications and high-end software and legacy systems, we are already experimenting a set of cognitive computing services in everyday activities, for example, through natural user interfaces and voice assistants, whose presence is becoming pervasive. In practice, more often than we think, we are interacting with machineries that apply sophisticated decision-making processes with very low time constraints and a high level of accuracy. E-learning is one of the fields of application that can mostly benefit from this situation, due to its complexity and to the variety of disciplines that must be adopted concurrently to achieve good learning outcomes. Especially, the use of big data strongly empowers the process of personalization and individualization of the learning processes. Moreover, e-learning is also called to provide suited solutions to the problem of learning to use and exploit such new technologies, which cannot be achieved in environments designed for generic purposes. This raises the problem of developing a new generation of TEL platforms.

The paper introduces the vision of the authors, where a self-made, highly customizable virtual community platform will be integrated with scalable, top-notch cloud platforms and congruent cognitive algorithms applied to the different parts of learning processes, from material selection to educational path suggestions, from peer evaluation to big data discovery for decision makers. The process is still in its infancy, mostly because these three worlds (TEL platforms, cloud services and cognitive computing) are still separated and mostly focus on their own scope. What we are trying to do is merge the three disciplines into one single research area, with precise objectives and deliverables, thus allowing e-learning to maximize the advantages of the fusion of the three.

The two experiences presented in this paper can be regarded as an embryo for the development of future, unpredictable e-learning solutions. To this aim, the results achieved while using the integrated environment for exponential learning deployed at the Federico II University convinced us to scale the process on a wider and even younger audience, in order to test the real simplicity of such a TEL environment. Another lesson learned is that the surrounding world has become so complex and the changes so rapid that they will never be as slow as in the past. We should not waste our precious time any more in installing software, configuring applications, customizing solutions, tuning databases, maintaining laboratories, etc. Students and teachers definitely have to devote their intellectual power to more creative and less repetitive activities. Moreover, the applications we started using will increasingly have to analyze large amounts of data and therefore be cognitive. Future developments of the OLC also will follow in the direction of providing more advanced cognitive services and making the best from the available information mixing data from different online sources.

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Publication IV

Molinari, A.
Designing Learning Objects For Italian Public Administration: A Case Study

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DESIGNING LEARNING OBJECTS FOR ITALIAN PUBLIC ADMINISTRATION: A CASE STUDY

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Abstract

This research aims at analyzing the effectiveness of SCORM-based e-learning material in introducing companies to innovative practices, specifically the use of Digital Signature and Certified Electronic emails. These two tools have recently become mandatory in the Italian Public Administration, thus forcing them to pursue innovation through dematerialization processes. This innovation involves millions of Italian citizens and companies that now have the opportunity to interact with public bodies in a more efficient and effective way. Nevertheless, neither the Public Administration nor most of the companies (especially Small and Medium-Sized Enterprises - SME) were ready for this radical change in the use of electronic communication. A significant training effort has been delivered to allow end-users to absorb the concepts, tools, methods and procedures that take advantage of citizen-to-government and business-to-government communication. Most of this effort relied on e-learning and virtual communities' tools and services, providing support to citizens and organizations facing this new technical and organizational challenge. The authors present the successful experience in the design, creation and delivery of the distance learning materials designed for these purposes, together with the best practices and lessons learned.
Key words: *e-learning, public administration, dematerialization, learning objects*.

Introduction

In 2005, many radical changes were introduced into Italian Public Administrations (PAs) by the Digital Administration Code (CAD), with the precise objective of changing processes through dematerialization and ICT innovation. This will have an impact on the processes of most Italian citizens and organizations dealing with PAs, not least because of the constant interaction with the PA itself for different reasons (from tax payments to requests to granting). This revolution in Italian society will also influence the way citizens and companies will exchange information in the future. Since 2005, the Italian Government has been working on the "Codice dell'Amministrazione Digitale" (CAD - Digital Administration Code) in order to modernize and digitalize the processes of Italian Public Administrations. Subsequently integrated and amended, the CAD is now operational and in December 2012, a new version with important novelties was issued. The CAD, which despite its name applies to both private and public bodies, sets out a completely new scenario for using ICT to make the PAs more efficient and reactive in their relationship with stakeholders. Among the many innovations, four are particularly important:

a) use of the electronic signature for signing electronic documents;
b) use of certified emails;
c) use of a digital protocol to track in/out document movements;
d) rules on digital preservation.

Moreover, since April 2015, any invoice sent to an Italian PA must be issued in the form of "electronic invoice" following a precise XML schema and sent through specific certified channels. Implementation will certainly not be instantaneous, but the many changes implied (organizational, technological and legislative) will have a tremendous impact on Italian society. Italian PAs are therefore moving in this direction, and the implementation of the digital signature and electronic certified emails has already made significant progresses, while the other two themes are taking off. In the future, administrative procedures will be managed exclusively through electronic transmission, and interaction with citizens and businesses will be moving even more in this direction. This will profoundly change Italian PAs, but will also have a deep impact on the lives of citizens and businesses. These elements radically change the scenario for ICT usage inside organizations in general and PAs in particular.

Besides the design, realization and re-engineering of information systems and applications to support the new methods, business processes and procedures will also have to be re-engineered. This re-engineering process could start directly from public servants who, while performing their manual duties, could contribute in the event of inefficiencies with their knowledge to improve application of the CAD provisions. These people are normally experts in their field, but are probably not so expert in the specific domain of the CAD. The main expertise is hidden and not shared, formalized or clarified. The PAs will have to extract this information from tacit knowledge and transform it into explicit knowledge. Finally, Italian legislation stimulates the sharing and reuse of any educational resource produced by/for the PAs, in order to optimize investments and maximize the uniformity of view regarding the topics.

In order to deal with this situation, millions of citizens, public and private employees and organizations must be trained. Companies are often reluctant to adopt innovative solutions, stopped by the cliché that new technologies can only lead to complex and critical processes, especially if the stimulus to innovation comes from a PA. The question can now no longer be seen in these terms: companies must adapt to the indirect requirements of the CAD, or they risk not only to be excluded from a modernization process which paradoxically involves and is generated by the PA, but which is also likely to have consequences in terms of fines and sanctions.

The real problems related to the impact of the CAD on Italian society have been clearly identified as a training issue. The organizational and technological solutions outlined by the CAD (e.g., the problems associated with, and technologies needed for, the qualified digital signature) have clearly demonstrated the backwardness of large digital layers of Italian society. Moreover, most of the organizations were convinced that this innovation process was part of the Italian habit of proposing innovation and then not implementing it. On the contrary, it is clear that the document dematerialisation process is irreversible and the best is yet to come.

One of the reference points in the relationship between the CAD and businesses is without doubt the Chamber of Commerce. When the CAD was mature and stable enough, the problem set in 2011 with the Trento Chamber of Commerce work group was simple. The research project wanted to help companies improving certain processes without distorting them, with advantages in terms of speed, efficiency and cost containment through application of the dictates of the CAD.

Before 2011, Trento Chamber of Commerce, together with trade associations and the Province of Trento, had used a number of tools to raise awareness on the topic: sending printed material and newsletters, organizing dedicated events, publishing articles in newspapers or magazines with dedicated spaces, creating specific spaces on the website and launching various initiatives and seminars. Over a two-year period, all these efforts had reached about 300 companies in our region. However, reaching a larger number of organizations on schedule for the CAD deadline was clearly impractical and thus e-learning naturally became the means to achieve:

- low cost and appropriate timing;
- a broad audience

according to what has been presented by Stoszkowski, Collins and Olsson (2015), Colazzo, Molinari and Villa (2009), or Moore and Kearsley (2011). So, the objective of the joint research with the University of Trento has been to verify the effectiveness and the costs related with an extensive use of SCORM-based learning objects (IEEE Standard for Learning Object Metadata, 2002) in order to reach a wider audience of companies in the Trentino. These learning objects, and all the organization of groups of participants have been conducted through the virtual communities platform called "Online Communities" developed by our group and presented in Colazzo, Molinari and Villa (2011). The differences in previous knowledge about digital signature and electronic email were two elements to be evaluated, according to the different level of knowledge on ICTs available on the market. Another element of observation has been the habit of being trained through e-learning material: previous experiences on such a large scale (potentially more than 50.000 SMEs in the observed region) were not available in the area. The Chamber of Commerce supports all the companies in the area, of any size and of any market category. A third research question was related to the acceptance of innovation (both in the content and the vehicle of knowledge transfer) by different segments of the market. A last element of analysis was the composition of the virtual communities created for the training interactive sessions, in terms of composition, age and background knowledge.

Learning Solutions for Public Institutions

The results presented in the European Digital Agenda (EDA) Scoreboard 2012 clearly demonstrate the needs of e-government in Europe, considering all the stakeholders involved. The target of the European Digital Agenda (EDA) is to increase regular Internet use to 75% of the population. The confident projections of last year's scoreboard have been reviewed and the 75% target will probably be reached in 2014, rather than in 2013, although still ahead of the EDA target year of 2015.

Although e-Government usage by citizens is stable at 41% with some significant progress in smaller countries, the main reasons explaining the reluctance of citizens to use online public services are:

a) lack of need;
b) lack of trust;
c) lack of skills.

The digital agenda is nevertheless pushing for the adoption of ICT-related procedures and process re-engineering. Citizens and firms will steadily increase the requirement for e-Government services (usage by firms has increased steadily from 76% in 2010 to 84% in 2011) and civil servants will be forced to adopt ICT not only for their ordinary work, but also to improve their processes according to ICT availability. This is a great effort, as the incomplete digitalisation of public services is an important barrier to increasing e-Government take-up.

The "EPSA Trends in Practice - Driving Public Sector Excellence to Shape Europe for 2020" initiative demonstrated the need for integration, contacts and networks to be established among those PAs able to showcase their achievements in terms of a) modernization, b) innovation c) smart solutions able to withstand budget constraints, increasing demands from citizens and improved service delivery. The milestone for this is availability of the EPSA learning platform.

Some market research has demonstrated that almost 90% of public sector Learning Departments plan to increase the use of e-learning technologies in order to meet the cost reduction targets set in the Comprehensive Spending Review (CSR). According to FLAG-Flexible Learning Advisory Group (2013), while at the beginning of 2009 only 50% of Learning Development managers expected to increase their use of e-learning, 88% currently anticipate an increase, and more trainers expect to use collaborative learning techniques, like highlighted by Ho and Kuo (2010). In this sense, the current economic period of austerity is clearly having a deep impact on these considerations, with little distinction between the private and public sectors.

This clearly emerges from the examples reported in market research. The City of Edinburgh Council Interactive Learning (CECiL) started four years ago, providing online learning for all employees and reducing training costs by more than £800,000. The conditions required to obtain these savings are well known: high volume training to be delivered in a short period of time.

Learning solutions for the public sector have been promoted in many different ways in the past, with results that did not meet expectations. During periods of recession such as the one we are experiencing today, Technology Enhanced Learning (TEL) has been indicated as a panacea for future learning, a sort of "killer" of classroom training. However, many times in its history TEL has not lived up to the hype. The public sector expects to use e-learning to improve the level of service delivered to organizations despite budget cuts. This seducing metaphor attracted the public sector, fitting in well with the drive towards e-government.

Despite this, the reality showed a different picture. A large number of research projects and application studies have been carried out into the use of TEL in the public sector, if we consider educational institutions from primary schools to master degrees as "public sector". However, if this important category of use is excluded, the traditional Public Administrations have not been studied as a possible field of application for TEL-based training programs. Many examples of the use of TEL to train employees seem driven by the idea of cost saving, or of replacing missing educational paths (such as, for example, the requalification of civil servants without a degree in their curriculum).

Most use cases are concentrated in the period 2004-2010: Murty, Gilmore, Richards and Altilio (2012), Qiyun and Zhiping (2012), Stamatios and Tsihrintzis (2013) and Nisar (2004) are reporting these use cases, with different experiences coming from different countries and a different vision of the specific characteristics of the public sector. In terms of the state-of-the-art of TEL in the public sector, the situation is therefore not as clear as in the private sector, or the traditional educational system. Many studies have concentrated their attention on the application of TEL to institutional training, supporting traditional training with technologies, methodologies and tools. On the contrary, little attention has been devoted to TEL inside Public Administrations and their employees, with their specificity and needs.

Public Administrations, together with their employees, have been involved in TEL applications mainly for lifelong learning projects, considering public servants as people who will stay a long time in the same workplace and therefore an interesting case study for lifelong learning research and applications. Even if we exclude educational institutions from the field of application, the public sector is nevertheless a place where all the theories, methodologies and tools studied and implemented in Technology-enhanced Learning (TEL) could be profitably applied. Most of the new approaches and tendencies in TEL, like storytelling, MOOCs, gamification etc., could be applied to the large ecosystem of public stakeholders. Public Administrations are particularly interested in TEL:

- because they consider e-learning and web-based resources as fundamental elements of their training processes;
- because of TEL's ability to deliver contents over the Internet anytime and anywhere at competitive costs.

Most of the well-known problems have now been overcome. It therefore seems that, given the disappearance of many technological barriers, the progress of TEL - always on the point of spreading extensively and then for some reason never quite succeeding - should no longer be hesitant. Other obstacles have also been cleared away, such as standardization and the reuse of learning material.

Almost all public institutions have at least considered using one of the different available approaches (blended or full online). The tools available today can guarantee the service level required from Public Administrations: platforms such as Learning Management Systems (LMS), technologies such as videoconferencing and standards for learning metadata or objects like SCORM (IEEE Standard for Learning Object Metadata, 2002).

Another effect of TEL's maturity for the public sector regards the large amount of educational material produced and now available in various forms. Various institutions have created several Learning Objects (LOs), mostly freely available. Together with reusability, cost reduction, time optimization and a more modern view of the PA, these elements have contributed to raising expectations about TEL in the public sector. In terms of the factors influencing the adoption of TEL in PAs, some studies conducted in PAs indicate that the opinion of civil servants regarding e-learning was significantly influenced by their satisfaction and this in turn was affected by:

- job relevance;
- expectation confirmation;
- perceived ease of use;
- perceived usefulness;
- computer self-efficacy.

Other studies show that adult learners perceive the effectiveness of e-learning in the workplace positively, as for example reported by Ifrim, Stănescu and Stefan (2010).

The Digital Agenda and the Italian Digital Act

Preventing resource wasting is today a "must" for every PA and the digitalization of paper-based procedures represents an opportunity to contribute to this prevention. The need for process digitalization, especially in PAs, has been recognized since the 1980s and is one of the areas where ICT can produce evident advantages. In this field, the term "dematerialization" has been used to identify the progressive elimination of paper-based processes in favor of their digitization.

In this context, since 1997 the Italian PA has undertaken the complex task of creating a legal and normative framework that facilitates the digitalization of processes through the modernization of PA information systems. In 2005, the "Digital Administration Code", (CAD - Codice dell'Amministrazione Digitale, Legislative Decree no. 82 of 7.3.2005 as modified by Legislative Decree no. 23 of 30.12.2010) clearly and extensively defined what should be done in order to create a "digital Public Administration".

It sets out a completely new scenario for the use of ICT, thus allowing PAs to be more efficient in their relationship with stakeholders. The CAD came into force for all Italian PAs, but despite its name, it covers both private and public organizations and in practice all Italian citizens and organizations. The aim was to reestablish order, addressing and setting rules for every aspect of technological innovation introduced into Italian society. In the CAD, there is a strong commitment to dematerialization and this is the point where to intervene with the use case involving e-learning. More specifically, the CAD gives legal validity to the digital documents involved in processes and procedures conducted using ICT. Among the many innovations, four are particularly relevant:

a) the use of electronic signatures for signing digital documents. This classifies the probation effectiveness of the different electronic signatures, specifically the "advanced electronic signature" that plays a leading role on the Italian market today in certifying the identity of a document's subscriber/s;
b) the use of certified emails. The certified email (Italian acronym PEC) provides citizens and organizations with legally valid electronic documentation of the sending and delivery of electronic documents to certified receivers and conversely, receivers have legal evidence as to the sender of a certified email;
c) the use of digital protocol to track in/out document movements, thus not only allowing certification of these movements through the Information System, but also providing a way to centralize the storage of documents officially sent and received by the organization;
d) rules about the digital preservation of electronic documents. This is a specific

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instance of the larger problem faced today by organizations worldwide. According to one of the many well-known definitions, digital preservation “combines policies, strategies and actions that ensure access to digital content over time”. In the Italian CAD, this problem regards every single organization that undertakes to comply with the provisions of the CAD. It is the logical and inevitable final item in the full, automated digital communication process. Nevertheless, it also introduces a great many technical issues that heavily impact the day-by-day activities of the organizations: ICT infrastructure to preserve contents, methods to search and retrieve digital objects etc., but most of all, competencies and people specifically devoted to and skilled in digital preservation.

These four elements are revolutionizing the processes of Italian Public Administrations, allowing new scenarios for the interaction between PAs (government-to-government), PAs and citizens (government-to-citizen), and PAs and companies (government-to-business). Specifically, these innovations have an enormous and unexplored (so far) potential in re-engineering the PAs processes, thus allowing obvious but crucial advantages, such as considerable savings, flexibility in managing processes and relationships, speed in fulfilling requests for services, transparency of procedures (especially towards citizens) and the possibility of measuring the performance of individuals and public organizations.

In addition to the design and realization of applications supporting such new methods, intensive personnel training must be performed in order to take advantage of the opportunities created by the CAD:

- new rules, new systems and new procedures must be acquired by all civil servants acting inside PAs;
- business processes and procedures will need re-engineering.

The problem for Italian PAs is not a lack of people able to optimize and improve processes, but that Italian PAs and citizens are unable to metabolize the innovations offered by digitization and dematerialization due to an endemic resistance to change. Table 1 presents the situation of PEC adoption in some of the most “efficient” Italian provinces, where the Autonomous Province of Trento occupies the top positions. This data are extracted from 2013 annual report of the Agency for Digital Italy (AgID - Agenzia per l’Italia Digitale).

Table 1. Adoption of Italian certified emails among large corporations and SMEs.

Chamber of Commerce	N. of Companies	With PEC	%
Cuneo	24.843	22.569	91
Sondrio	6.543	5.920	90
Bolzano	21.494	19.351	90
Forlì	19.834	17.526	88
Trento	22.297	19.632	88
Pordenone	12.054	10.544	87
Prato	16.644	14.461	87
Bergamo	47.636	41.036	86
Belluno	6.992	6.023	86
Mantova	17.649	15.170	86

Against a national average of 74% adoption of certified email, in the Autonomous Province of Trento, 88% of organizations have formally adopted this tool. However, if companies are considered, the situation changes radically (Table 2).

Considering that most of the time enterprises correspond to citizens, it is clear that Italy has a serious problem in diffusion of the CAD digital agenda. Moreover, PEC is without doubt the easiest of the four elements promoted by the CAD, because of the similarities with traditional email box management.

Another interesting element of analysis, always from Ag ID, concerns the traffic of certified emails during the last six years. This clearly shows increasing adoption of the CAD and this could in turn indicate that while few organizations and individuals are adopting the CAD provisions, they are using them extensively and progressively. It is interesting to note that since 2007, PEC domains and mailboxes have increased respectively by 27 and 45 times, while the number of PEC messages has increased just four times. This is an evident effect of the compulsory nature of the CAD prescriptions, but does not represent intimate and convinced adoption.

Table 2. Adoption of Italian certified emails among individual enterprises.

Chamber of Commerce	Individual Enterprises	With PEC	%
Firenze	53.909	2.399	4.45
Prato	16.506	704	4.27
Livorno	18.458	781	4.23
Rimini	19.944	834	4.18
Teramo	21.643	853	3.94
Crotone	12.276	482	3.93
Ancona	26.885	1.047	3.89
Pistoia	18.227	699	3.83
L'Aquila	17.455	664	3.80
…..	…..	…..	…..
Trento/PAT → ranked #103	29.423	359	1.22

Italy now has the legal framework and ICT provides the technological tools for adoption of the CAD provisions to take off. The missing link is now an extensive initiative to train individual users and organizations in the tools introduced by the CAD. Promotion of this cultural growth in Italian citizens and organizations is clearly the responsibility of the PAs.

Table 3. The diffusion of PEC domains, mailboxes and messages over the last six years.

Year	Tot. Domains	Tot.Mailboxes	Tot.Messages
2007	42.369	618.165	116.376.864
2008	111.244	1.147.208	218.477.050
2009	295.220	3.943.160	253.098.716
2010	578.258	11.518.079	327.476.760
2011	840.404	17.797.879	324.125.539
2012	1.164.829	28.297.727	459.662.512
Grand Total	3.032.324	63.322.218	1.699.217.441

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Creating Learning Objects for the Italian PA: Methods and Results

Since 1998, the research group has developed extensive experience in e-learning applications, specifically in the Public Administration. The authors are currently delivering e-learning initiatives with many public and private partners, including the Autonomous Province of Trento (~12,000 employees), Trento Chamber of Commerce (~55,000 individuals and users in Small and Medium-Sized Enterprises), Trentino Development Agency (~1,000 users/companies), the Academy of Commerce and Tourism (~1,000 users/companies) and of course the University of Trento (~ 15,000 users). Through the experience of e-learning in PAs, authors have proven that excellent results can be obtained, not only using e-learning as a substitute for traditional classroom activities, but also involving and motivating the public servants directly in the creation of learning objects. These results can be obtained if the following elements are available during creation of the educational path:

a) a common methodology for gathering, formalizing and delivering the required training, thus avoiding uncontrolled production;
b) a different approach for traditional face-to-face interaction with teachers/experts, less formal and "boring" compared to PowerPoint-like presentations;
c) a virtual place with a strong collaborative connotation in which to share ideas and results with other colleagues, in order to compare different views and interpretations of the process, especially from a legal point of view;
d) the availability of consultants on legal topics able to provide straight-to-the-point advice: a teacher is needed, rather than a consultant;
e) a way to see activities recognized and rewarded, at least in terms of reputation, a formal way to recognize the work done in e-learning material production.

Many learning packages and training initiatives have been started since the advent of the CAD, but no tangible results were clearly emerging. As direct experience, the decision was to specifically develop e-learning SCORM packages covering all the CAD topics. The working group produced 14 hours of learning objects explaining in detail the two tools mandatory for companies today, i.e., the digital signature and certified email. This initiative was launched in 2011 together with the Autonomous Province of Trento and involving various professional associations.

In the Autonomous Province of Trento, out of more than about 50,000 enterprises (large public and private corporations, SMEs, individual companies), approximately 700 participated in this joint initiative involving the Autonomous Province of Trento, the Chamber of Commerce and the University of Trento with the fruition of e-learning material completely free-of-charge. In order to interpret this data correctly, the authors considered how most public servants and professional associations used our e-learning platform. Then a different approach has been experimented. In the last months of 2012, the research group experimented an approach to content creation for some associations related with the local Chamber of Commerce, covering three processes:

- permits to open new hotels in tourist areas;
- registration of a new company in the Local Registry of Enterprises;
- cancellation of a company from the Local Registry of Enterprises.

This time, the domain experts created the material, but with intensive interaction with the public servants in charge of the above processes. A new paradigm for delivering training to public servants, citizens and companies has therefore been introduced, by changing the producer and the methods of production, sharing and using the e-learning material. It is nevertheless clear that the level of complexity in the re-engineering of processes as a result of the CAD can be managed by these "prosumers" when explicitly supported by experts acting as consultants rather than teachers.

The two themes of the "Digital Signature" and "Certified Electronic Mail" were treated separately, to provide different ways of adapting training needs to the pre-existing knowledge or skills already present in the organization. For each item, three distinct levels of learning have been provided, adaptable to the needs and to specific questions. The material can, in fact, be accessed both by following either a sequential approach or an application-driven approach, allowing the user to immediately identify the topics of interest. These are the three levels:

- the "information" level, aimed at disseminating knowledge on the issues and then answering questions on the correct professional procedures to follow. This is obtained by clearly expressing the benefits and points of attention resulting from its use, as well as gathering the questions raised during the training sessions and telephone follow-up implemented by the Chamber of Commerce on a sample of 50 firms
- the "use" level, designed to provide practical tools for the two topics by means of tutorials guiding the user step-by-step through activation of the instrument, its use and verification of the correctness of the operations. At this level, recorded sessions of interaction with the software tools to digitally sign and send certified emails has been used;
- the "deep knowledge" level, devoted to users or potential users of the two instruments who wish to become more aware of the implications deriving from their usage, particularly in legislative terms. During design of the learning objects described above, the legislative aspects covered were, in fact, reduced.

The level of participation to the online courses was on voluntary base. Among the potential 50.000 companies involved, many of them had already different ways and supports to stand the novelty introduced by the CAD. Especially for the certified e-mail, a vast majority of them were already equipped with traditional e-mail, and some seminars delivered by the Chamber of Commerce have been sufficient to clarify the (few) differences between the usage of a traditional e-mail system and the one needed for the certified e-mail. Then, a second group of companies have not been involved as their relationships with the public administration are mediated by intermediary organizations, like associations, or accountant technicians that most of the time intermediate between the affiliated company and the public administration. This is not a positive aspect of Italian way to innovation, because companies tend to postpone the introduction of innovative tools inside the company, simply because somebody else is taking care of it. Innovation in this case is seen as something to delegate to external bodies, and plenty of services in Italy are available to follow the easy way of innovation.

Nevertheless, there is a third component of enterprises that are not supported, that are not equipped with the appropriate technologies and internal processes, and that have to face the new tools in order to communicate with the external world, especially with the public administration. Small medium enterprises, cooperative farms, small consultancy firms: this is another set of companies that needed to be trained, and that approximately represents the fifteen percent of the whole market in this region.

An informative campaign has been organized in order to promote the initiative of free, online-based training sessions, starting from 2012 till the beginning of the mandatory deadline, i.e., 6th of June, 2014. The results of courses followed by companies using the e-learning platform are represented in the following table 4.

Table 4. Companies enrolled in on-line courses from 2012 to June 2014.

Digital Signature and Certified email – Online Courses	
Year	Enrolled Companies
2012	165
2013	213
2014	63
Total	438

Due to the very positive feedback received both regarding the approach and the contents, the Chamber of Commerce decided to invest in e-learning for the creation of video lessons on the common practice of "balance sheet management" and the "Business Register". The Chamber of Commerce is considering how to reuse the material produced for blended learning, which could further encourage companies to participate. The results of this further experimentation is interesting: this time the population involved was very limited and specialized (accountants and consultants involved in providing services for accounting and bookkeeping), and there were no legal obligation to be complied. The initiative of using e-learning material in a blended context to substitute the traditional face-to-face training delivered by the Chamber of Commerce was an autonomous decision of the Chamber of Commerce itself.

The blended approach implied for the participants to follow two or three face-to-face meeting, and all the rest of the course has been delivered online. The level of participation, considering the selected potential target, has been high, with 37 participants in 2013, and 95 in 2014.

Discussion

Since 2011, more than 700 companies have benefited from the material made available on the platform and have progressively reported a need for other training covering other types of content, and among these, more than 400 followed courses available in the platform. For this reason, in 2012 the Chamber of Commerce decided to make some specific topics available to other communities, relating specifically to the aspects that gathered more questions or more errors.

Respect to the original research questions, the sample of companies that have used the online material is sufficient to draw some conclusions, corroborated by feedback received in public meetings, telephone calls and a short questionnaire. Companies that participated to the online courses were predominantly with limited or no background on the technologies that were the subject of the online courses. According to this homogeneous distribution, no significant differences have been noticed: most of the companies were SMEs with a consistent deficit of ICT knowledge, and therefore in great difficulties not only with the new technologies proposed by the CAD, but in general with the computer.

The preliminary results of the presented research clearly show that the changes in the approach and in the tools used to deliver technical topics to a large audience have been significantly appreciated by end-users. Especially the parts of materials directly produced, or produced with a direct interaction with the public servants, taking advantage of their expertise, have received specific appreciation, a sort of liberation from "traditional, boring slideshows" (as reported by some participants through the feedback questionnaire). After having tested other methods such as the creation of learning objects by academic experts, it is clear that learning objects created by internal people with a high reputation are much more appreciated and trusted.

As a general conclusion, surprisingly no clear evidence emerged respect to the different economic sector of the companies. A greater difficulty of companies coming from remote areas (Trentino is a mountain region in the middle of the Alps) and/or from primary sector with connected markets (like for example farm tourism) was expected, but again also this data has not been confirmed. No significant differences in terms of appreciation or dislike of the CAD innovation came from the different economic sectors. The real difference came from the age of the person that the company decided to enroll in the e-learning courses: specifically, younger people demonstrated much more appreciation both for the CAD innovation and for the innovation in the training methods.

Respect to the acceptance of innovation (both in the content and the vehicle of knowledge transfer), very few companies had a previous experience of e-learning courses attendance, although nobody have complained about this new modality. This element appears a little bit strange, considering the previous point i.e. the lack of a solid ICT knowledge. In any case, although the overall judgment of the new training modality has not been negative, almost all the companies contacted after the course (online questionnaire and following direct telephone call in case of negative feedback) expressed their aversion to the novelty introduced by digitalization and dematerialization. Neither the pressing campaign of the Italian Government, nor the e-learning material convinced the most conservative component to jump into innovation.

The biggest problem, arising during the design phase when material provided by experts had to be converted into learning objects, involved both estimating the effort required from our development team and Trento Chamber of Commerce, specifically quantifying the remuneration for the authors of the material and learning objects. This is a typical case of the industrial production of learning objects where a "teacher" should be acknowledged a number of hours far superior to the total duration of the learning objects produced. This issue has been solved by adopting the cost for the creation of online learning objects presented in Casagranda, Colazzo and Molinari (2013)

As a set of side effects of this research, there have been clear indications about best practices to be used in conducting these experiments, and in building the respective learning objects for contexts otherwise unreachable:

a) particular attention should be applied to the micro-design of the contents, scheduling single items in a very fine-grained way instead of providing non-specific, long sequences of concepts and contents;
b) the use of a virtual community demonstrated to be a better container for e-learning tasks. This result is similar to other successful experiences, like Stoszkowski, Collins and Olsson (2015), Donlan (2014), or Sannia, Ercoli and Leo (2009). The virtual community has been created for each edition of courses (50 companies at the time), so limiting the access to members and key stakeholders, in order to increase the quality of the final results. This means that a platform structurally designed to implement the idea of a virtual community is recommended outside traditional academic contexts, rather than simply managing a classroom or training event;
c) the remuneration of the actors involved (teachers, content experts, e-tutors) had to be increased using a cost model specifically designed for e-learning by increasing the evaluation of the time spent in producing learning objects. The production of learning objects have encountered many resistances on the teachers' side, especially those used to deliver courses on the subjects;
d) a clear idea of lifelong learning context emerged as interesting global conclusion, in the sense of providing companies a perspective of permanent training helping them to follow the pace of innovation that the Italian Public Administration have started. In the questionnaires, companies clearly perceived and expressed the conviction that "like it or not", the road has no way back, so an appreciation to a life-long learning path has been expressed as more than a desire. This means for the future, the need of designing a path that includes migration of many of the training, information and updating activities of Trento Chamber of Commerce towards e-learning materials, thus guaranteeing to companies the possibility of staying up-to-date. This demonstrated the benefits always professed by e-learning research, but which now seem even more indispensable for any Public Administration involved in digital modernization.

The authors are conducting further activities to raise the awareness of companies, including through evaluation of a partnership with the Association of Public Accountants, a reference point for many small and medium-sized entrepreneurs.

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A New Approach to the Use of Semantic Technologies in E-Learning Platforms

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A New Approach to the Use of Semantic Technologies in E-Learning Platforms

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***Abstract*—Semantic technologies have been studied and used in different areas of computer science. E-learning has been one of this, but the most frequent use of semantic technologies in this discipline has been in the extraction and indexing of contents, like forums, blogs, learning objects etc. The research presented in this paper aims at taking advantage of semantic technologies in a different way respect to the mainstream use that has been done in the past. This new approach refers to the use of semantic technologies in the management of the persistence layer of Learning Management Systems (LMS), i.e., where all the contents are stored. Our research follows the idea of using semantics technologies as a support, if not an entire replacement, of the backend and persistence mechanisms of LMSs. As a testbed, we will present the design and early results of the application of this approach to the persistence layer of a Virtual Communities System, where these technologies will enriched the platform to address two fundamental issues: a) entities disambiguation and identification inside the persisted objects b) adding new features to the platform without refactoring it.**

***Index Terms*—Learning Management Systems, Semantic Technologies, Learning Objects**

I. INTRODUCTION

After many different phases, e-learning seems to have reached a successful position inside every organization. In the past, the application of semantic technologies to educational settings attracted a lot of attention, in particular regarding those approaches and software tools able to enrich, categorize and retrieve learning objects.

Many researches and developments in the field of eLearning analyzed the various possibilities for existing and future e-learning frameworks to take advantage of semantic services, interoperability, ontologies and semantic annotation. Nevertheless, much of the current research seems to limit the discussions to the recurring theme of how the semantic web will enable knowledge engineers, instructors or instructional designers to construct elegant ontology-based annotations for existing web-based resources and mainly Learning Objects (LO) and to further expand metadata schemes. Minor attention has been devoted to other applications of semantics technologies to Learning Management Systems (LMS), specifically as a replacement of the backend and persistence mechanisms.

In this paper we will present a line of investigation regarding the application of semantic technologies to “Online Communities” (OC), a virtual communities platform that we are using in several projects with public and private institutions to support educational processes. We present the design and early results of the application of semantic technologies to the persistence layer of the platform, where these technologies enrich the platform to address two fundamental issues: a) entities disambiguation and identification inside the persisted objects; b) adding new features to the platform without refactoring it, by using graph-based representation techniques to add knowledge to the existing datasets. In order to address the first item, our implementation takes advantage of the entity-centric tools developed in the Okkam EU-funded project. These tools provide a solution to uniquely and permanently identify entities (people, locations, organizations etc.) inside contents, specifically using the Entity Name System (ENS). The ENS supplies a persistent identifier, called OKKAMid, to any entity included in the knowledge base, together with advanced entity matching methods for detecting the occurrence of the same entity in different contexts and data sources. Once the entity in the LMS has been profiled, it is possible to connect any content where the different occurrences of the same entity have been mentioned inside the LMS, and also to connect any other content outside the learning platform where that entity has been named, for example web pages or social network contents.

Furthermore, we extended a domain ontology (SIOC) for the conceptual representation needs of the application, and added an RDF graph mapped onto the database, in order to add new functionalities to our virtual community platform. This allows us to take advantage of the inference processes available through a reasoner, and to substitute some parts of the business logic of the application.

To improve the semantic representation of concepts and to allow the mechanisms to interface with this knowledge base, RDF data stores have been implemented. Changing the traditional database-oriented representation of data towards a richer format (i.e. RDF statements), other than a richer representation model, gives a high level of flexibility in the definition of persistence and data representation models. RDF has been selected for data representation, while tools like Hadoop, Flink and NoSQL databases have been used and tested as a replacement of “traditional” relational databases, and a bridge towards big data scenarios. These tools and techniques have been experimented in other application fields, specifically in data integration inside the fiscal evasion domain, where different data sources are reconciled through the use of the ENS for entity disambiguation.

The paper is divided as follows. The next section will be devoted to a quick overview of how semantic technologies have been used in e-learning. The third section will briefly present the virtual communities platform where we are experimenting the entity-centric approach to e-learning platforms. The fourth section will present a summary of the entity-centric approach promoted by the OKKAM project, and discuss how this approach can be applied for our refactoring and extension objectives. The last section will briefly present the achievements obtained with the application of semantic technologies and an entity-centric approach to our virtual communities platform.

II. E-LEARNING AND SEMANTIC TECHNOLOGIES: STATE OF ART

Most of educational institutions have recognized e-learning resources as fundamental assets for their training processes, mainly for the capabilities of delivering educational contents to participants over the Internet anytime and anywhere at competitive costs[1]. In these institutions, we can find many different implementations and customizations of available approaches (from blended to full online e-learning) and tools (platforms like LMS, technologies like videoconference, standards for learning objects metadata like LOM or SCORM [2][3]).

The maturity level of e-learning is visible also in the increasing amount of educational material available under various forms, and in the availability of many Massive Open Online Courses (MOOCs) involving people around the world. Considering the complexity of learning tasks, any new technology that can help to accelerate and improve these processes, catalyzes the attention of specialists. Semantic (web) technologies made no exception, providing a landscape where web-based information and services are understood, processed, interlinked and reused not only by humans but also by machines [4].

These are some of the suggestive perspectives about the use of semantic technologies in the e-learning field:

- the outlook to integrate learning objects enriched with metadata into an adaptive learning environment;
- the possibility of overlapping and integrate an ontological representation of the content into the functionalities of the LMS;
- the idea of integrating reasoning facilities to e-learning platform in order to infer knowledge and not previously created or complex links among educational materials.

The widest application fields of semantic technologies inside e-learning contexts have been content classification, retrieval and enrichment through the use of knowledge representation instruments, like vocabularies, taxonomies and ontologies.

Another perspective sees the semantic web as the possible implementation of a reliable, large-scale environment of machine-understandable and interoperable services that intelligent agents can discover, execute, and compose automatically [5]. Other researchers used semantic technologies to build a brand new generation of learning applications from scratch, or to enrich existing software platforms that deal with educational settings [6]. In any case, despite the excellent opportunities of combining e-Learning platforms with semantic technologies, there is no magic solution to exploit this integration: spreading the "magic powder" of semantic technologies over a LMS does not guarantee measurable improvements.

Currently, different educational standards for describing contents in learning resources exist, and a number of organizations have been involved in producing metadata standards specifically for learning technology: SCORM, IEEE LOM and IMS Learning Resource Meta-data Specification can be identified as the commonest and most robust ones[7]. Standard metadata are used by IEEE-LOM, mainly for interoperability between different LMSs but, unlike RDF based metadata, the standard only allows for a hierarchical structure. Semi-semantic metadata extend the IEEE-LOM standard with some semantic component, for example extending the relational field in the standard with a semantic net to interconnect different LO [8], or adding term associated to some pedagogical or domain ontologies [9]. Semantic metadata can be defined as "…the process of attaching semantic descriptions to Web resources by linking them to a number of classes and properties defined in Ontologies" [10]. Applications using semantic metadata rely on domain ontologies to define their metadata using RDF to express the semantics of a learning resource.

There are several advantages of using RDF over the standard metadata approach [11]: a) an RDF data model is based on the assumption of selecting metadata potentially from heterogeneous ontologies, while standard metadata are taken from a LOM-based, closed-world approach confining metadata to the particular LMS implementation; b) with RDF, complex statement can be created, thus expressing logical networks, while LOM can express simple composition of statement possibly extended through taxonomic classification; c) simple forms of inference (e.g. class inheritance, consistency check, transitivity) can be applied, this way reducing the costs of developing ad hoc solutions to implement the functions which requires them.

Annotating LO is therefore a fundamental task to guarantee and facilitate access, sharing and reuse of the learning resource. Annotation is also a keyword for the semantic world; in fact, annotated contents transform a full text to be scanned by keyword into a structured, semantically-enabled content. However, there are some obstacles to use structured learning material as a perfect knowledge base for learning activities.

Firstly, most LO have not been enriched with metadata, or have been enriched with automatic, title-related or filename-related attributes that are semantically poor and sometimes even counterproductive. Second, learning objects are not the only source of knowledge inside a LMS, and LMS platforms are not built just of learning objects. Web 2.0 tools and services, like blogs, wikis, forums, FAQs, glossaries, questionnaires etc. are most of the time very useful for the conduction of the learning process [12] especially in educational paths with a high degree of interaction among participants and instructors.

As a further element, organizations can replace their tools and platforms along time, but the investments on LO should be preserved. This means that a great attention should be paid to content and data interoperability and migration. For those materials that have been created under some standard's umbrella, the problem should not exist, but for other contents like those created with Web 2.0 tools, the availability of an RDF-based representation simplifies the mapping process between data schemas of different e-Learning platforms [13][14] thus facilitating contents migration among different LMSs. As LOs could be very complex multimedia artifacts, these problems could be frustrating for any interchange of educational material.

Another aspect where semantic technologies could play a fundamental role in learning settings is the addition of search capabilities to a LMS. The integration of semantic technologies is mainly devoted to get meaningful results from user queries about the knowledge base managed by the LMS itself. Parts of such a Knowledge Base that could be affected by semantic categorization could be contents, course materials, students' profiles, etc. [15].

A direction where semantic technologies frequently intercept the e-learning field is the connection with the WWW. The Semantic Web extends the categorization of existing WWW resources, allowing "computers to intelligently search, combine, and process Web content based on the meaning that this content has to humans."[16]. There have been several projects and researches that combined these three factors into e-learning systems, focusing on determining the standard architecture and format for learning environments, and this helps the integration with what has been famously illustrated in Tim Berners-Lee's "Semantic Web Stack" representation [17].

These standards, however, are trying to model the interoperability of educational information that are relevant to the educational process[18]. IMS and SCORM sequencing models define the educational activities and system implementation, together with the method for representing the intended behavior of an authored learning experience, but not the contents' knowledge in educational activities. Other authors [19] used the taxonomy of learning resources and stereotypes of teaching models for educational contents and sequences, but these aspects are heavily platform-dependent and lack standardization and reusability.

A central role is played by ontologies, here intended [20] as conceptualizations of a specific domain in terms of concepts, attributes, and relationships. Ontologies enable the representation, processing, sharing and reuse of knowledge among applications. In e-learning settings, they play a crucial role in a number of ontology-centered researches where web technology standards, such as XML and RDF(S), allow to share and reuse any web-based knowledge system [21].

The impact of the merge between e-Learning and semantic technologies is, in our opinion, deep and permanent, for reasons that we shortly presented but that have been largely discussed in different research areas [22]. Nevertheless, much of the current research seems to limit the discussions on how the semantic web will enable instructors to construct elegant ontology-based annotations for existing web-based resources, and to further expand metadata schemes[23].

Our approach is less focused on contents and more oriented to a different usage of semantic technologies, for managing unique identification of entities and increasing the information extraction from the e-learning knowledge base.

III. SEMANTIC TECHNOLOGIES AND LMS: "ONLINE COMMUNITIES" PLATFORM

The above aspects of semantic e-learning clearly emerged while expanding our virtual communities platform called "Online Communities" (OC) [24], specifically when we started to connect the contents with external sources of information (like social networks or other web resources). OC is a collaborative environment totally designed and developed by the Laboratory of Maieutic – University of Trento (Italy) which aims at supporting cooperative processes, and teaching/learning activities in particular. Currently, Online Communities is mainly used outside the university campus, serving approximately 1000.000 users from different public and private customers against approximately 15.000 students in our University.

The core of the application is composed by some abstract entities, called "Virtual Communities", viewed as an aggregation of people to which some collaboration and communication services are available in order to obtain certain objectives [25]. (Virtual) Communities can be aggregated into larger ones, with hierarchical relationships and unlimited nesting levels, thus allowing to represent hierarchies between different types of communities (such as Faculties, Didactic Paths, Master Degrees, Courses, Departments, Organization charts etc.).

The cooperative virtual space of "OnLine Communities" is actually closed. The users participate in the system directly with their real identity. In fact, a person who enters a virtual community of our system is authorized by the community administrator and from that moment onwards he/she is automatically in contact with the people inside the community. Members of a virtual community typically have similar objectives of acquiring and sharing knowledge about specific topic.This is also why anonymity is relatively important. Lack of anonymity and control of the external accesses have origin in two explicit requirements of our first customer, the Management and Business School of the University of Trento. The exclusion of anonymity is the result of a belief that the anonymity into virtual learning environment should be banned, so that the actors cannot shirk from their responsibilities. The second circumstance (access control) stems from the will of a substantial number of teachers to block the publication on the network of their courses' Learning Objects. These choices made the system impermeable to the users' social dynamics, or to the communities existing in the social networks. Here, the role of semantic technologies could be also counterproductive, if someone wants to keep the material protected from external reference.

The architecture of Online Communities is based on five pillars: Person, Community, Service, Role and Permission. The combination of roles and permissions defines the Profile for each user. Each Community avails itself of a certain number of services, i.e., applications that enable users to communicate in synchronous and asynchronous ways, publish contents, exchange files, coordinate events, etc. Services of a community are activated by a community manager on demand, and users of a community have different rights on them.

Over the years, the system evolved into a platform for professional training oriented to lifelong learning outside academia, embracing the (social and technological) context where teaching and learning take place.

Another aspect deals with the relation between LMS and the information system of educational institutions. At the moment e-Learning platforms seem to act in a restricted circle made up of only teachers, tutors and students. In Online Communities, instead, the community is a container ready for teaching processes, but not only: research teams, recreation groups, friends, secretariats, board of directors, colleagues, anything that could represent an aggregation of people around a scope could be implemented in OC.

Given that a most detailed list of functionalities is beyond the aim of this presentation, the evolution of the platform is keeping us fully busy in studying a series of articulated functionalities:

- "traditional" services: asynchronous (forum, agenda, upload & download of learning objects, newsgroup, notice-board, classroom management, management of course pamphlets and of users, etc.) and synchronous ones (chat, streaming audio/video) and "Personalized" Services, closer to the aspects of life-long learning and "training on the job" (tutorship, training on demand, research tools with problem contextualization, semantic web, FAQ etc.)
- Integration services with external information systems (for example, the Personnel information system of the organization)
- Services for the fruition of "off-line" courses, i.e., courses already held and recorded, digitalized and made available to controlled communities of users (with the possibility to synchronize the video with slides, podcast, webcast, SCORM modules, etc.).
- Services for the management of courses delivered as Massive Open Online Courses (MOOCs). This addition meant to reuse most of the services already available in the platform, but to adapt them mainly to the "M" of MOOCs, i.e., the potential massive enrollment of people. Most of the enrollment user interface controls and widget had to be changed according to the perspective of supporting thousands of users.
- Services for the creation of evaluation test, quizzes, polls etc.
- Statistics about the users behaviour (using an internal data warehouse enriched by activity logs).
- mobile Services to support mobile learners. There are some innovative services which meet the mobility needs of the subject who wants to learn "on the move", performing learning/collaboration activities directly through his/her mobile device (mobile phone, PDA, tablet PC, IPod, etc.).

The platform is constantly added with new services, coming from research projects, users requests and our intuitions. Among these functionalities, one is particularly frequent in users' requests and in our "future development" discussions,i.e., propagating the visibility of files along hierarchical paths inside the communities. Let's see a simple example: imagine a situation of communities' relationship like the one presented in figure 1.

The file management services that are built with traditional relational technologies present several issues and limitations when requested to provide the following:

- a member of the Community "Project Management" wants to share "File 2" with its sub-communities;
- a member of the Community "Group A" wants to share "File 3" with community "Master Degree in Business Administration";

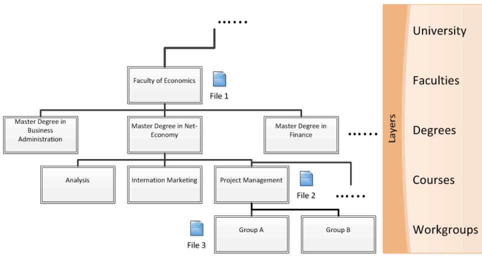

Figure 1. example of files' inheritance in Online Communities

- the Dean of the Faculty of Economics produced a document "File 1" that should be distributed to all the communities of the Faculty.

The implementation of these functionalities have passed through different design processes, considering even the use of low-level DB-relational technologies and Object-relational mapping tools. None of these alternatives proved to be really interesting, as we should have to modify the DB and/or profoundly change the software, without considering the "brute-force" approach of replicating files in parent communities or in child communities. The three examples above are very frequent in everyday activities of OC users, and represent the need of the following mechanisms:

- *propagation*, i.e., allowing a document to be spread in sub-communities through a replication process that keep into consideration the permissions of the source and the target communities;
- i*nheritance*, i.e., the previous mechanism but in the opposite direction: sub communities that want to share documents with super-communities, typically when a student produces a content that could be shared with parent communities.
- *trasversality*, in the sense of linking communities located in different branches of the communities' hierarchy.

The problem is even more compelling, considering that in our platform, the inheritance mechanism is appliable not only to documents, but also to contents (in the sense of posts of a forum, entries in a FAQ, comments in a wiki etc.) and, most of all, to services (the user could inherit permissions on a service in sub- or super-communities, like writing permissions in a forum). In all these cases, we have two technical solutions when dealing with traditional software platforms:

- Replicating the documents where requested, with obvious drawbacks (disk usage, alignment, complexity, permissions management etc.)
- Create a (soft) link to the document needed, with a certain number of problems

All over these mechanisms, permissions and rights on services and documents must be guaranteed for every user.

Having these problems, it has been clear that the graph representation typically used in semantic technologies and representation languages could have provided a very interesting path to explore, specifically for the set of relations that are created to implement the above features.

This perfectly fit into a language of knowledge representation that allows a method of logic calculation and automatic reasoning to provide responses and take decisions. In whatever of the above conditions, traditionally engineered software application can provide solutions. In OC, most of these mechanisms are implemented and "hard coded" in the business logic and in the persistence layer of the application, but we have to face many issues:

- Query performance: we could have dramatically poor response time.
- Complexity of the overall management of these mechanisms, especially from a conceptual point of view for the user.
- User interface for rendering the inheritance relationships: for example, when a document is displayed in a list of the documents of the community, how do we represent those documents coming from other communities, or those shared with other communities?

More than this, the fascinating idea provided by semantic representation regards the idea of graph, naturally related with our idea of communities network: building an RDF graph that represents all the possible (labeled) connections among objects maintained by our platform can open new scenarios when a reasoner is applied, thus allowing the inference of logical consequences from the set of triples using appropriately rules.

From an application persistence perspective, semantic representation standards like RDF and OWL could be put aside relational representation in order to extend and empower it, allowing the implementation of new features that would be otherwise very expensive in terms of software refactoring. Apart from this economic consideration, other aspects have stimulated the development of this integration:

- the relationship among virtual communities, both hierarchical and transversal, can be more expressive than those implemented in relational databases;
- the implementation of services that use "relationship" among communities in order to inherit contents and services from related communities (files, wiki, FAQ, forums etc.);
- a graph-based navigation interface for the end-users, based on an RDF graph and interpreted through an ontology starting from the SIOC ontology [26];
- the availability of a development team with a deep knowledge of the source code of the application, that has been developed from scratch;
- the categorization of communities and contents through a tagging mechanism that allows aggregation of any object inside the platform;
- the implementation of an inferential process to access to objects/services available from parent communities, allowing the creation, for example, of "transversal wikis", "inherited blogs", "parent's files", "similar communities" and so on.

Building an RDF graph representing relevant (labeled) connections among objects can open new scenarios, especially when reasoning is applied thus allowing the inference of logical consequences in the knowledge base. Another example regards users and their management of contact lists: this is different from managing community members as a list of "friends", or to connect people enrolled in the platform with the FOAF vocabulary to link people inside the platform and outside the platform through the FOAF ontology [27].

As a final example, users can accumulate many communities enrollments. These communities have contents that could be related in some way to what the user needs, but with no possibility to be inter-related with other contents in other communities. Thanks to classification and semantic representation of relationships among communities, we can create now different views and aggregation of communities (figure 2), in the future any other content that has been semantically tagged.

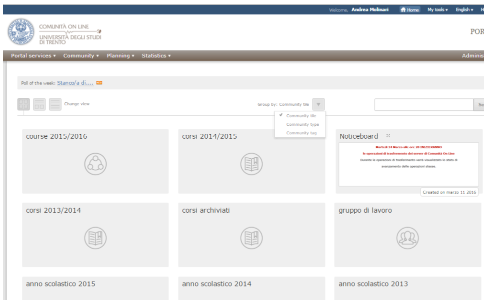

Figure 2. the tile view of tagged communities

IV. ENABLIG SEMANTIC TECHNOLOGIES IN LEARNING MANAGEMENT SYSTEM

In this section, we describe how we are modifying OC with semantic technologies to achieve the results discussed above. One of the most evident advantage for the learning ecosystem was to start integrating semantic technologies with the persistence layer, in order to achieve the following results:

- linking internal contents with contents that are external to the platform;
- the creation of new "semantic-enabled" services;
- the replacement of existing services with new semantically-enriched services;
- the improvement of existing services through the use of semantic technologies
- the provision of new graph-based navigation in the platform's entities.
- Inference on the facts represented in the semantic knowledge base

The work is inspired by the results produced during the Okkam EU project, a Large Scale Integrating Project cofunded by the European Commission between 2008 and 2010, where the core technology is the Entity Name System (ENS) [28]. The main purpose of the ENS is to provide unique and uniform names for entities for the use in information collections, so that the same name (identifier) is used for an entity, even when it is referenced in different contexts, inside and outside our platform. By reconciling entities inside the OC database, it is possible to tag "entities" inside the contents with a globally unique and persistent identifier (technically, an HTTP URI), this way providing a fundamental milestone for integrating OC with linked data available on the web.

Recognizing that information from different sources refers to the same (real world) entity is a crucial challenge in instance-level information integration, as it is a prerequisite for combining the information about one entity from different sources. The first conceptual block is the adoption of what we called an entity-centric view at the level of data and content in the persistence layer. The hypothesis is that, if all the contents inside the eLearning platform, inside the organization's information system and inside the external resources were "entity-centric", i.e., using the notion of entity for annotating and classifying data and content, the linking process among instances of the same entity through the different data sources would be straightforward. In a nutshell, this was the vision behind the Okkam vision.

The ENS is a global service (centralized or distributed, application- or private- or public- oriented) that acts as an authority for storing, recognizing and disambiguating every single entity, thanks to a unique identifier assigned to that entity. The ENS should "cut to the root the proliferation of unnecessary new identifiers for naming the entities which already have a public identifier" (inspired by the well-known Ockham's razor from the XIV century).

The first step towards the creation of a new semantic layer for OC is coupling primary keys in our database with OKKAM identifiers as provided by the ENS. We identify any relevant entity (person, place, organization, object, event, etc.) in different columns of the database tables, making sure that (i) it is recognized as an entity by the system (the "things, not strings" concept) and (ii) the same entity is always recognized as being the same entity in any type of data and context (entity resolution) .

Identifying and annotating entities with OKKAM identifiers allows us to overtake several limitations of primary key usage in entity identification. While a primary key in a database represents an identifier for that record, many problems could arise from the usage of primary keys as entity identifiers:

- if the entity "XYZ" is mentioned for any reason in any content of the LMS, this will be simply taken as descriptive data, and cannot easily be connected to the other occurrences by simply annotating the text with the primary key of our table;
- identifiers generated in this way must be kept aligned with other applications of the information system where that entity is referred;
- identifiers will be invalid/useless outside the scope of the application (e.g. a LMS) where they have been created.
- identifiers should be forced by the application as a foreign key every time a relationship between our tables and other tables is established, not forgetting that this referential integrity must be reinforced by the DBMS.
- Finally, if our entity "XYZ" is present in other information systems, a) the two applications should share and preserve a common identifier, or b) the different development/ management teams need to share/exchange/align the different unique IDs, or c) the two systems will identify "XYZ" with different identifiers, thus preventing the idea of interlinked data.

This last point is particularly relevant for our argument, as it is one of our main objectives in extending our learning platform towards the semantic web. Indeed, the metadata about an entity in the ENS contains also a list of pre-existing web URIs for data about an entity on the web (mappings between an OKKAMid and other linked data URIs). So an entity in our system can be easily linked not only to any occurrence in the system itself, but also with external data which can be fetched and integrated with a simple HTTP call to other datasets about it. This is exactly paving the way towards the "web of entities" envisioned by the OKKAM project that we are embracing and presenting in this paper.

Entity identification and mapping is of course not enough to enable a full-fledged semantic application. Ontologies can be very helpful in content interpretation and integration. Also the different level of knowledge and lexicon between teacher and learner can complicate the relationship and the learning processes, also here an ontology can help a lot in sharing and transmitting understanding and knowledge. Another interesting application of ontologies in "traditional" software is to map the columns of DB tables onto concepts represented in the ontology, i.e., resolving differences among heterogeneous databases from different domains using different concepts to represent the same entity.

Using ontologies to associate unambiguous content to columns is a common approach in semantic data integration [29]. In this specific field, the ontology is a middle layer mainly used to map references to the same concepts among multiple data sources. Several techniques of schema matching have been presented, aimed at mapping elements of different database schemas that are semantically corresponding to each other in order to enable co-processing of data collected against different models.

Semantic integration of data models should also provide a way to interpret relationships between entities. The point presented in this paper sees the integration of ontologies with the Okkam entity-centric approach, useful to connect data from multiple structured and unstructured data sources referring to the same entity. What has been done so far in "okkamizing" the persistence layer of "Online Communities" platform is the extraction of primary entities from database tables, and some experiments in the analysis of forum and communities. For the purposes of the prototype we extended a very famous ontology, i.e., SIOC (Semantically-Interlinked Online Communities) to our needs. SIOC provides a Semantic Web ontology for representing rich data from the Social Web in RDF, and is commonly used together with FOAF vocabulary in order to conceptualize and present personal profiles and social networking information. We therefore used SIOC to ontologically describe some services existing in the platform, and we extended SIOC with time, events and other specific concepts available in services present in OC and not provided by SIOC or by social networks.

As a final results, we applied our idea of semantically transforming a "legacy" application into a semantic application starting from some contents of the database, mapping this part onto the ENS, adding OkkamID to entities found in this part of contents, and then creating an RDF graph with the mapped portion of the DB. This knowledge base is navigable with a browser and queryable via SPARQL.

The addition of an entity-centric approach will allow to identify entities inside contents of the platform and connect these contents with the URI referring to the same entity, thus creating a true linked data environment for e-learning. In a near future, the improvements obtained using Okkam's entity-centric approach will be quickly usable inside OC. The following are some examples of an entity-based enrichment of the knowledge base, where we can search for an Entity (not for a text) inside many different contents and services of the platform. What we did was to transfer the structure of communities and of wikis in the triple store, insert of a rule by which the reasoner infers new triples, and then prepare a web page where the prototype shows the list of Wikis and their communities before and after inference

V. CONCLUSION AND FUTURE DEVELOPMENTS

In this paper we presented a short description of experiments regarding how semantic technologies could be coupled with e-learning software, with some final considerations about the application of semantic technologies to our collaboration platform that, thanks to the metaphor of virtual communities, facilitated this kind of integration and evolution.

The early implementation revealed two of the most interesting aspects we wanted to test, i.e., the ease of implementing and/or new functionalities to a software platform when semantic technologies are wisely integrated with them. A partial objective that has been investigated regards the identification of those issues that could be generalized to any initiative aimed at extending a software platform. The idea is to put semantic technologies aside with traditional development technologies, identifying entities in contents, using persistent identifiers for storing their unique ID taking from an entities' central repository called ENS

Some further elements should be investigated, in order to have a clear vision about pros and cons of this approach, specifically regarding sustainability and investments in re-factoring e-learning applications, and in general software applications. A second item that emerged from our experiments regards performances of semantic persistence layers. Intensive tests have been conducted using the same big data-oriented technologies (Hadoop, Hbase, Flink etc.) but in different contexts, where big-data range of operation is required. As results are very encouraging, we have conducted some preliminary tests with the knowledge base available in the virtual community platform. Another items regards the exact moment where to align the database and the semantic store in case some management operations are available to the public. Finally, the potential that semantic technologies could provide to e-learning and collaboration in general is very vast, but the problem here is the usability of contents and services. Enriched by this semantic functionalities and contents, the risk is that they could become complex to be understood and therefore unusable. A great help will come from semantic tools for data visualization and navigation.

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Estimating the Effort in the Development of Distance Learning Paths

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Estimating the effort in the development of Distance Learning paths

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Abstract. In this paper we present a model for better understanding the ratio between costs, production of didactic material and activity of monitoring and facilitating e-learning tasks. The quantification of the effort required to produce e-learning material has been always subject to the proposal of some "magic numbers" not always supported by a method or analytical data. In this paper we propose a method for calculating the effort required to design and develop e-learning paths. Our model is based on a systematic gathering of data regarding the effort of the different actors involved (teachers, tutors, instructional designers etc.) from a series of e-learning projects carried out at the Laboratory of Maieutics over the last five years. In the first two years we collected ex-post data on design and development times, being careful to include a variety of different teaching methodologies. In the following years we identified critical variables which allowed us to abstract and generalize a possible costing model. The model proposed could be used as a reference point for professionals working on the development of content in their estimation of costs linked to the design and development of learning materials, providing a calculation basis which takes a number of methodological approaches and educational objectives into account.

1 Introduction

This paper presents an analysis of the problem never completely solved of the costs of e-learning. It tackles it through a pragmatic approach based on the experience of our group gained in designing and implementing a training process in blended mode. The attention focuses in particular on the aspects linked to e-learning costs and the various modalities that ICT offer to people who design training, especially concerning the evaluation of online activities that can support "face-to-face" situations in a blended way.

Organizations have always calculated a series of factors such as costs, duration, quality of learning, customer satisfaction, in order to choose the most suitable training approach to be employed. None of these variables is easily defined and measured but the cost analysis, in particular, seems to be the most complex. One of the elements frequently emerging from existing studies is that e-learning is less expensive compared to the residential editions of the same course at the increase of numbers of participants [1].

Over the years the fortunes of Distance Learning (DL) have see-sawed, for reasons both cultural and technological: among them, a reluctance to replace face-to-face interaction with instructors; inadequate communication lines for the transmission of complex learning objects (LOs); insufficient bandwidth for the reliable streaming of multimedia material and also a lack of standards for tracking and certification of on-line courses. Most of these problems have now been overcome: it therefore seems that the hesitant progress of e-learning – always on the point of spreading extensively and then for some reason never really succeeding - should not have to continue any longer, given the disappearance of most of the technological barriers.

In fact, we believe, there is another - considerably more insidious, not being linked to the inevitable progress of technology - obstacle which threatens to further slow the spread of DL. This obstacle is the economic advantage of instructors in the production of LOs in relation to the traditional method of being paid an hourly or daily rate, linked to their verifiable, physical presence in a classroom. This point seems rather crass and mercenary, but we have observed early signs of such resistance, especially as it is now clear, at the industrial level above all, that e-learning will become indispensable.

To associate a cost model that is limited to the traditional retribution of a teacher/tutor calculated per hour, is to run the risk of overestimating the low cost of e-learning initiatives with respect to traditional training and, on the other hand, of demotivating all the people involved in an e-learning process, given the constant contribution they are called upon to give. We are convinced that the use of Web 2.0 tools can intensify the learning process, especially when conceived as relation created or facilitated by the teacher. On one side, integrating traditional educational tasks with web 2.0 tools (like forums, wikis, FAQs etc.) can help to avoid that the participant should perceive the value of e-learning as simply downloading didactic material and filling in final progress tests. On the other hand, this is undoubtedly an extra effort for trainers, therefore amplifying the problem, as normally these web 2.0 activities require a lot of time and resources.

In this paper we will present a model for better understanding the real costs and efforts to produce didactic material for e-learning paths. In our opinion, when a blended or a full on-line course is being designed, it is necessary to be prepared to understand the various factors involved in the development and delivery of the training process, by building up a list of cost factors applicable to the needs of the organization and the context.

2 The origin of the problem

E-learning has always been considered mainly as a way of saving money over training budgets. Others are the benefits of e-learning, as widely demonstrated, but for this paper we refer to those cases where e-learning has unquestionable advantages independently from budget considerations, for example: a) large numbers of people to be trained in a short time; b) people widely dispersed or hard to access physically; c) training regarding software or ICTs usage.

All the above cases include factors which could be considered to “justify” fair pay for the creators of LOs (instructors, instructional designers, tutors, etc.). A comparison of the production costs of the LOs with how much it would have cost to run a face-to-face course normally justify the choice for an e-learning initiative. On the other side, however, we find the perspective of the creator of the LOs, who should be highly paid due to the number of users involved and due to the strategic value of the training itself. We are thus witnessing an extension of the online course offer, which is going to involve an increasing range of subjects, ever more closely linked to those areas (like soft skills) traditionally not “favorable” to e-learning. Nevertheless, this potential burst of growth in LOs production presents a number of criticalities:

- a more detailed planning is required in order to create interactive, reflective, self-rating situations for the learning of soft skills;
- LOs are delivered by instructors who are often unfamiliar with ICTs ;
- LOs represent an area of the market which is still very profitable for traditional classroom based education.

Regarding the last item, resistance on the part of instructors, who have always been the authors of the destiny of e-learning initiatives, is presumable – and, as far as we are concerned, already verifiable. By instructors we mean everybody involved in the development of courses and related educational objects. The argument is very simple: considering for example the business of professional training, teaching a given subject requiring 20 classroom hours to 100 people allows an instructor to suppose N repetitions of the course, each multiplied by 20 hours, multiplied by their hourly pay. The economic final reward (FR) for the instructor, by which to calculate the threshold of convenience in creating the LOs, is function (at least) of the following parameters:

$$FR = f(r, h, hr, d, ph, hpc)$$

where
r = No. of course repetitions;
h = No. of hours of each edition;
hr = hourly rate of the teacher for that course
d = rate for design activities
ph = preparation hours needed for LOs creation
hpc = hourly preparation costs

Other elements should be considered, like the location of the course, travel expenses, credibility of the organization etc. Sometimes, moreover, a flat rate is paid for design, or it is not always recompensed, since instructors receive a good hourly rate for classroom hours (particularly as they become more senior).

In the simplest situations, the function can be easily calculated as follows:

$$FR= r * h * hr + d - ph * hpc$$

There's no doubt that unless a pay scheme for e-learning courses at least as attractive to instructors as that for traditional courses is provided, there will be a further brake on the spread of e-learning. A number of studies have focused on the determining of parameters, and many authors have already pointed out the complexity resulting from methodologically and educationally based choices in the construction of e-learning courses. [2] [3] [4].

To a great degree, over-simplifying the idea risks, we believe, the reoccurrence of the initial problem, the "inexpedience" for experts of transferring their knowledge through DL. We have already drawn attention [5] to criteria for calculating the production costs of LOs, but extensive subsequent trials have revealed the need to refine and integrate the model, especially in the LOs design stage. In this paper we will propose these extensions and refinements to our e-learning costs model. We have added more importance to the design stage, in order to allow the a-priori estimation of the work done by the different experts involved in project development.

3 THE DESIGN OF EDUCATIONAL PROJECTS

The detailed preparation of an e-learning course or environment needs to be done in advance. The instructional designer should identify the subject matter, define it operatively, decide how to evaluate students' knowledge and skills and introduce occasions for feedback in order to support learning. Therefore, we begin by identifying the different phases of planning stages and then suggest how times and costs might be calculated.

All e-learning projects include at least four basic stages which lead to the delivery of a course. We believe that in the evaluation of the effort involved, we should quantify, optimize and recognize:

- the design of the educational project;
- the design of LOs through an analysis of subject matter, which we introduce as modeling in this article;
- the development of educational material, the utilization of which has already been described by other researchers [6];
- the management of interactions with students in order to further learning, mostly following web 2.0 approaches and tools (forums, blogs, wikis, social network interactions etc.), as already mentioned in previous articles [5]

When discussing the design phase, we include a number of dimensions, already mentioned elsewhere[7]:

- demand assessment: information about clients' expectations is collected, clarified and selected, through hypotheses which designers develop considering technological issues about the creation of LOs ;

- the proposal of hypotheses: the variables and points of view involved are multiple and it is hoped that decisions / solutions can lead to the presentation to clients of a number of possibilities;
- fine tuning of the project: when a possibility has been chosen the – almost inevitable – next step is the development of the project, a recursive research process in which the direction of the project is defined.

We started from the presumption that the infinite variants of training initiatives make it difficult to immediately comprehend the main characteristics of each. We believe that the concept of model could help us to organize and coordinate the various phases of a process required, offered, chosen and the operative design of a training activity. For this reason, as a starting point we have used and adapted two models:

- model CLEAAB 16 [8] [2] [3], to describe the process of phases and activities that characterize the design of a blended training path. Five macro activities of design have been chosen, later distinguished for further relative under-activities: planning, preparation of material resources, human resources training, implementation and evaluation;
- the study of G. Battaglia [9], suggesting the identification of the various models through a three dimensional matrix and a check list descriptive of the main characteristics of the components of the training product, has been used for the selection of the four didactic models of reference. The three dimensional matrix representative of the models is then developed considering three dimensions:

1. type of the main didactic objectives: knowledge, knowing how to do, knowing how to decide/act;
2. importance of the vertical interactions according to the principle of authority of the teacher, distinguishing the role of the moderator, facilitator and main figure of reference for the path; we have integrated the model by inserting also the figure of tutor who generates a further vertical interaction. Thus we can note how the role of teacher and tutor are strictly correlated and interdependent: when the teacher is the main person of reference for the course the tutor supports him mostly as observer. On the contrary, when the role of the teacher is that of moderator, generally the tutor acquires major relevance in the training context, especially in the possible distance versions of the didactic process;
3. relevance of the horizontal interaction according to the principle of collaboration and confrontation on a large scale that goes from collective learning to individual learning.

The combination of the three dimensions generates a “training space” in which it is possible to identify twelve training models. Among these, four can represent relatively “pure” models and, therefore, usable for general reference:

- the didactic model aimed at knowledge: characterised by strong vertical interaction between trainer-trainee, by a weak horizontal interaction among trainees and a training objective identified in “knowledge”;

- the didactic model aimed at method: characterized by a s strong vertical interaction, by a weak horizontal interaction identified as “knowing how to do”;
- the didactic model aimed at ability: characterized by a strong vertical interaction, by a strong horizontal interaction and the training objective of “knowing how to do”;
- the didactic model aimed at competence: characterized by a weak vertical interaction, by a strong horizontal interaction and the training objective of “knowing how to act/decide”.

The collocation of a specific training course within a training model supports and “justifies” the identification of the roles of teacher and tutor, as well as the choice of instruments coherent with the didactic objectives and the vertical interaction, from the design phase to the phase of realization and it offers a departure point for the estimate of costs.

If we take as reference the courses, object of the experiment, and try to collocate them within the model, we see that, for example, an Excel™ course focused on training people in the usage of the software uses a format aimed at method. The training objective is indeed that of “knowing how to do”, while the vertical interaction is strong since the teacher represents the main point of reference while the horizontal one is weak since learning in this case is mainly individual.

Conversely, a course aimed at training people on “Safety on the building site” is collocated in a format aimed at ability where the teacher is the main point of reference, but the horizontal interaction is strong. Here the objective is to know how to do, meaning knowing how to apply the norms learnt during the training course, and the objective is reached both through individual study and collaborative work.

Through a consideration of these three critical variables we can create a 3-dimensional matrix representing the educational models:

- the principal teaching objectives;
- the importance of vertical interaction according to the principle of instructors’ authority;
- the importance of horizontal interaction according to the principle of collaboration and dialogue.

As said, the combination of educational objectives has been graded in three segments: knowledge, technological skills, the development of cognitive skills.

The second dimension focuses on the importance of instructors as a source of knowledge and as an expert in the field. The two ends of the continuum are the “Central figure” or “reference point” at one extreme, on whom the learning process depends, and the “Neutral moderator” of students’ study, at the other.

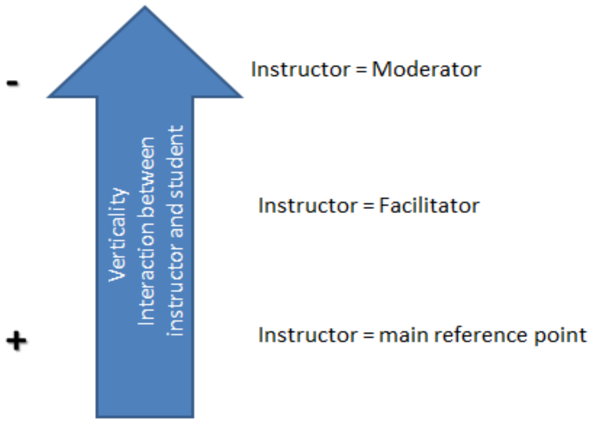


Fig. 1. The vertical interaction dimension of an educational model

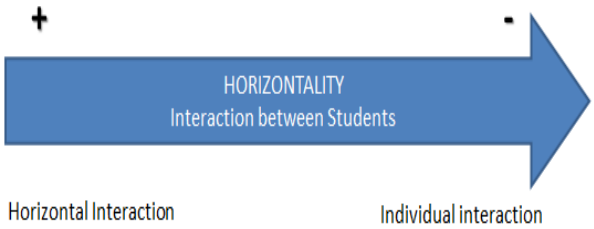


Fig. 2. The horizontal interaction dimension of an educational model

In our terminology, "Verticality" represents the degree of interaction between instructor and student, while "Horizontality" refers to the degree of interaction between students. Note that the two dimensions are independent, allowing four different combinations: the weak vertical - weak horizontal combination represents independent learning, while the strong-strong combination represents the development of elaborate educational projects, in which the instructor assumes the role of project manager and strong group leader. The combination of the three dimensions generates an cubic "educational space" in which twelve educational models can be identified. Some of these models are relatively "pure" and can therefore be used as general points of reference.

We can place the tutor in this educational space, alongside the instructor. This allows us to see how closely correlated and dependent on each other these roles are: when an instructor is the central role for a course, the tutor – to a large extent an observer – supports him; conversely, when the instructor's role is that of moderator, the teaching role of the tutor is potentially greater, particularly for any Distant Learning versions of a course. In our studies, four educational models have been identified:

1. models aimed at the acquisition of knowledge: characterized by strong vertical interaction between instructor and student, weak horizontal interaction between students;

2. models focusing on method: characterized by strong vertical interaction, weak horizontal interaction and a focus on technological skills;
3. models aimed at increasing ability: characterized by strong vertical interaction, strong horizontal interaction and a focus on technological skills;
4. models aimed at increasing expertise: characterized by weak vertical interaction, strong horizontal interaction and with a focus on the development of cognitive skills.

Note that the variable of technology is not one of the dimensions of the model: the characteristics of the technological tools used to deliver on-line courses cannot be considered primary criteria for the classification of educational models.

We could have different models for the same educational proposal, depending on the methodology that is considered more effective for the learning process. The detection of the predominant model is useful to determine the educational objectives, while it is relevant for our cost model in order to determine the type and the extension of the support activities in the educational processes, as presented in tables 1 and 2 at the end of this paper.

The central role at this stage and across the other proposals is the e-learning project managers, who support and coordinate those involved in the development of the educational project. The overall organization and implementation of the e-learning system is their responsibility.

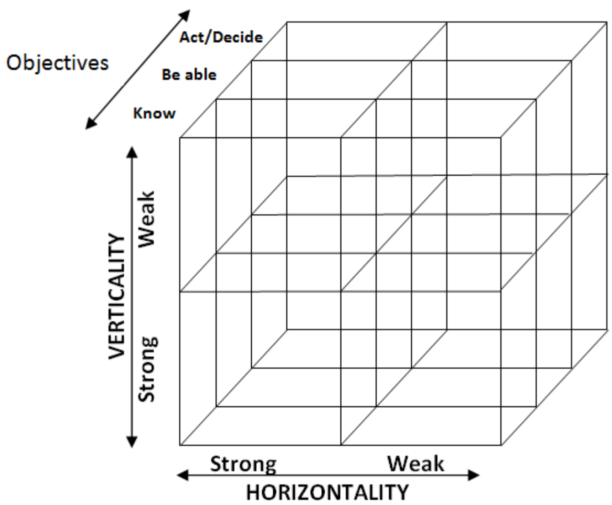


Fig. 3. The "educational space" through the identification of educational formats

They supervise the planning, development and administration of the project and are responsible for its educational content. The project manager undertakes to:

- schedule and coordinate the e-learning program
- identify users' profiles of the e-learning system
- analyze the educational requirements / demand of users
- define the objectives of the e-learning system
- define the type of service to set up

- define the criteria and indicators for the monitoring and evaluation of the service

We examine the roles of the collaborators later on, in particular those of the content manager and instructional designer.

4 LEARNING OBJECTS DESIGN THROUGH CONTENT ANALYSIS

When LOs are being planned, after the appropriate educational model has been identified, we can start to apply our costing model. The most significant variables, which we introduce for the first time in this model, are[7]:

- content “definability”: can the content be processed in a standard way, or does it require discussion and comparison and need to be created for a specific group of participants?
- content “interactivity”: can the content be conveyed through text, images and graphics, or does it require interactivity? Simulations, for example?

The definition of the content (how much structured subject matter there is, on a scale: low – medium – high) lies on the vertical axis. The lower the value, the less time the instructor will need to plan specific content and design time can be devoted to the methodological structure and to the search for stimuli that can be offered along a study path (e.g. facilitation of the study community, where the educational task and support while the work is ongoing will be more recognized) [10][11].

The indicators reported in this paper are multipliers that result from an ex-post analysis conducted over five years of design and creation of learning objects. We collected the detailed data from the roles involved in the process regarding design times and creation times. Afterwards, we identified some recurring variables in the process, and their average influence on the time used to produce the learning objects.

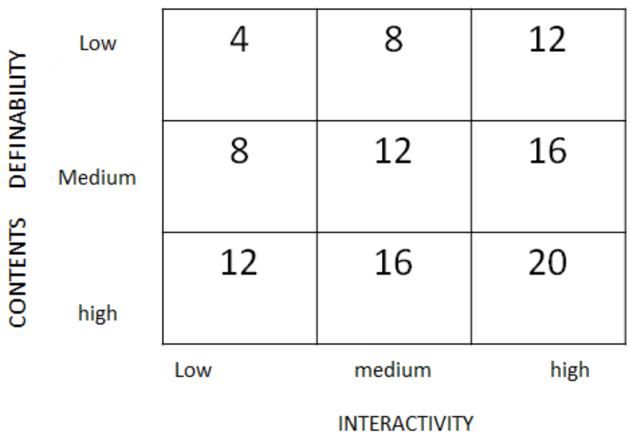


Fig. 4. Model for the calculation of multipliers in the planning of material

We have placed the level of interactivity on the horizontal axis. According to our formulation, here follows some examples of LOs with low levels of interactivity:

- narrative LOs, which introduce suggested courses and/or single modules;
- expository LOs, which refer to text based information and concepts, images.

The following are examples of medium levels of interactivity:

- Demonstrations: animations which illustrate a series of operations
- Interactive LOs: participants are required to interact with the material – providing answers, commands, links, etc.
- Tests: drag and drop, classification tests that start with given possibilities, problem solving tests, etc.
- Guided exercises: step by step instructions on what to do
- Case studies

The following involve high levels of interaction:

- Simulations: presentations of simulated situations in which the student must achieve an objective (e.g. using particular software)
- Role based LOs: contexts in which participants are asked to take decisions, etc.

Each cell in this model is assigned a different value which is multiplied by the expected length of the material being developed. We have excluded "serious games" from the calculation / estimate that can be made at this stage of our experiments / trials. The serious games category is a broad one, nevertheless it always entails, at all stages of development, a quantity of work which definitely cannot be reduced to the elements represented in our model. Currently, there are experiments / trials on-going in this field, but they are still at too early a stage to provide accurate data.

At least two figures are involved at this stage of design, their contributions can be identified using the same parameters (from the point of view of co-planning), using the matrix above:

- the instructor, who:
  - participates in the definition of course structure
  - identifies the possible testing and evaluation methods to be included in the program
  - supports and collaborates with the instructional designer in the creation of LOs
- the instructional designer, who:
  - gives advice on educational methods and strategies for the delivery of content and resources for e-learning
  - decides which software to use for the generation of content
  - manages the multimedia resources
  - identifies the strategies and tools for evaluation and practice most appropriate to the purposes of the course.

5 THE DEVELOPMENT OF EDUCATIONAL MATERIAL

Regarding another component in our model for determining the cost of production, i.e., the development of educational material, in other studies (Casagranda et al, 2010) we suggested a method for estimating the amount of time spent by instructors on the creation of LOs. We will shortly present this part, considering the following questions: a) will all the material be new, or is there any material available for reuse? b) to what extent might the material be reusable in the future?

The possibility of reusing existent material for the development of LOs has a great impact in the perception that end users have about the originality of the creator's work, and sometimes is even subject to negotiation between the educational institution and the instructor. In our model, this aspect lies on the vertical axis, on a scale: absent – low – medium – high. The higher the value, the less time the instructor needs for the preparation of the LO.

The replicability of material – how possible it is to reuse the same LOs for other courses or users (Huddleston and Pike, 2005) – lies on the horizontal axis. The scale we use is the same as the last one: the higher the replicability the bigger the multiplier, as the same material can be used for many versions and subjects and costs can thus be recouped. In contrast, if there is little or no possibility of replicating the material and an LO is useful only in one, or a limited number of, context/s, instructors will be paid proportionately less since they will soon have either to generate new material or update old.

We hypothesize that the values of the variables of the multiplier on this axis will be lower than those on the vertical. All the cells in the model are assigned a different value which serves as a multiplier for the expected useful life of the material being developed. Moreover, the concept of "reuse" can be based on an estimate of the number of versions expected and on the number of possible users, or even on estimates of recombinability in other contexts.

The following factors are to be considered when determining the "reuse of material" variable:

- Absent: it is the first time that instructors have developed a course like this, so they have neither classroom nor online material available with which to begin the preparation and must start from zero, or near zero;
- Medium: instructors can adapt material which they have previously used in the classroom for use online, or have a limited amount of relatively unstructured online material available;
- High: instructors have some structured material available, suitable for their chosen type of distance education, and only small changes or updates are required.

The variable regarding the replicability has been constructed referring to the average participation to courses held for University and public administrations in our territory. It is complicated to "universalize" this parameter of replicability, that in our case sets a "high replicability" when courses involve up to 100 participants.

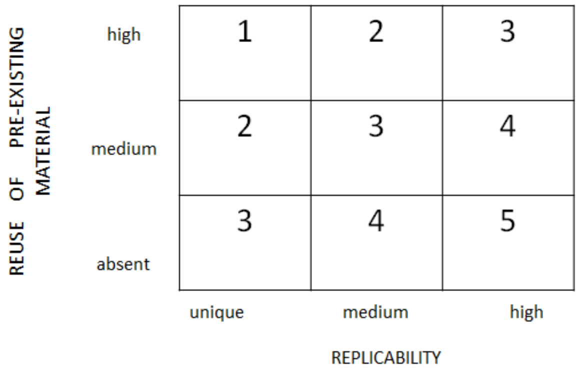


Fig. 5. Model for calculation of multipliers in the creation of material

This parameter could hence be a limit in different contexts respect to those used in our analysis, and should be recalculated and adapted. At the same time, having collected data from several courses editions, in environments very close to what the market nowadays provides, we are confident to have a good basis for future analysis.

Instead, on the horizontal axe we put the repeatability, meaning the possibility to be able to reuse the same LO for other training courses or further users. The scale here is developed on three parameters (univocal – medium – high), converse proportion to the previous one: the higher this value, the larger will the multiplier be since it will be possible to reuse the same material for more editions and participants, and, therefore costs will be amortized. In order to identify the degree of repeatability in this training context, in our context we base ourselves on a future estimate of the number of predictable editions and the number of possible users.

Finally, we have substantiated our hypothesis through the analysis of a large number of historical courses held by our partners, verifying the distribution of frequency of participants in similar areas of training courses. The hypothesis emerging from the analysis made during the last training years is the following division:

- univocal, as inferior to 40 participants
- medium, from 40 to 100 participants
- high, more than100 participants.

The calculation becomes crucial in complex and articulated situations such as the one of our context, in which courses are offered with extremely varying number of participants. At the moment, an experimentation and an application on various training types is being carried out in order to be able to evaluate the validity of the first hypotheses and to identify possible updating of the parameters so far identified.

At this stage we are also faced with the following questions:

- What are the best technologies for the running of the course? For content management? (We are here referring to LMS and LCMS.)
- What technical support is needed for the production of the material?

Sometimes the instructor him/herself will be able to produce the educational material, sometimes a specific person will carry out this function. The person producing material will have the time recognized using the model in Fig. 5. It is important to add, however, that it would be helpful to add an extra multiplier to our model, both to quantify the work involved in reviewing the content / work, in checking that the material meets established LO standards, and for the professional editing of the material itself, as set out below.

At this stage we add another value, when two roles dominate the work: the content manager and the LO editor / LO production expert, who guarantee the quality of the LO at all stages of its production, and especially:

- when the stages of production and their durations are being decided;
- for the writing of LO storyboards;
- for managing professional standards in the multimedia content (videos, narrators, graphics, etc.)
- for editing of the LO

From our evidences, we derived these multiplying factors, that must be confirmed in further analysis:

Content manager	Responsible for the review of video content: video time multiplied by 3
LO editor	Responsible for editing: video time multiplied by 33

Fig. 6. Model for calculating the multiplier for creating material

The incidence of this element on the production time of LOs is clearly relevant, and in our experience this is particularly true for those institutions that do not have a LO editor at their disposal, thus forcing them to turn to external expertise.

Accessibility of learning objects is a serious issue, and the attention devoted to people with disabilities is never too much. Thus, we observed in our tests to which extend the impact of enriching / modifying material to be usable by this category of users was. When accessible materials are being created, we have identified a further increase in time to be recognized for this activity:

Accessible materials generated by the LO editor
- Addition of Text: Creation of material + Video time - Addition of Subtitles: Creation of material + Video time multiplied by 1.5

Fig. 7. Model for calculating multipliers in the case of accessible material

6 SUPPORTING THE LEARNING PROCESS

Finally, as already discussed in other papers, (Casagranda et al, 2010), we consider the choice of teaching model to be very important for the estimation of the maximum number of hours that tutors and instructors will spend on the delivery of a course. The estimate of this effort for the people involved in e-learning is one of the main obstacles in estimating the e-learning costs: well known are the studies on the frontal hours / didactic material preparation ratio (even if such a ratio is quite questionable, subjective and depending on context), and there are some hints at an estimate of the overall engagement of the people involved in e-learning paths.

We believe that such information is not sufficient to guarantee an equal compensation to who creates work on the implementation side. Furthermore, as already mentioned, teachers, tutors, instructional engineers, multi media designers, etc., need updated models able to suitably calculate the respective efforts and the right retribution for such efforts. To associate a simplified cost model to these activities, that limits itself to the traditional hourly retribution of the teacher and/or tutor, could contribute to nourish two important risks for e-learning:

- on the one hand, there is the risk of over-estimation of the costs of the e-learning initiatives compared to traditional training. Often e-learning appears enormously more advantageous in the economy scale compared to the same editions of frontal paths and relative retribution to who is in the classroom. But, if we want to compensate all the activities that a complete, interactive, collaborative e-learning environment creates, the centre of attention should be moved from the costs (still present but not so high) to the quality of the training service offered.
- on the other hand, it could mean an economic disincentive towards people who are involved in an e-learning experience, if the activity carried out by the teacher and tutor is not suitably recognised. Qualified teachers and tutors could be little stimulated to participate in e-learning initiatives, given the amount of hours to be dedicated to the various activities, the loss of income on the repetition of the e-learning editions, the complication linked to the use of less known instruments and technologies.

These risks emerge above all when the e-learning initiatives are carried out on large scale, as in our case, where we are facing a Public Administration that has a very ample training catalogue. Therefore, the necessity arises for adopting an adequate model of costs that should guarantee to teacher and tutor an appropriate economic compensation in the administration of the didactic phase in order to thus favour a legitimization of the competences and contribute to the motivation towards e-learning.

On the basis of these presuppositions our group's aim is to define for each type of didactic model, on the basis of experimentation and taking into consideration various combinations of classroom and e-learning that we have activated, maximum percentages of recognition of the hours worked in e-learning on various services and instruments, both for teacher and tutor (Fig. 1).

For the final calculation of the cost estimate for the production of didactic material we have hypothetically introduced another fundamental parameter, meaning the total number of participants in that specific course and, consequently, multiplied the hours resulting from this percentage by the number of participants.

The calculation of these hours is based on the application of a percentage on the total number of course hours for face-to-face and DL, shown below:

% in class room	% in Distance Learning	Expertise	Ability	Method	Knowledge
100	0	///	///	///	///
70	30	5%	4%	3%	2%
50	50	6%	5%	4%	3%
30	70	7%	6%	5%	4%
0	100	8%	7%	6%	5%

Table 1. Adjusting factor for distance learning courses based on teaching model for teaching

This table presents the Percentage of the maximum number of instructor's hours recognized based on combinations of classroom and/or DL hours (supporting students' learning and communication during the course). The following figure, instead, represents the percentage of the maximum number of tutor's hours recognized based on combinations of classroom and/or DL hours (supporting students' learning and communication during the course)

% in class room	% in Distance Learning	Expertise	Ability	Method	Knowledge
100	0	///	///	///	///
70	30	4%	3%	3%	2%
50	50	5%	4%	4%	3%
30	70	6%	5%	5%	4%
0	100	7%	6%	6%	5%

Table 2. Adjusting factor for distance learning courses based on teaching model for tutoring

The percentage is doubled if it is expected that an instructor's presence in the medium term will be required, either to allow students more time to complete certain activities (e.g. in blended courses: within 3 months of the last classroom based lesson), or to guarantee that the course web pages are updated (e.g. the instructor agrees to update FAQs, regulations, etc.).

7 APPLICATION OF THE MODEL

In this article we describe the application of the model to a self-study course run in 2011 and 2012. Our results were extremely encouraging: a deviation of about 10% between the "ex-ante" calculation, based on the a priori application of the suggested parameters, and the "ex-post" statement of accounts (allowing an a posteriori evaluation of the hypothesis).

See below a short summary of the course characteristics:

- Course title: "Digital signatures and Certified electronic mail";
- Participants: almost 22,000 private businesses;
- Course objectives: divided into two areas;

- Information component: a presentation of the main characteristics of digital signatures and certified electronic mail, the related legal aspects, the main uses of these tools, the necessity of adopting them, limits to their use, opportunities for their use;
- Application component: showing how digital signatures and certified electronic mail work and making available practical demonstrations of their use.
- Effective duration of the educational material–information component: 6 hours, application component: 2 hours.

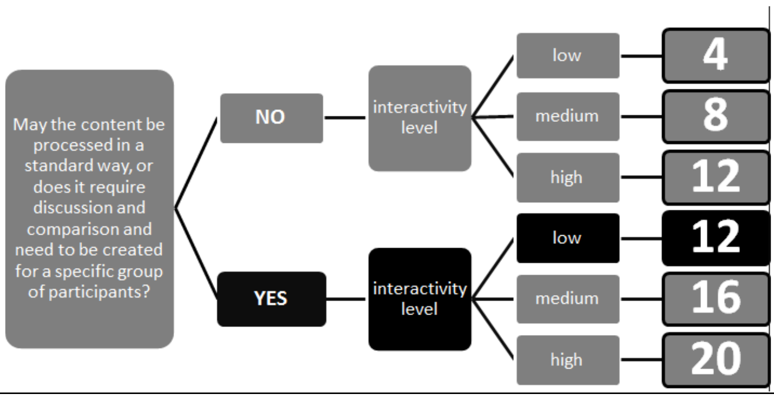
Choice of Educational Model

- Information component: model directed towards knowledge
- Application component: model directed towards method

Fig. 8. Educational model

Calculation of planning time

- Information component: narrative and expository LOs
  - Instructor/expert: 6 hours (effective duration) * 12 (multiplier: high definability of the content/ low levels of interaction) = 72 hours
  - instructional designer: 6 hours (effective duration) * 12 (multiplier: high definability of the content / low levels of interaction) = 72 hours



- Application component: simulations
  - instructor/expert: 2 hours (effective duration) * 20 (multiplier: high definability of the content/ high interactivity) = 40 hours
  - instructional designer: 2 hours (effective duration) * 20 (multiplier: high definability of the content/ high interactivity) = 40 hours
  - total planning hours: 224

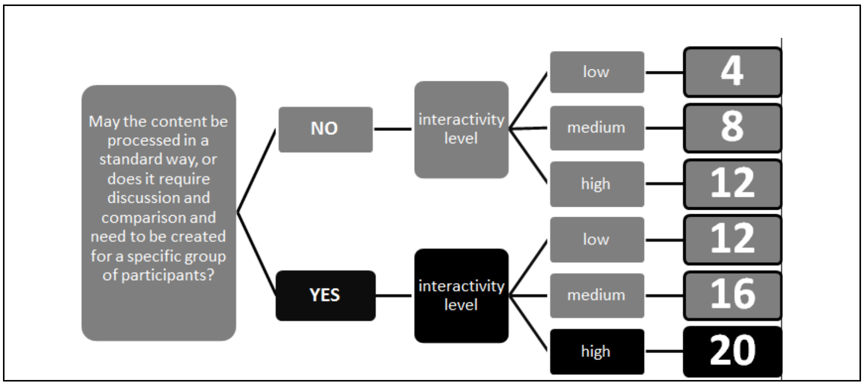


Fig. 9. Calculation of planning time

Calculation of production time
- Information component ○ instructor: 6 hours (effective duration) * 5 multiplier (material replicability high and reuse of existing material absent) = 30 hours ○ content manager: 6 hours (effective duration) * 3 (multiplier) = 18 hours ○ LO editing: 6 hours (effective duration) * 33 (multiplier) = 198 hours; ○ accessibility 6 hours (effective duration) * 1.5 (multiplier) = 9 hours - Application component ○ instructor: 2 hours (effective duration) * 5 multiplier (material replicability high and reuse of existing material absent) = 10 hours ○ content manager: 2 hours (effective duration) * 3 (multiplier) = 6 hours ○ LO editing: 2 hours (effective duration) * 33 (multiplier) = 66 hours; ○ accessibility 2 hours (effective duration) * 1.5 (multiplier) = 3 hours ○ Total LO production hours: 100

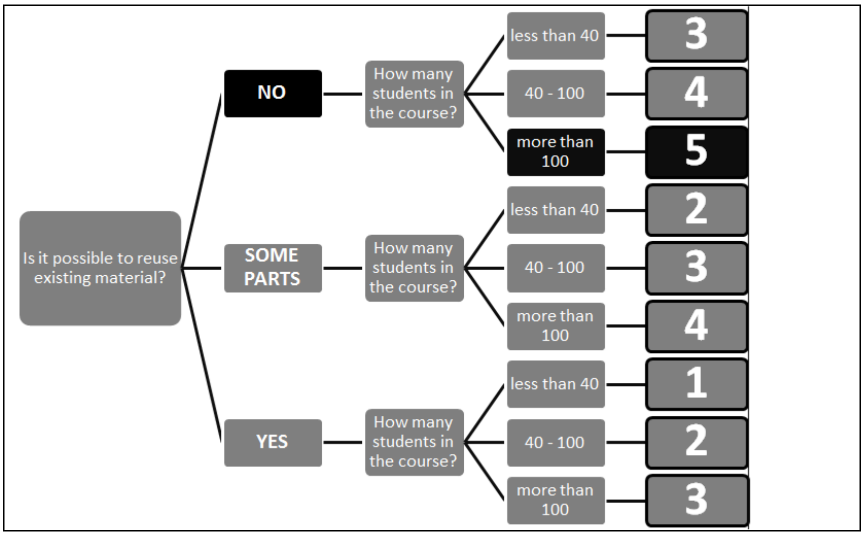
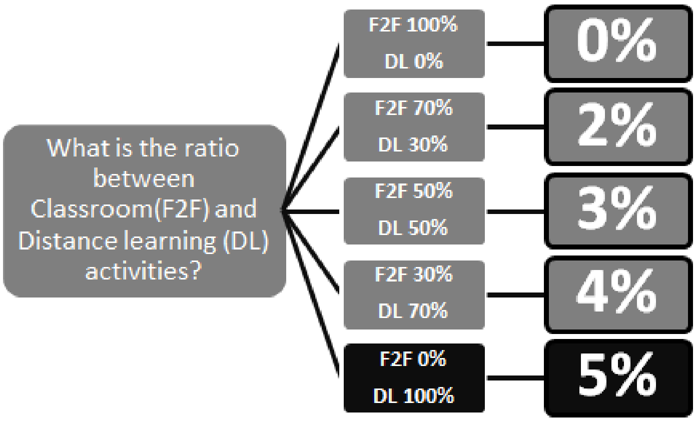


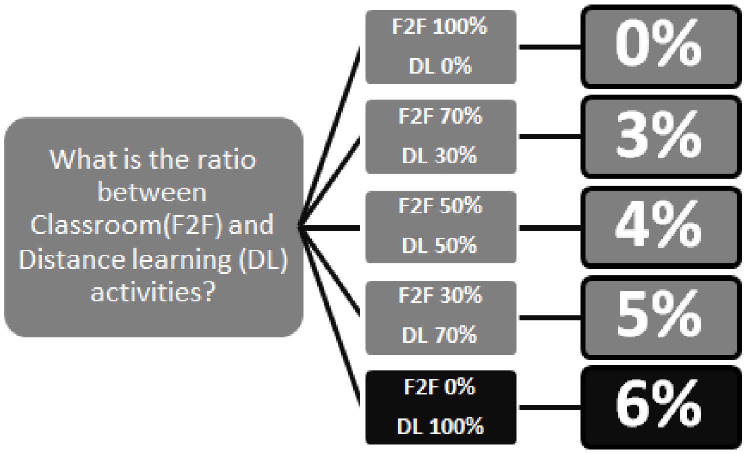
Fig. 10. Calculation of production time

Calculation of time spent in supporting the educational process

- Information component:
    - instructor: max 5% of total hours * number of participants



- Application component:
    - instructor: max 6% of total hours * number of participants



In the case study, given the number of users, no educational support was factored in.

Fig. 11 Calculation time spent supporting the educational process

In summary, the original course has been planned as a 6 hours + 2 hours course. With the application of our model to this specific instance, the global effort has been calculated as follows:

- Planning Time: 72h+72h+40h+40h = 224h
- production Time: 30h + 18h + 198h + 9h + 10h + 6h + 66h +3h = 340h
- Support time: n/a

Total Effort: 564h respect to an effective duration of the educational material of 8 hours.

8 CONCLUSIONS

This article describes a model for the estimation of the time spent by the various people involved in the planning and production of distance learning material. We attempt to address the problem of calculating total numbers of hours worked by all the actors, providing a general framework for this complex calculation (in the sense of quantity of variables and situations to be considered).

This is largely a result of the lack of an adequate model for standardizing the measurement of the effort required to create online material, leading to instructors receiving completely inadequate recompense for their work. We believe that the lack of this calculation could be one of the possible factors which could slow the spread of DL. Our model calculates, using multipliers and reference tables which have been trialed in the field in some revealing projects, the number of hours worked by the creators of DL courses to be recognized against the number of hours scheduled for the online course. Most of the trials / experiments with this model were carried out under the auspices of the DL program of the Autonomous Province of Trento and the University of Trento, where we applied the model on a set of 37 editions of different courses run in 2011/2012.

As mentioned, the model is in the process of being refined, but has already shown a series of advantages that encourage us to carry on the research:

- clarity in calculating the acknowledged hours: the teacher "undergoes" the parametrization of the model, yet contributes with his/her own evaluation and has a direct match at the conclusion of the production phase
- predictability of costs in the yearly budget phase: the organization can indeed classify "ex-ante" the courses that it intends to offer, categorize them according to the parameters of the model and precisely estimate the cost of the various e-learning initiatives without having to resort to less "stimulating" models for the actors and while having a precise idea of the expenditure
- comparability of costs regarding course editions that end up in the same boxes of the model
- clarity in the temporal engagements taken on and the modality of implementation on behalf of the actors: the roles of teacher /tutor can be precisely defined, as well as the instruments to be used, and how much time (approximately) they will need to dedicate to these activities
- more profitability for teacher and tutor compared to traditional costing models: doubtlessly an element of motivation for the same to participate in e-learning initiatives

Our results were extremely encouraging: a deviation of about 10% between the "ex-ante" calculation, based on the a priori application of the suggested parameters, and the "ex-post" statement of accounts (allowing an a posteriori evaluation of the hypothesis), based on the systematic gathering of data from the roles involved (teachers, tutors, instructional designers, etc.). Further experiments are needed to confirm or adjust the multipliers stated in the model, especially regarding new media and new educational models and approaches. The evaluation of the multiplier for multimedia learning objects is a crucial component: we are already working on a method that progressively decreases progressively the effort respect to the length of multimedia learning objects to be produced.

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Publication VII

Bouquet P. & Molinari A.

Sport, Dual Carriers and Education: The E-Learning Way

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SPORT, DUAL CARRIERS AND EDUCATION: THE E-LEARNING WAY

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As addressed in the EU Recommended Policy Actions in Support of Dual Careers in High-Performance Sport, athletes involved in professional sports activities often face challenges to combine their sporting ambitions with education. Very demanding, intensive training sessions and competitions at home or abroad can be hardly combined with a sufficient involvement in academic activities, not only in terms of results but especially in levels of motivation, commitment, resilience, and responsibility from the athlete. A possible solution could be the support provided by e-learning services, which most of the Universities have in operation today. Unfortunately, the standard e-learning services are forged for "regular" students, not for people never attending courses, never participating to the social life of the University, never reading push or pull information academic life coming from the different sources, never having contact with respective coursemates. This paper presents E.DU.CA (Education for DUal Carriers), a project from the University of Trento whose aim is to customize an already existing Virtual Community System to the needs of this category of students, to support and stimulate their academic carriers through a set of innovative services that will try to solve the above problems. The project, on this basis, wants to design and deliver these services for a broader category of users, i.e., working students, that present very similar (if not identical) problems and whose support from Universities is not so high as it should be.

1. INTRODUCTION

Sporting practice is now universally recognized as a fundamental element of human, social and relational growth, as an element of socialization and expansion of the subject's experiential sphere, particularly in the development of soft-skills. In the University systems of many countries (including Italy) there is no real plan to exploit this educational aspect of the sport, which instead continues to be perceived as a (good) way to pass the time after studying or working. By contrast, the skills that can be developed through practice and sports experience are crucial to completing the training of our students.

The University of Trento (UNITN) is investing consistently to consolidate and improve its inter / national leadership as a reference point for those who want to combine sport and university study. Combining time and resources needed for both activities is not always possible for students, it is even less so for those who do sport at a professional level, or who for sports reasons must take time away from studying and attending classes. It should also not be forgotten that the practice of sports is indicated by many studies as a factor not only of physical and psychological well-being but also as a factor that improves the level of employability of a graduate and - on equal terms - of better economic conditions.

Suitable services and tools are therefore needed to make the University of Trento more and more attractive for this large catchment area, not only geared towards top sportsmen but anyone who wants to see their sports and wellness activities supported and stimulated.

The objective of the paper is to present E.DU.CA – E-learning for DUal Carriers, a project launched in 2018 to consolidate the national and international leadership of UNITN in these contexts, offering new services that put our University at the forefront in a strongly promoted area both nationally and at European level, with agreements and guidelines in this direction signed both at national and EU level. The project aims to provide the University with a series of technological and training solutions that can become national and international models on two distinct but integrated levels: a) support for the dual career of elite athletes (TopSport, UniTeam, and TopTeam programs), b) the strategic use of sport in soft skills training projects for a large part of the student population.

The project is also based on the assumption that some of the solutions that will be developed for student-athletes may in the future be extended to other categories of students who present similar difficulties, starting with working students. This also requires the creation of push-based services that inform and guide the student in the daily questions of interaction with the academic institution. Indeed, one of the major problems reported by top athletes is their lack of physical presence in the daily life of the University, feeling this as a very high risk of withdrawal of an academic carrier, or at least a barrier that is often more complex than the learning part itself.

There is another aspect that is added to the technological aspect in the project, i.e., a strong organizational support to these dual carrier students [5], given that many athletes are penalized not only on the aspects of study, but they are penalized mainly because of the difficulty of finding / asking for the right thing at the right moment, which can range from a trivial administrative aspect to the simple presence of an intermediate test defined by the teacher in the classroom. Respect to the Dual Carrier concept, "The Commission's support for dual careers will ensure that young sportspeople receive an education and/or professional training alongside their sports training. It will also help European athletes perform well and compete at a high international level while reducing the number who drop out of school, university and sport.". In this line, the E.DU.CA project presented in this paper aims at facilitating these sportspeople to complete their academic studies, providing the technological support to remove some of the obstacles that complicate their permanence inside the University.

2. DEFINING THE SCOPE: SPORT IN THE EU ECONOMY AND THE RELEVANCE FOR EDUCATION

From many perspectives and different analysis, sport is much more than just «sporting activities». Inside the 2007 White Paper on Sport [6], the European Commission announced that a fundamental objective of the following years, in collaboration with the Member State, will be to develop a European statistical method for measuring the economic impact of sport as a basis for the construction of national Sport Satellite Accounts, which could in time lead to a European Satellite Account for sport. Accordingly, the EU Working Group and Sport and Economics, set up by EU Sport Ministers in 2006, developed a common joint definition, the "Vilnius Definition of Sport", as the basis for the collection and production of data for the compilation of a Sport Satellite Account. This definition can be considered composed of three different items:

- a statistical definition: "Sporting activities" as defined in NACE* 92.6 Rev. 1.1 [6]
- a narrow definition: all activities which are inputs to sport plus the previous statistical definition
- a much broader and complete definition: all activities which require sport as an input plus the previous narrow definition

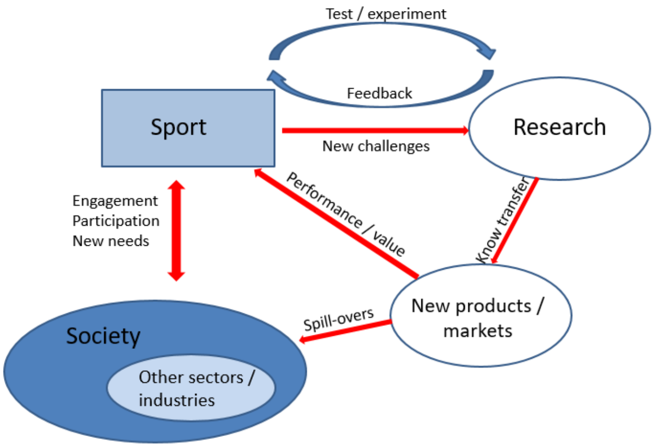
We find other interesting definition of "sport" that put the emphasis on the quality of this human activity. In 2015, the UNESCO came to a definition of sport: «... physical activity and sport form part of humanity's intangible heritage … Every human being has a fundamental right to physical education, physical activity, and sport …». In 2000, Nelson Mandela said Sport has the power to change the world. It has the power to inspire. It has the power to unite people in a way that little else does."

If we look like a sport in a policy perspective, in [8] we find that «... Sport can play an important role in driving the development of regions and cities. [...] Sport not only helps to keep us fit and healthy. It has the power to strengthen communities, and supports us in building more inclusive societies»

Also from an economic point of view, the figures reported in Fig.1 present the sport-related GVA of the EU-27 countries, in million Euro and the shared respect to the EU GVA.[7] Furthermore, it must be considered that these figures do not include the (positive) impact on the healthcare system, and the impact of volunteering

	Statistical	Narrow	Broad
Direct	28,160	112,179	173,855
Direct + Indirect	48,774	186,206	294,359
Direct	0.28%	1.13%	1.76%
Direct + Indirect	0.49%	1.88%	2.98%
Multiplier	1.73	1.66	1.69

So, Sport makes a significant contribution to the EU economy (the GVA is equivalent to agriculture plus fishery plus forestry sectors combined), Sport is a growing industry and is resilient to economic cycles, and finally, Sport is labor intensive, so it leads to jobs creation (Fig.2)



In line with the above considerations, the University of Trento started a set of initiatives to increase the sports activities within the students that are enrolled to the various offered degrees. The most relevant activities for our argumentation are the following:

- creation of an app for self-organization of workouts/events
- Lifestyle self-monitoring and analytics
- academic credits for sports activity & volunteering

The last initiative is related with the adaptation of an existing distance learning platform with services created to support the participation of élite athletes (top athletes) to the academic life in a general sense, helping them as much as possible to be part of the academic community even when they are away because of training and/or competitions. In the next chapter, we present the main characteristics of the existing platform, and in the following chapter, we will present the additions and new services developed.

3. A VIRTUAL COMMUNITY SYSTEM FOR DUAL CARRIERS

In the academic year 1999/2000, the Faculty of Economics of the University of Trento decided to have a software system able to enrich its traditional teaching as an extension on the Web. The first aim was to settle the increasing number of teachers' personal web pages into a single platform. To pursue this result it was necessary to have a Learning Management System (LMS), capable of supplying a virtual environment able to support the educational courses of the Faculty. The resulting system started to function from the second half of 1999 and during this period, the system counted approximately 1,200,000 accesses and online satisfaction surveys showed a very high level of user satisfaction. Being a quite traditional LMS, in 2002 some observation convinced us to redesign the software:

- The needs for cooperation within the academic environments is extending to all the activities that constitute the context in which didactic takes place, not just to the specific "lecture";
- Models of teaching/learning (such as learning by problems, learning by projects, cooperative learning, and their combinations) can hardly be connected to the e-Course, especially when the software directly represents the metaphor of traditional courses;
- The organizational didactic scenario changed with new regulations made by academic institutions, and these changes inevitably reflected on the LMS functionalities. It is important to note that these types of changes are usually the result of a debate process in which both elements of cooperation and negotiation interact;
- The didactics of a university are not built only as a set of studies and tests, but these activities are inevitably intertwined with the university's organization and its information system;
- In an academic context, not everything concerning teaching: for example, the entire faculty is more than a container of degree courses and a degree course is more than a container of lessons.

To answer these (and other) needs, another founding paradigm was needed, with at least four basic characteristics:

1. Provide services not necessarily related to educational settings, but generalized services open to different forms of collaboration communities;
2. Provide the possibility for enrolled users to performed different tasks under different roles inside different communities, thus allowing, for example, the application of different instructional strategies like an ante-literam flipped-classroom approach
3. suitability to support cooperation processes among different roles of users, not only students or teachers;
4. possibility of mapping the organizational structure and roles of the educational Institution inside the system, thus preserving roles and responsibilities of the different users.

The answer to these characteristics was lying in a new collaboration paradigm emerging with the first social networks and with the collaboration platforms available through the Internet, i.e., the concept of virtual community. The system that arose, called On-Line Communities (COMOL) [1], was delivered in 2003. The collaborative approach [2][3] has been a very strong incentive for us to develop this platform; the philosophy that led us to rebuild the system is to allow the exchange of users' experiences within a virtual environment and within well-defined areas known as "communities". This approach is very different, for example, from the traditional one available in other LMSs. Our work started before the boom of web 2.0 [4], that has now invaded and changed the way people think and build services on the net. The main characteristics of a community could be summed up as follows:

- Each Community offers many services to registered users that have different roles/permissions inside the community
- The services are general applications that enable the users to communicate in a synchronous and asynchronous way, to publish contents, to exchange files, to coordinate events, etc.
- Services offered by a community are activated by a manager of the community according to the needs, and the users of a community can use them with different rights and duties.
- Rights/duties in the community are different from rights/duties for the services
- Communities can be aggregated into larger communities with hierarchic mechanisms and infinite nesting levels. Communities can also be aggregated in an arbitrary way into larger communities disregarding the possible position of a hierarchical structure, in a sort of "transversal" link that overcomes the concept of "hierarchy" and follows the idea of "mesh". Thanks to these features, a complex but powerful mechanism of propagation of services/roles/permissions/ rights/duties can be set among communities of the same branch or of different branches.

- All users are recognized by the system and by the community: people external to the system can see public part of the community (services, material, contents, etc.) only if managers allow this (ex. a blog of one community could be opened to external contributions)
- Services can take advantage of the “mesh” structure of Online Communities to provide some interesting though non-existing features, like “transversal wikis”, or “merged blogs”. One blog, in fact, can be the “fusion” of all the blogs of children communities, or a wiki can take the definition transversally from all wikis in related communities.
- Last but not least, a VC is a container for collaboration processes not limited to educational activities, but for any collaboration activity needed in an organization. Research teams, recreation groups, friends, meetings, conferences, secretariats, the board of directors, colleagues, next to social dinner, anything could be an aggregation of people around a scope that can take advantage of the virtual spaces offered by the Virtual community.

The core of the application is composed of some abstract entities, i.e., VCs as an aggregation of people to which some communication services are available in order to obtain certain objectives. With this approach, it could be possible to represent all the hierarchical relationships between different types of educational communities (such as Faculties, educational Paths, Degrees, Courses, etc.), like any other relationship among communities inside organizations.

4. THE E.DU.CA PROJECT: PRELIMINARY RESULTS

Little or nothing exists today to use TELs to support those who practice sports at various levels[11][12], and therefore divides their time between study and sport, often sacrificing the study (eg professional or semi-professional athletes) or sport (with often unintended consequences on the student's physical and mental health)[10]. The project therefore wants to give a strong impetus to the various initiatives related to sport in UNITN through the creation of new TEL services designed and created for those who want to dedicate time to sport, at a professional or personal level, and extend them to those who need to follow didactic activities that take place at a distance, in remote places or with subjects simultaneously dispersed in different places.

As said, COMOL is a platform entirely created internally, consolidated but in continuous evolution, which feeds on new stimuli thanks to the various applied research projects[9]. Furtherly, the daily practice with very high numbers of users (about 16,000 UNITN members, more than 20,000 registered in PAT, about 50,000 companies of the Trento Chamber of Commerce, etc.) makes COMOL actually an enterprise-class web platform, with almost 500,000 single accesses every year.

Through this project, we want to extend the current services, or create new ones, in order to support students with the aforementioned peculiarities. The dual carrier students are interesting for our experimentation because they represent a wider class of potential students, i.e. a) students that frequently out of office b) students that are not able to attend training events and in particular exams, but also laboratories or workgroups c) students that are not able to follow the administrative life related to one's career. In this wider category of students that can benefit from E.DU.CA deliverables, we can, therefore, include all the working students. Below is a list of new services that will be added to COMOL:

- online student’s registration to exams, events, meetings with the contemporary creation of a video-conferencing session with all and only the participants to that event;
- adaptation of existing services for the delivery of MOOCs (Massive Open Online Course) specifically created for these students, so with special elements that will count the time used in a different way and with different rules respect to what MOOC platforms (like Coursera or EDX) normally do. These services will provide complete management of the lifecycle of a MOOC, available for any project of interdepartmental or university interest, supporting the initiatives of the sports office in favoring dual career projects for students who follow these paths in the various Departments. This implies the provision of support services, such as the organization of shifts for MOOC tutors, or the possibility of booking direct assistance sessions, or the semi-automatic composition of FAQ based on the questions entered in the forums. These services can also be extended to those who in general find themselves in the condition of not being able to be at the same time or in the same place as the training event (Erasmus students, participants in other

exchange activities abroad, students who take part in business games, marketing games, workgroups, local laboratories, etc.)

- services to allow remote examinations together with the related administrative processes, like for example remote student's identification, visual check of the absence of any auxiliary material in the remote room, and any other element (for example, double webcam) able to provide legal validity to the (remote) exam session.
- push information on regulations, schedules, appointments, examinations, administrative deadlines, etc. taken from an RSS feed available from certified sources, other UNITN platforms or applications (like for example the ERP where all grades, exams' date are recorder)
- self-organizing study communities to support remote students, without any intermediation of teachers, where students are allowed to manage any aspect and where most of the services are focused on providing educational material to the participants
- Online tutoring with the possibility (similar to the remote exam) to book the service, to see the agenda of the tutor, to share materials only for that session, etc. The online tutor service for athletes will support them in everyday activities that are trivial, but essential and therefore particularly difficult to manage for those who do not physically attend University spaces. The contents of this virtual assistant could be coordinated with research projects already existing in the University on virtual assistants, or use open and free tools already available. Certainly, it is the most challenging component of the project, but probably the one that will solve most of the practical problems of student-athletes (and not only). The idea here is to create a chatbot with a domain ontology that will provide domain-related answers to questions supplied by athletes and related to a knowledge base that will be created by indexing feeds and news coming from heterogeneous data sources.
- Services available to registered users for conducting remote exercises with some other member of the same community, collect results and comments or personalized feedback from the other community's members;
- Services that support the students to comply with administrative obligations, through a personalized agenda updated in push mode that will help to organize their time and physical activities. This will be delivered through social extensions that exploit virtual communities and related services (doodle, reservations, VC, sharing documents, forums, bulletin board, messaging, etc.)
- Deliver innovative training practices (eg serious games, business games), in order to run the game in an environment that before and after acquire the analytics necessary for the trainers
- Record lectures when the top athletes cannot be present in video format, possibly using a SCORM format with audio/video integration, notes, and comments from the other members of the community. These services that allow to follow lessons remotely, or see the video recordings coordinated with content and audio/video track, have already been used in COMOL. In this context, the working group has already developed considerable experience at the international level, both in the context of European projects (whose experimentation is currently underway in UNITN) and for European institutions (European Institute Of Technology – EIT) and international (IEEE - Institute of electrical and electronics engineers);

The COMOL team provides twenty years of international experience in TEL services, from the methodology to the training planning to the platform to the supply. Some undeniable competitive advantage factors converge at UNITN:

- University at the top of international sports - innovation - university studies;
- receptive and active territory with many initiatives, and is internationally recognized for its success with the 2013 Winter Universiade;
- lack of competition regarding training courses for athletes where e-learning, as specified by the EU directive, is an essential implementation tool.
- presence of Sport Office and Placement Office support (for soft skills) and UNISPORT /

TOPSPORT / Top-team projects

The investment made on E.DU.CA has other returns for unitn. COMOL is active both in UNITN and in many other public and private institutions, so services created for E.DU.CA will be available to other partners and other situations. COMOL is entirely developed internally in UNITN, without any dependencies or additional costs from external suppliers. among other things, COMOL has already been used in combination with sport communities, for collateral activities also during the XXVI WINTER UNIVERSIADE, held in our region in 2013, as well as for various events, masters, external training courses, initiatives in which virtual communities were needed to support the activities.

As regards a second group of objectives, namely the development of innovative training objects (eg MOOCs, serious games, Business games, laboratory materials, tools for the collaboration of workgroups, etc.) on issues related to soft skills , the proposal is to create advanced training objects that are used on athletes to experiment distance learning services made with high-quality teaching materials. Using sports as a theme and training metaphor, these MOOCs will be transversal to the various UNITN specializations, will allow them to integrate what the individual academic programs are unable to do on these issues and thus support the Placement Office in soft skills training initiatives. The MOOC will be introductory and will serve to test and measure user satisfaction and applicability.

The effects of the project are varied and at various levels: for example, the dispersion of top team sports students who cannot follow the lessons due to frequent transfers, training, international commitments, etc., or those students who during their university career could change team and therefore should leave for logistical reasons UNITN.

This type of innovative services to support study programs is also connected with the territory and with recent initiatives of the educational path in high schools related to sport, such as the so-called "Sports High Schools" and the various activities of facilitation of higher paths for sports. The attractiveness of an athlete who in high school has followed these paths, even at the national level, and who then decides to join UNITN to pursue his sporting interests and at the same time obtain a University degree is evident.

5. CONCLUSIONS

The paper presented E.DU.CA, a project of the University of Trento for dual-carriers students, that aims to support top-sport athletes with a set of technological services that will help them to proceed in their academic carriers. There are many ambitious objectives in the project, started in June 2018. First of all, the quality of the activities carried out, in particular, the quality of the training and quality of the organization that will support these athletes, through integration between administrative tasks and teaching activities, in a bidirectional sense, in order to benefit the student and the administration. Another expected outcome from this project is the increase in the reputation of UNITN, thus attracting students who practice sports at various levels, offering integration between sport, innovation, and research. This attractiveness, whose increase comes from working and study conditions and the opportunity for individual growth also through the possibility of exercising in quality sports facilities, implies also the creation of strong partnerships with economic and academic partners, like for example sports clubs (of any level) that stimulate their athletes to join UNITN given the possibilities of dual-carrier offers. At the moment, we have this kind of agreements with the two professional teams of the city, playing the respective Italian premier leagues of BasketBall and Volleyball. Together with these technical and organizational aspects, there is also a well-defined objective related with the promotion of well-being practices among students, not only by facilitating top athletes but above all by rooting the idea of sport as an element of well-being in all students. All these ambitious objectives will be hopefully achieved thanks to organizational flexibility and management efficiency, a crucial element for sports students, and with a set of new technology services based on a virtual community platform.

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E-Learning and Project Management: Adding New Features to Learning Management Systems

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E-LEARNING AND PROJECT MANAGEMENT: ADDING NEW FEATURES TO LEARNING MANAGEMENT SYSTEMS

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Abstract

The paper presents the idea of adding project management services to educational environments, specifically to Learning Management Systems (LMSs). Project Management here is referred to as a general approach to time management, and educational contexts are no exception respect to this need. From managing the educational path of a participant to following a thesis in a university, from the preparation to an exam to the organization of a team of students working on a project, in many situations the educational tasks are mixed with project management tasks. The different types of educational "communities" could also take advantage of time and project management services. As a testbed for understanding time-management needs students, a special case of athletes enrolled in our University has been analyzed, where the needs of this special community of students have been used to validate time and project management needs. For example, how to manage appointments, deadlines, milestones, etc for such a special case of University student has inspired some special features of the mobile application associated with the LMS. The paper describes how our software platform, traditionally used for e-learning activities, has been equipped with a fully-fledged set of tools compatible with the most used project management standards, including task planning, costs, and resource management functionalities.

Keywords: E-learning, Project Management, educational services

1 INTRODUCTION

In this paper, we present some possible extensions of traditional Learning Management Systems (LMS) towards a more extended provision of services oriented to manage the time of the LMS users, specifically teachers, students and administrative personnel involved in educational tasks. On the market, there are many different tools that project managers can choose to plan and manage their projects.

There is not such an extended functionality inside LMS, where services like critical path method (CPM), Critical Chain Method (CCM), PERT, etc. are not available even if the educational activities are full of project management concepts. Deadlines, cost management, task duration, resources, these and many others are problems that everyone involved in educational tasks are forced to face. Moreover, using project management concepts and tools for students of any course would be a fundamental store of knowledge for their future professions.

Since the advent of open source LMSs, Technology-Enhanced Learning (TEL) is a consolidated research topic, and a lot of tools and techniques are available for creating, delivering and managing online educational paths with plenty of solutions for every educational institution. What is less available inside the technological solutions that support our daily educational tasks is the integration with project management tools and techniques to manage tasks, resources, and costs within educational settings. We can find a plethora of platforms and cloud services available today, even for free, that support at different level activities related to a project, but in order to implement project management discipline suggestions inside educational processes, a teacher (or a student) is forced to exit from his learning environment (for example, Moodle or Sakai LMSs), and use an external platform to manage project.

This, in turn, could be problematic as most of the items that are the subject of the educational project are inside the LMS, so the user is forced to duplicate the material. Then, if we consider not only the trivial aforementioned problem of document sharing, but we extend the analysis to other typical project management tasks (like for example checking deadlines), the situation is again complex: the educational platform and the project management platform are completely disconnected.

What we can mostly find inside LMS under the label "project" or "project management" is a sort of task-list or to-do list service, that must be managed directly by the user. In few other cases, the idea of managing projects is simply implemented with a set of steps of a predefined workflow, in some way linked each other, but this is clearly very limited even respect to elementary project management tools.

If we consider the world of education in its full complexity and what educators do every day, we can find plenty of activities that can be fully defined as a "project", but strangely software platforms that are so useful for educational purposes are not providing adequate support to this.

In this paper, we present our solution to this issue: we have created our own Learning Management System called "Online Communities" that has a much broader objective than simply providing support to pure learning processes, but is much more oriented to collaboration services among members of a (virtual) class, that in the end, we consider as a particular type of a virtual community. In this platform, we have added some project management tools that we will quickly describe in the next sections.

2. PROJECT MANAGEMENT SERVICES IN LEARNING CONTEXTS

According to the de-facto standard in the Project Management discipline, a project is "a temporary endeavor undertaken to create a unique product, service, or result" [5], while Project Management is "the application of knowledge, skills, tools, and techniques to projects activities to meet project requirements. Project management is accomplished through processes, using project management knowledge, skills, tools, and techniques that receive inputs and generate outputs." According to the definition from [6], Project Management is the application of a collection of tools and techniques (such as the CPM and matrix organization) to direct the use of diverse resources toward the accomplishment of a unique, complex, one-time task within time, cost and quality constraints. Each task requires a particular mix of these tools and techniques structured to the task environment and life cycle (from conception to completion) of the task [7].

Even if everybody talks about team working, tasks, milestones, deliverables, i.e., using the typical jargon of Project Management, the application of this complex discipline has not been so widespread, and surely not applied in education. According to several studies [8], even today that we have a wide range of tools and techniques available, projects are frequently out of time and/or out of budget [9]. These poor results in terms of successful performance could have many interpretations, being the most common the one that "project management continues to fail because included in the definition are a limited set of criteria for measuring success, cost, time and quality, which even if these criteria are achieved simply demonstrate the chance of matching two best guesses and a phenomena correctly" [6].

Project Management has historically a difficult relationship with the computing world, in terms of cultural, technical, organizational and, not least, social perspective. It becomes even more complicated when applied to simple collaborative environments present in social networks (sharing files, messages, lists), what is called Project Management 2.0 or social Project Management [14]. The issue of integration of e-learning platforms, project management, and social media is closely related to the world of collaboration mediated by ICT (CSCW). Thanks to the social earthquake represented Facebook®, Twitter®, Whatsup®, Youtube®, etc., the world of e-learning and PM need to consider the expectation of users due to the social interaction that today is so common even in workplaces [1].

The theme of Computer Supported Collaborative Work has been widely debated [2][3][4], especially in the last decade and in accordance with the systems of project management support. This area is studying the idea of using ICT tools to perform and coordinate (collaborative) workgroup activities. Applications and technological tools to support collaborative work are instead called groupware or technology cooperation[9][11]. One of the variations of this approach focuses on training, especially in e-learning; in this case, we speak of systems of Computer Supported Collaborative Learning (CSCL). The need for training in many areas of organizing the teaching approaches of learning by doing, learning by project, etc. require systems of e-Learning to incorporate collaborative technologies.

Project Managers, today, can choose among many techniques and software to plan and manage their projects. The widespread usage of network approaches, like Gantt charts, critical path method (CPM), etc. have simplified the planning and controlling steps, while project management software has reached a solid maturity level. In order to define the scope of the project, the Work Breakdown Structure has been adopted as a (graphical) tool to delimit the things that should be done in the project, separating them by unwanted and/or unpaid requests. WBS is the hierarchical decomposition of the work to be executed by the project team to fulfill the objectives of the project and make deliverables. It organizes and evaluates the overall scope of the project. Information for a WBS is basically taken from project objective statement, historical files of previous projects and project performance reports. An appropriate WBS encourages a systematic planning process, reduces the possibility of omission of key project elements and simplifies the project by dividing into manageable units.

Another area heavily interlaced with PM is collaboration. Collaborative spaces are available within the project team to contribute towards the success of the project's objectives. New generation tools of PM enable this functionality. Project is lead and developed by the whole team, and each member has full information about the project, with all the related documents. Project's progress is visible to everyone anytime, according to permissions granted to the subject. When the project manager is free from the routine tasks; s/he can put more efforts into project vision and choose the direction for the project development. [13] discusses methods and tools for collaborative project management. Project alignment is the process of ensuring that project key stakeholders share a common understanding of project work processes, operational procedure, objectives, and plans. Collaborative Management of Projects is exactly devoted to fulfilling this objective: (a) shared project management, (b) delegated management responsibility, (c) self-organized and trusted approach, (d) non-hierarchical (and participative) management organization, and (e) results based assessment of progress. Management of Collaborative Projects means: (a) management of projects in a networked and distributed environment, (b) distributed processes, (c) participants and organizations in different locations, countries, cultures, etc., and (d) either central project responsibility and tracking or collaborative management.[15]

There are three most typical and popular applications that enterprise can adopt while they use PM 2.0 for their project: wikis, blogs, and collaborative planning tools. All these tools, together with file sharing (documents, reports, agendas, comments…) represent a clear stimulus to consider also an e-learning platform as a possible provider of support and services to PM. These services, like many others, are very common both in collaborative environments and in e-learning platforms, as presented in [16][17]. Likewise, many different situations in educational settings could take advantage of PM services. Some examples can be the following:

- the management of a thesis assigned to a student is a real project with tasks, milestones, deliverables, and costs (even if not directly sustained by somebody);
- a research project led by a teacher or researcher is, by definition, a project, involving again different resources, costs, deliverables, and milestones;
- an educational path and all the tasks that any participant has to manage is another example of a "project"
- a complex training path providing professionals with a certification at the end of the activities, with respective assistance of external resources and tutors, is a project from the perspective of the organizing institution. Here we have a typical mix of educational needs (the LMS's most traditional services) and PM tasks
- a massive open online course (MOOC) initiative, with all the tasks related to the various phases of creation, marketing deployment, execution, support, and final certification is a project, both for the institution that delivers the MOOC and for the participant that has to perform tasks, to pay attention to milestones, to respect deadlines.

The possibilities of using these tools and services inside LMSs is even bigger, if we imagine to use a Virtual Communities system not only for managing "communities" devoted to educational purposes but also in larger contexts typical of collaboration, like a research group, a recreation organization, a secretariat, a board of directors, a club, a sport team, etc. All these "communities" need services that are available inside LMSs (like document sharing, forums, wikis, FAQ, sync, and async communication, etc.).

3. A NEW APPROACH TO FACILITATE PROJECT MANAGEMENT IN EDUCATIONAL CONTEXTS

E-learning systems are increasingly becoming software platforms aimed at supporting cooperative interactions among participants, not just a simple file repository. Web 2.0 and other collaborative paradigms (like social networks, or more in general systems that support decisions) have become very popular among users, thus creating similar expectations in the educational fields. E-learning became so popular thanks to many factors, like network availability, multimedia, increased power of client workstations, flexibility, low costs, etc., but the role of software platforms like Moodle™, Docebo™, Dokeus™, Sakay™, Webct™ is clearly a central role.

Today, the evolution of distance learning sees the phenomenon of Massive Open Online Courses (MOOCs), where the massive inclusion of people into prestigious e-learning paths is a great example of what technologies can do today. At the same time, it poses a set of questions regarding the software services, how they can improve the educational experience of hundreds of thousands of users from all over the worlds. Usability, manageability, responsiveness, performance, scalability, modularity, just to mention some of the challenges this category of software is facing nowadays.

At the same time, these approaches have proven to be effective in contexts not necessarily connected to academic education, therefore posing the issue of the evolution of software platforms towards services that are not necessarily related to traditional academic tasks. Last but not the least, the integration of e-learning (or collaborative) software platforms with the rest of the information system of the hosting organization represents clear evidence of the role of software platforms today in education.

From a meta-architectural point of view, e-learning platforms have based their pillars on the idea of “course”, or “class”, meaning that the basic container for relationships among users of the platform is a virtual place that resembles in some way what happens in any educational organization: collecting people in a (virtual) classroom. From my perspective, what clearly emerged from the evolution of last years and from my preliminary experiments is a need of a different funding paradigm for software platform: the “community”, or “virtual community”.

The virtual community is a container ready for didactic processes, but not only: research teams, recreation groups, friends, secretariats, the board of directors, colleagues, anything that could be an aggregation of people around scope using virtual spaces on the web. The core of the application is composed of some abstract entities, i.e., virtual communities as an aggregation of people to which some communication services are available in order to obtain certain objectives. In detail, a virtual community

“Online Communities” [16] is a space on the web devoted to a collaboration objective, populated by people who communicate with each other, using a series of communication systems. With this approach, it could be possible to represent all the hierarchical relationships between different types of communities (such as faculties, didactic paths, master degrees, courses, etc.). The main characteristics of a virtual community could be summed up as follows:

- each community avails itself of a certain number of services
- the services are general applications that enable the users to communicate in a synchronous and asynchronous way, to publish contents, to exchange files, to coordinate events, etc.
- the potential services of a community are activated by a manager of the community according to the needs, and the users of a community can use them with different rights and duties
- the communities can be aggregated into larger communities with hierarchic mechanisms and infinite nesting levels
- the communities can be aggregated in an arbitrary way into larger communities disregarding the possible position of a hierarchical structure
- all users are recognized.

4. PROJECT MANAGEMENT SERVICES INSIDE E-LEARNING PLATFORMS

The inspiration for the inclusion of project management services inside e-learning came mainly from the experience of the team in the techniques of project management, on the one hand, but also from everyday tasks: consider, for example, as part of learning community college, the need for a teacher to coordinate a number of undergraduates involved in the long task of drawing up their thesis. The activities of the individual, the professor, or those that are shared between them have often intertwined/ associates and impose the need to manage time, deadlines, relationships, and mutual dependencies. More complicated is the situation on the teacher’s side, where s/he could have more thesis to follow, so more projects of this type to manage. We, therefore, believe that the lack of a tool of this kind can be solved naturally with valuable tools for planning and managing existing projects, but these:

- do not integrate platforms
- on average, they are complex
- they are much more appropriate for people with specific expertise in the complex and multifaceted discipline of Project Management

The idea of implementing Project Management services inside learning contexts benefitted a lot of the availability of “Online Communities”, the virtual spaces dedicated to each community (what we call the virtual community). This collaboration space is equipped with services provided to the users, so it was simply a matter of creating new services related with PM but aware of all the rest the platform provides, and integrate the PM services with this. Another fundamental factor from the virtual community that we used in assembling the new services was the concepts of “roles”, “rights”, and “permissions” that are assigned to each user for each separated community. This allows a fine-grained, sophisticated way of managing and controlling who is doing what on a certain task.

Tasks and users can also be shared among different communities, with the same inheritance mechanism. Users have on the one hand an institutional role inside the organization, and one or more functional roles in each community to which they participate. Examples of institutional roles are those of the classic academic institution (student teacher etc.) As examples of functional roles, we have the administrator of a community, participant, moderator, blogger, secretary, member, dean, writer, etc. Roles can be freely created, assigned with respective permissions for each service available in the platform, PM services included.

In order to have a consistent approach to both the creation of complex projects or simple reminder/to-do lists, we decided to consider the main project as a normal activity at level zero, indicating the root of the project, distinguishing from the other only by the absence of a parent. The most complicated part of this has been the creation of a fully functional Critical Path method, that starting from a) the definition of a calendar b) the start date of the project c) the tasks and their dependencies, is able to produce in output a) the start and finish date of all the tasks b) the critical path, i.e., the tasks that have a total float equal to zero.

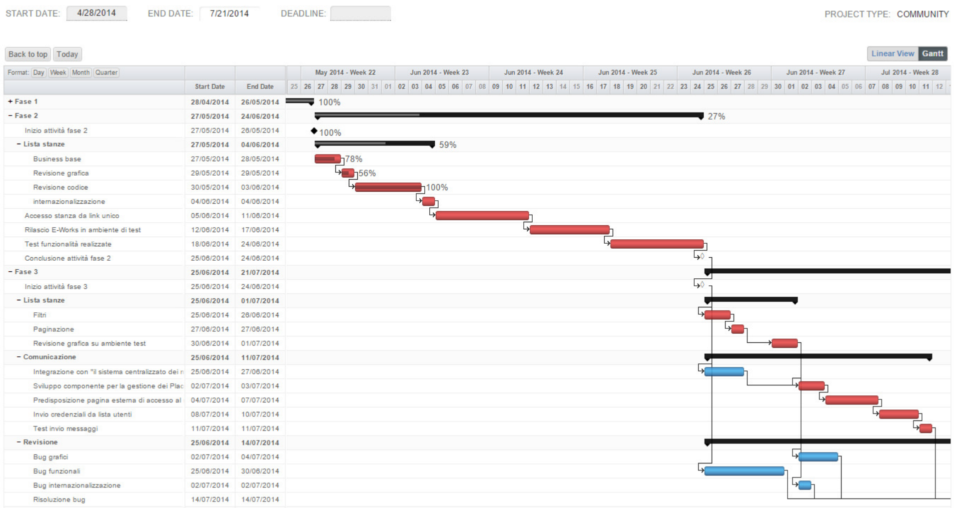

Fig.1: the WBS with critical path, predecessors and completion percentage

Activities and projects will have the same properties and the same mechanisms. All remarks made on tasks shall also be applied to projects.

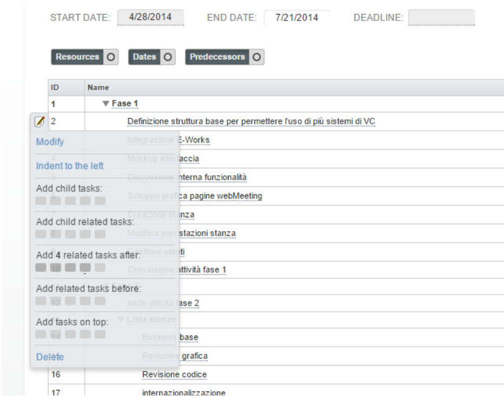

Fig.2 Structuring a WBS with child tasks and predecessors

Each task or project has constraints and deadlines. A task has the following features:

- Status: The status indicates at what stage of development is the project. Son provided the states active (the task is in progress), inactive (the task is still in progress), pending and completed.
- Priority: low, normal and high. They are an indicator of the urgency of execution of a task.
- Temporal constraints: An activity has three dates that mark its production cycle: start date, (the start of the task), end date, deadline (maximum limit for the completion of the task). To allow the creation of milestones (used to indicate the achievement of the objectives set at the design stage) we allowed the three abovementioned dates to coincide.
- Percentage of completion;
- Category: allow a subdivision of projects according to the subject
- Description;
- Attachment: you can attach any file that has been uploaded in the file repository of the community.

A user holding the appropriate permissions is allowed to create a project with an arbitrary number of sub-tasks, to which different resources can be assigned. The roles that we have decided to support are:

- Owner of the project: role assigned when creating the project. Owner is the user that has total control over the project and has no limit in respect of assignment of roles, cancellation of tasks, attachment, etc.
- Manager: this role will have the same potential of the project owner, with some restrictions on the tasks created by other managers. A manager may appoint other managers or simple resources. This can be done only on the task of which the manager is the owner (creator). Same goes for the cancellation and modification of activities. Note that the role of the owner of the project is distinguished from all others because of its total control over every single part of the task list regardless of the assignments. Task manager and the owner will also be asked to indicate the status of a task or project, thus introducing the control over the work of other users.
- Resources or executors of the project: these users will have a limited subset of actions since its main purpose is to perform the task and inform the manager through a report.
- Guest: this role is meant for those users who want to enable you to view a project, without, however, afford to interact with it in any way.

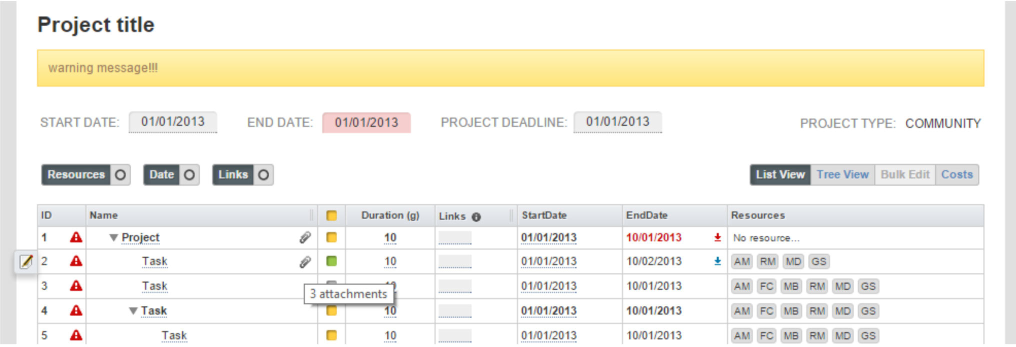

Fig.3: WBS with attachments and assignments of resources taken from the community's users

In the platform, you can create three different types of projects or task lists depending on confidentiality and context required. You can create personal and public projects within a community or personal projects at portal level, i.e. outside any specific community. A task list is visible only to the creator of the same and to the assigned people. A public project, however, provides the necessary permissions for users with admin rights within the community to view and interact with all users involved, inviting external people from other communities or even not enrolled in the platform. We get more flexibility in the case of a portal tasklist, conceptually associated with a super-community, where all subscribers to the platform (here we are at the highest level of the communities' hierarchy) are considered within the same context. This allows us to engage in a project potentially all people registered to the platform, regardless of the inclusion in any community.

5. CONCLUSIONS

The paper describes the process of integrating Project Management functionalities for users of learning management systems. We wanted to highlight how the management of tasks within an educational environment shows a series of constraints and issues that need to be managed with appropriate tools, like those supplied by Project Management. In our case, online and virtual communities provide associated participants a set of features to manage projects, create tasks, use Work Breakdown Structure and Critical Path Method tools to define scope and plan tasks' sequences, assign resources and control costs associated to a project, with a combination of role-permission to a level that can properly administer the security, confidentiality and privacy of the activities. The integration of these features within a typical e-learning platform guarantees the enlargement of application fields of Learning Management Systems, allowing them to be used not only for traditional educational activities but also more collaboration and cooperation-oriented tasks

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Publication IX

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Implications of Learning Environments on the Information Systems of Educational Institutions

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Implications of learning environments on the Information Systems of educational institutions

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***Abstract*— Since the early years where they started to enter the market, Learning Management Systems (LMS) have reached a very high level of maturity, providing professional solutions to mostly any educational need referring to distance learning. In this paper, an analysis of how LMSs should evolve in the future is presented, according to authors' experience, in terms of functionalities and services provided to users. Behind these new functionalities and services, we foresee research fields that could provide interesting and fruitful stimulus to the market and to these platforms. The foreseen direction is the one that goes towards an expansion of the collaboration services, where virtual learning environments should be mixed with typical Computer Supported Collaborative Work (CSCW) tools and approaches that put collaboration at the heart of the system. Nevertheless, also traditional e-learning services should be improved with additions coming exactly from this integration with cooperative / collaborative services. The reference point is a virtual community platform created and developed along the years, used in the authors' institutions and in several public and private organizations. The platform is oriented towards the support of collaborative processes, where of course e-learning is one of the most important, but not the only one, and where new services supporting collaboration in different ways are constantly added.**

Keywords-component; Learning Management System, Information System, customization, open source software

I. INTRODUCTION

Computers today play a central role in many sectors of our life, by the presence of hardware and software tools covering most of tasks human beings perform. Education is not excluded from this list, both for content providing and for supporting educational tasks with Learning Management Systems (LMSs), Virtual Learning Environments (VLEs) or other labels that refer to software platforms and services devoted to education.

The e-learning sector is well guarded by different groups of LMS platforms. The first group of LMSs is based on open-source solutions, open, free or both, readily available, at no cost of acquisition (if the configuration needed by the educational institution is simple), with source code available, requiring an in-depth knowledge for management and customization. These aspects have created an interesting market for consultancy and services devoted to the customization of the platform for specific needs, like the integration with other services of the information system. Here very well-known platforms are available, being Moodle™ the most famous one.

A second group include the so-called "closed" solutions, in the past linked to major players, now mostly developed on the basis of specific requirements expressed by major customers. In this category many variegated examples can be found, with solutions created from scratch, customizations of open source LMSs, or customization of other software platforms created for other purposes "forced" to become technology-enhanced learning environments. The most frequent case is the customization of Content Management Systems (CMS), like Joomla™, Drupal™, WordPress™ etc. to some educational needs.

Recently, a third group of software solutions for education can be identified that take advantage of the many positive aspects of cloud computing. Normally these platforms are the porting of one of the previous categories, or native platforms only available via cloud services.

This paper is based on almost 30 years of experience of authors in the field of creation of software solutions for education, specifically the creation of Virtual Learning Environments for different public and private institutions. The paper will discuss the pros and cons of one of the aforementioned groups, i.e., the custom solution. It is our strong convincement that, in many situations, a customized LMS provides better services from the educational perspective, but most of all it provides services to other sectors of the information system of the institution that normally are not labelled as "educational services", but that could be found inside LMS. Moreover, equipping a LMS with services not only devoted to the pure educational context, but related to the support of collaborative tasks, could provide a lot of advantages for the institution and for the administrators of the information system itself. The paper is organized as follows: section 2 will present the testbed for our argumentation, a custom virtual learning environment created to support digital training processes. Section 3 will be a frank analysis of the implications of open-source learning environments on the information systems of educational institutions, with respective pros and cons. Section 4 will discuss the relation between LMS and more general information systems of educational institutions, while section 5 will present an example of integration related with tools for decision support systems.

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II. THE TESTBED: A CUSTOM VIRTUAL LEARNING ENVIRONMENT

This paper presents an analysis of the opportunities related with the use of e-learning services in different contexts respect to pure training, and the integration of these tools with the rest of the information system of the organization. Normally, e-learning is perceived as a separate world respect to the information system. However, when the size and variety of e-learning needs grow, turning the platform from a simple repository of material to a tool devoted to integration, collaboration and cooperation between virtual communities, at that point the management of e-learning services becomes much more complicated. It is exactly in these contexts where both open-source platforms and closed-source mainly fail, and in our opinion this is due to their conceptual foundations. What has been experienced is that distance education is nothing but a tool for collaboration between teacher and participants, but extending these tools to other contexts significantly expands the application fields. In what follows, however, an adaptation of the platforms, their customization, or assembly of different tools in "patchwork" often reveals to be inefficient and unusable. In general, this means for organizations to heavily intervene through customizations on platforms created by others, often distorting and then losing or compromising compatibility with future releases, or devoting considerable efforts to keep this compatibility. The growing phenomenon of MOOCs, for example, sees a proliferation of platforms created to handle these complex contexts of massive training, thus forcing educational institutions to adapt their educational model, services, processes etc. to what the LMS provides.

In our opinion, the flow should work in reverse: software platform should be customized on the educational processes that the institution decides to apply, and this creates a competitive advantage for educational institutions. Secondly, the integration with the rest of the information system is crucial to the success of the institution, or at least of the educational initiative. Nowadays software educational platforms should provide services that include the administrative components of educational services, like enrolment, taxes, exam records, students' secretary, single sign-on, certifications, online payments etc., being these services typically provided by the main information system through the organization website.

To validate our argumentation, the authors will present their experience in the creation of a custom platform constantly developing since 1998. Some cases and situations of partners that adopted our platform and collaborated with the team to implement the integration with the respective information systems will be presented,. The system development started at University of Trento for blended teaching 20 years ago. The development started in 1998, largely before the advent of Moodle™ or similar platforms: at the time, there was a market of web-based Learning Management Systems, and the dominant player was BlackBoard/WebCT™. After having finished the first version, in the academic year 1999-2000 the Faculty of Economics of the University of Trento decided to adopt our software system in order to enhance its traditional educational activities. This platform should have absorbed the many different personal initiatives taken by several teachers who had activated autonomous web pages to support their courses. Three options were presented to the Faculty: purchasing commercial software, using free software or building from scratch a new platform: a very similar situation compared to today's alternatives. The decision to build its own platform was a consequence of various reasons [1], which can be summarized as follows. At the time, the use of commercial software appeared to be impossible due to very high costs, considering the total cost of ownership of such solutions: acquisition, maintenance, management, training, software insurance, hardware required, personnel etc. On the other hand, at that time free software was rather rudimentary (if not in a prototype stage), and was limited to very few examples mainly created by single research groups / Universities / freelance consultants.

After a first 5-year of extensive usage, our team focused on carrying out a platform based on the idea of virtual communities. Facebook was probably still in the creators' mind, so the idea of virtual community, according to our interpretation, was not the result of a process of social networking. In fact, it was (and it is in the current implementation) a virtual space shared by people with a common goal, following approximately the original definition of Rheingold back in 1993 [8]. A community's virtual space can be simple or complex; for example, it can contain further virtual communities, thus establishing a hierarchical "parent-child" relationship. The (virtual) community can be an open space accessible to anyone, or can be a restricted space, the access to which is reserved only for some people authorized by the community administrator. The users can have different roles with rights and duties, which vary in the use of space and collaboration services activated in a virtual community. The system maintains the consistency of the completely social environment of the virtual communities, which are active at a given time, in that it provides users of a community with a range of on-demand services that can be activated and used in accordance with the permissions granted and the roles assigned.

Respect to the change of paradigm from a LMS based on the traditional metaphor of a "class" to the metaphor of a "virtual community", here some observations are summarized:

- Models of teaching / learning (such as learning by problems, learning by projects, cooperative learning and their combinations) can hardly be connected to the idea of a class, especially when the software directly represents the metaphor of traditional courses;
- The needs for cooperation within the academic environments can be extended to all the activities that constitute the context in which didactics takes place, not only to the simple activity of teaching. The organization of a research group, for example, is surely a (virtual) community that requires many of the services used in a (virtual) classroom: file repository, videoconferencing, forum, FAQ, blog etc., but surely should not be organized as a (virtual) class: different roles of participants and different services needed;
- The organizational scenario is changing under the effects of new regulations or exogenous decisions, and these changes will inevitably reflect on the LMS functionalities. It is important to note that these changes are usually the result of a debate process in which both

elements of cooperation and negotiation interact, and very often are on a national scale if not regional if not of the single University. Expecting that a world-wide software platform (like Moodle) will add features (sometimes very impacting) for such specific context is rather unlikely, while respectable local attempts to create special plugins can clash with Universities that adopt internationalized versions of the platform;

- The educational processes of a University are not built only as a set of lectures and exams, but these activities are inevitably intertwined with the university's organization and its information system;

- In academic contexts, not everything concerns teaching: for example, the entire Faculty is more than a container of degree courses, and a degree course is more than a container of lessons. So the hierarchy of the organization is relevant for any software platforms, LMS included, for example for the propagation and sharing of documents at different levels of the hierarchy. A general communication of the Dean to all the communities of the Faculty could be propagated without replicating the file in any classroom by simply implementing an inheritance mechanism among communities. The hierarchy mechanisms and the connected propagation effects are normally not implemented in mainstream LMSs, while our platform has these mechanism built-in by design.

To answer these (and other) needs, it was necessary to find another founding metaphor respect to what LMSs have implemented implicitly or explicitly in their code, which had at least three basic characteristics: a) to be general to support any collaboration process, not only learning processes; b) to be capable of modelling adequately the organizational aspects of an educational institution c) to be flexible to provide services to the rest of the information system. This metaphor was found in the concept of virtual community. The system that arose, called "Online Communities", started to offer its services in 2003 and runs uninterruptedly since then. It is still the platform at the Faculty of Economics and at other Faculties of our university, and since then has been adopted by large public bodies and private organizations.

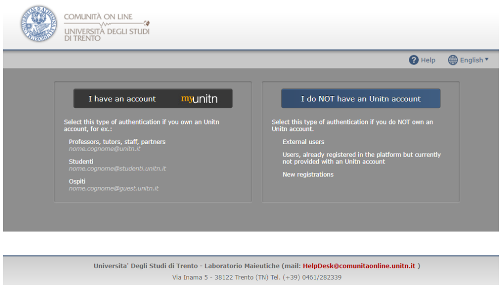


Fig.1 The internationalized home page of "Online Communities"

The complexity of managing virtual communities is objectively quite different from managing a course [2]. It requires a different approach also in the management of roles and permissions. In the logic of integrating systems, there is an ever increasing need to provide a single point of aggregation of the various services in order to enable subjects and systems with different interests (if they are not divergent) to access the same object, acting according to their own competences.

The architecture of Online Communities is based on five fundamental entities: Person, Community, Role and Permission, and the combination of the roles and permissions that gives the Profile for each user. The central entity of the platform is the "virtual community". The main characteristics of a community could be summed up as follows:

- each Community encapsulates a certain number of services.

- The services are general applications that enable users to publish contents, to communicate in synchronous and asynchronous way, to exchange files, to coordinate events, to manage their personal learning environments etc.

- Services for each community are activated by an administrator of the community according to the community members' needs, and the users of a community can use them with different permissions that are specific for each service. The role of the administrator of the community is clearly crucial, not complex in technological terms but in an organizational sense.

- The communities can be aggregated into larger communities with hierarchic mechanisms and infinite nesting levels. The communities can also be aggregated in any arbitrary way into larger communities disregarding the possible position in a hierarchical structure.

- There is no anonymous access to the platform: being the user's profile the base for every operation, all users are profiled in the platform at least with one role and one community of belonging.

Over the last few years the system has evolved into a platform for professional training oriented to life-long learning outside academia, being preferred to mainstream LMSs because of three main reasons:

- the complete knowledge of the University development team on every single part of the platform, due to the complete in-house, from-scratch development;

- the metaphor of the virtual community that particularly fits with many organizational needs and educational methodologies used, more oriented towards a peer-to-peer, equal relationship within the participants of a community;

- The predisposition to be integrated with other components of the information systems, and the provision of services to be encapsulated in other components of the hosting information system.

The new implementation of the system (fig.1) has retained certain basic features of earlier versions, while also extending its functions in order to allow the application of business logics to the training processes. Such evolution has been required, for example, when the Massive Open Online Courses (MOOCs) idea came into the market. This brought the need to develop previously neglected aspects, especially with the aim of controlling the students' activities more extensively, and the accounting issue of invoicing participants precisely the amount of usage of the platform for their training processes.

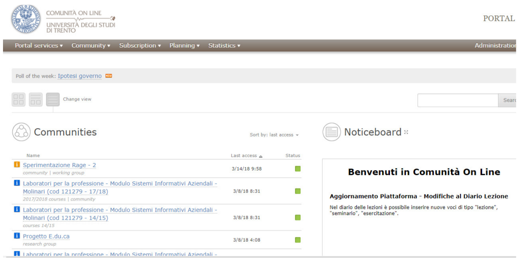


Fig.2 The User's home page, with the communities of interest

The connection with the Enterprise Resource Planning (ERP) software of the hosting organization has been another good example of our argumentation, being this the need of evolution of LMSs from a general-purpose platform of a generic educational institution, similar if not equal all over the world. On the contrary, what should be highlighted is that such an effective technological tool should embrace the (social and technological) context where teaching and learning processes take place, including other processes of the information systems. Going back to the origin of ERP, the problem was exactly the same: different silos of information systems treating the same data, but separated and not interconnected, with the consequent mess of customization and integration that created so many issues in the management of information systems. The solution and the time, still valid today, was to have a centralized system with a unique database where one single copy of information was managed. What proposed is an update of this idea to modern Restful web services, cloud computing, distributed databases etc. where best-of-breed services are provided to users by whatever platform inside the information system has been elected as the most suitable platform for that service.

III. Implications of Open-Source Learning Environments on the Information Systems of Educational Institutions

First, the authors want to clarify that the technical and organization value of platforms like Moodle is not under discussion. Moodle and the like changed the world of education because they supplied an easy and quick way to address the request of providing educational services through the web. Our argumentations start from a different perspective, i.e., the need of a mature institution that wants to apply a unique, customized, "personal" set of educational practices, being convinced that customized educational practices instead of standardization imposed by a software platform could be a competitive advantage. (differentiation from the other educational institution)

Public and private educational institutions adopted mainly open source solutions for various (quite obvious) reasons, substantially choosing the no-cost (or this was what they believed), easy way. Respect to this, authors experienced different issue. As a first element, the need of a development team that knows the platform, but being the platform developed by others (many others, in the case of Moodle), substantially the development is confined to a very limited customization, with the general motto "don't touch what you have not coded". So unless the institution has the technical background to fully manage the LMS, from hardware to software to network, having the source code of the LMS (like in Moodle) has a very limited value, and in the end leads to hire external consultants for the installation, the maintenance, the personalization etc., thus vanishing the expected benefits of "free" in the sense of zero-cost. To complete the matter, many Moodle owners know very well the famous "security patch" hassle, and the costs associated with mistakes on this side. There is clearly nothing new respect to any other software platform, but the lack of awareness of many (especially small) educational institutions created a very bad reputation to LMSs, thus hiding the enormous benefits they could bring.

Even if it is a technical issue, scalability is clearly something that in large organizations became a sort of buzzword, while Moodle was mainly created as a single-server box, one for each customer. If the institution is experimenting, for example, peaks of usage during the early days of an academic year, scalability becomes a serious issue. If we use the platform, for example, for a social event where all participants (students) will get a gadget, and in the meantime there are some online exam sessions, then scalability will become a serious issue. Theoretically, no problems exist in putting Moodle in the cloud, but then a) you'll need to spend extra money and resources to deliver this, but especially for public institutions b) not every organization is happy to publish online material dealing with internal topics (for example on security training policies and processes) on a cloud-based platform.

There is also an over-emphasis on the capabilities of customization of free/open source LMSs. If Moodle is taken as a reference, at the moment of writing the core components of this platform are around 800k of PHP lines of code, and close to 100k for Javascript. This excludes all the external libraries, modules etc. It is clearly a huge software effort, and whoever wrote a single line of code knows perfectly the possibility for an external person to safely and consciously put their hands inside this mass of code. Therefore, most of the time, when people claim "we have customized Moodle", they refer to some CSS style changes in visual aspects, labels, some logos, menus and very few other things. Real customization means, for example, to change the structure of a database table in order to add information coming from another component of the organization's information system, in order to connect the two systems, and to create this connection bi-directionally. The closest way to this request is to install a Moodle plug-in, but here other problems rise, related with the enormous amount of plugins from different sources of different quality, their reliability and stability in case of version change, the overlapping of functionalities among different plugins, the availability of more plugins for the same function etc. Even the simple change of the layout of a page, or of some pages of a certain service, or modifying some dashboards becomes complex, available only to seasoned developers with core competences in Moodle and with a deep knowledge of what will happen if that feature will be changed. Again, it is very well known, and also comprehensible from the perspective of Moodle's maintenance team, that in order to avoid instability and incompatibility situations, there are many roadblocks to (even) modest customization, forcing you substantially to consider the forking of the entire platform as an alternative. Forking is the very last resort for any institution, and the main reason why our "Online Communities" platform found some believers is mainly in this point.

Respect to this limitation in customization, another element could be considered positive in some contexts, but negative for other contexts. This could be label as "boring uniformity", in the sense that most of the institutions that adopt Moodle are stuck with the same layout Moodle provides in the default installation, and any deeper customization of the layout finds the same roadblocks seen before. This leads to a "boring" uniformity of most of the Moodle installation: the authors' never found a person that said "I change my University because I found the same Moodle".

There are many other issues that could be found, like in all software platforms, but this discussion does not want to appear like a demolition of one of the milestones of Technology-enhanced learning (TEL) like Moodle. The argumentation deals with the empty spaces left by the approach carried out by Moodle (and similar platforms) respect to a significant part of the TEL market, where there is a need of new services customized to implement new educational processes and approaches, and on the other side to connect the LMS with the rest of the Information system.

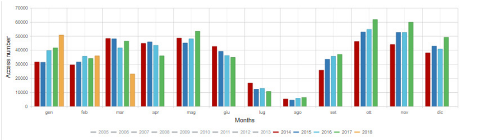
IV. LEARNING ENVIRONMENTS AND INFORMATION SYSTEM

After having presented the issues related with some approaches to LMS and their implementation, the central aspect of this paper deals with the relation between LMS and more general information systems of educational institutions. As previously stated, e-Learning platforms seem to be built to act in a restricted circle made up of teachers, tutors and students. On the contrary, in our system the community is a container ready for didactic processes, but not only: research teams, recreation groups, friends, secretariats, board of directors, sport teams, colleagues, anything that could be an aggregation of people around a scope using virtual spaces on the web.

At present, considering only the instance of the system used by the University of Trento, there are more than 7.500 active communities, 16.000 active users and in 2017 almost 500.000 unique accesses has been achieved (see Figure 2).

The evolution that Online Communities is going through implies increased implementation complexities respect to "simple" LMS settings, considering that the differences between the two approaches refer at least to four dimensions.

The first dimension is a temporal dimension. The concept is amplified on larger spectrum, that is to say, the life of the subject, not necessarily dependent on standard educational path (high school or University). At the moment, on of the largest implementation of "Online Communities" manages all the educational tasks of the largest public body in our region, i.e., the Autonomous Province of Trento, with approx.. 20.000 employees, and thousands of online courses delivered every years. The interest of the Province is clearly a long-term interest, in the perspective of managing an "educational portfolio" of the employee, thus implementing a life-long learning platform.



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2018	50.896	36.086	23.194	0	0	0	0	0	0	0	0	0	110.176
2017	41.637	34.134	46.627	36.113	53.461	34.961	10.703	6.496	37.141	61.832	60.007	49.174	472.286
2016	39.851	35.817	41.765	43.692	48.138	36.276	12.943	5.859	35.914	54.923	52.857	40.901	448.936
2015	31.579	31.749	48.079	46.054	45.330	39.210	12.281	4.664	33.545	52.905	52.894	43.178	441.468
2014	31.789	29.694	48.586	44.926	48.607	42.731	16.639	5.424	25.831	46.424	44.115	38.224	422.990
2013	34.738	35.189	38.009	38.239	43.888	33.607	14.325	4.760	22.012	42.877	40.157	31.817	379.618
2012	40.755	40.245	46.494	34.213	44.114	32.273	13.921	4.945	23.053	45.498	39.551	33.756	398.818
2011	40.332	38.348	50.906	40.500	52.708	38.877	15.363	7.543	30.385	44.947	44.505	38.866	443.280
2010	24.592	37.789	44.017	36.870	41.071	38.942	14.186	6.307	26.883	42.269	41.676	36.099	390.701
2009	29.638	43.823	41.887	37.224	34.200	36.523	19.775	8.291	32.003	41.336	40.053	30.531	395.284
2008	42.563	34.947	34.913	43.748	33.086	30.825	19.176	5.498	30.962	41.047	42.819	31.528	391.112
2007	37.670	30.050	35.917	35.130	30.617	28.492	16.316	5.734	24.880	40.290	34.868	27.252	347.216
2006	28.245	22.680	33.656	36.087	28.154	26.827	18.646	5.096	25.201	37.403	36.122	26.395	324.512
2005	0	345	663	2.435	15.817	14.055	6.681	1.637	18.250	28.184	27.100	20.033	135.200

Figure 3. Online Communities accesses (14th march 2018)

A second dimension is the social dimension. The platform could be used in social contexts of totally diverse life-long learning settings, even in conflict with each other. Let us take as example subjects who, while interested in continuous learning, change the country of their residence, company where they work, training needs, etc. Not necessarily all the information contained in their educational portfolio are relevant for other stakeholders, or vice versa, they are very interesting for them but not the owner of the portfolio.

A third element is the spatial dimension. The place where the learner is conditions the modality of delivery of the educational contents. Let us think, for instance, at the various situated learning needs of a person responsible for maintenance, or a medical doctor when facing an emergency case, or a tourist in front of a work of art in a museum.

A final dimension, more complicated to analyse in this paper, is the anthropological one. The subject uses the platform in completely different life periods; starting with pre-school age until the end of working activity and, not to be excluded, even beyond. The problems linked to these aspects represent something extremely stimulating and yet unexplored, as it is clear (and first evidences are emerging) that our social and even mental behaviors are affected by technologies in general, and social media in particular.

The platform provides, as a set or core services, the "traditional" services provided but full-fledged Learning Management Systems: asynchronous services (like forum, agenda, upload & download of learning objects, newsgroup, notice-board, classroom and users' management, forums, blogs, wikis, FAQ etc.) and synchronous services (chat, streaming audio/video). Other than these, some customized services, closer to the aspects of life-long learning and "training on the job" (tutorship, training on demand, research tools with problem contextualization, ticketing tools etc.) have been developed for specific partners, like the Autonomous Province of Trento.

A second set of services relates with specific integration needs with external information systems (for example, the Personnel information system of the organization) and with the acquisition of forms for external enrolment of students to university's programs. These services have been developed for institutions that have a selection process of candidates, mainly for master degrees, doctoral schools of private business courses. The Chamber of Commerce of Trento, for example, through its associated training Academy, provides many courses to affiliated companies and institutions, and heavily uses these kind of services to process enrolment, subscription to courses and even payment of fees.

A third set of services provided by the platform regard the fruition of "off-line" courses, i.e., courses already held and recorded, digitalized and made available to controlled communities of users (with the possibility to synchronize the video with slides, podcast, webcast, SCORM modules, etc.). These services are more typical of Learning Management Systems, but the issues related to the integration with a SCORM player provided us the stimulus to develop our own "meta-SCORM" engine, a service call "educational path" where many issues related to size of SCORM packages and rigidity of SCORM standards have been overcome.

As a fourth group of services, services for the creation of evaluation tests, exams, self-evaluation tests, quizzes, polls etc. could be mentioned. Together with this set, personalized reports with statistics about the users' behavior have been developed, using an internal data warehouse enriched by activity logs that overcome some problems of traditional LMSs in extracting detailed information about user performances. These specialized, business intelligence-oriented services have been developed avoiding the creation of sophisticated charting tools (already available on the market), but focusing on providing detailed information about every action that the user is performing while interacting with all the services of the platform. This allows us to follow some requirements for internal certifications.

An important category of services has been added for managing the interactions among members of the community, like project management services, agenda organization, time management, tenders and respective application forms, etc. These are the services that continuously see additions, improvements, new requests etc.

Finally, a set of mobile services to support mobile learners are provided. There are some innovative services which meet the mobility needs of the subject who wants to learn "on the move", performing learning/collaboration activities directly through his/her mobile device (mobile phone, tablet PC, smartphones, phablets, etc.).

Type of Service	Services
Syncronous Communication	Chat; Webmeeting
Asyncronous Communication	Whiteboard; Forum; Memo; Mail management; WebCast, mini-sites
Presentation and Course Details	Teacher information; Users Gallery; Users CV; Community Cover; Course Diary; Course Organisation; Syllabus; Links
File Management	Upload; Download; File Management; SCORM Player; SCORM Management and Statistics, mini-sites
Events Management	Calendar (Personal and Community); Appointments; News, sticky notes
Activity Management	Call for thesis; Tasklist (Project Management), todo-list, ticketing, face-to-face booking
Collaboration and Web 2.0	Wiki; Blog; Workbooks; Exercises, FAQ, glossary
Test	Polls; Questionnaires; Test; Statistics

Figure 4. A partial list of services provided by "Online Communities

The platform is constantly extended with new services, coming from research projects, users requests and the results of our almost 20-years' experience in designing, developing, implementing and using e-Learning system (LMS), with a specific approach in mind. This approach is, in some sense, "against the current" of standardization and "normalization" of LMSs, in our opinion too flattened over these pre-defined, pre-designed software platforms. From our experimentation, it is clear that an e-learning platform is not an external system respect to the rest of the information systems, but it is a crucial component for any organization. When such a platform enters into an organization, its effects are immediately visible:

- needs for integration with sub-systems existing in the organization: just to mention the simplest ones, integration with the single-sign-on system implemented in the company;
- overlapping of some functionalities of LMS/Virtual communities' platform with pre-existing functionalities in the information system of the organization. Examples: document repository, mailing distribution, virtual room management, forum, etc.;
- Competition with possible new systems entering in the organization, mainly due to the web 2.0 functionalities that nowadays most of the companies intend to implement, and that normally any (serious) LMS is able to supply:
- partially overlapping and competition with some functionalities already present, somewhere in some software.

These are the most insidious aspects, because none of the systems (LMS and other information systems) are able to satisfy the specific needs, but all of them are able in some way to supply part of the functionalities needed. The typical example found in the authors' experience is the support to document sharing for groups of people without having to mount some network disk for file sharing, normally not appreciated by system administrators, and most of the time not accessible via web. In this case, virtual communities are better candidates, as the on-the-fly creation of a virtual community with a set of services available for the members is a perfect solution for many of these situations, not necessarily related with educational activities.

The last example is what mainly led us, in 1998, to build a new system with virtual communities as the center of our approach. At the time, Moodle™ or similar LMSs did not exist or were not accessible to most of the people, and other solutions were particularly expensive, proprietary or not available. In our vision, a virtual community is a (virtual) space of aggregation for participants, thus supporting cooperative activities among users instead of just learning activities.

As previously stated, our platform has been created to be adapted and connected to the information system of the organization. Considering e-learning and collaboration platforms as external bodies, relegated to secondary roles inside the information system, is in our opinion losing an excellent opportunity to improve collaboration and open innovation inside an organization.

Integrating eLearning systems with existing information systems is not an easy task, mainly due to some resistance and ostracism against learning applications that are seen as not relevant for the organization by the ICT departments. Other difficulties come from the technical side, due to the diversity in these systems.

Universities are using LMS mainly for issuing educational services, but many other services could be provided, expanding the role of LMS more towards information systems and collaborative platforms. It becomes essential to have advanced tools to support activities that often are not limited to training, but that widen the horizon in different contexts in which the availability of a web-based software platform is not only a big help, but an essential element to reduce space and time barriers and enable collaboration "anytime - anywhere" so much desired by the digitalized institution.

In these contexts, limiting LMSs to educational services, limitations of the conceptual and engineering nature of training processes will have to be faced. What is the authors' experience is the need of new tools and services for the educational tasks that expand the idea of training activities to the more general collaborative activities: A non-exhaustive list of these activities found very profitable if integrated in a LMS follows:

- time management at different levels of implementation: calendars, event planning, meeting management etc.
- project management, where projects can be managed with their tasks, durations, critical path, constraints, resources etc. This is profitably integrated with core services provided by the platform, like the file repository (for attaching documents to tasks and resources), forums (to discuss topics about a task with resources assigned to it), or the decision support system, for example for supporting the qualification of a duration through the interaction among experts using a multi-criteria, multi-expert fuzzy algorithm;
- processes related to support decisions in different educational contexts (exam, vote, polls, questionnaires, community participation, group democracy etc.)
- enrolment services in different situations, from enrolling in a course to a single lab session, from organizing a walk with classmate to enrol in a serious game session

Similarly, with the increase of complexity of educational activities, tools for collaboration are becoming increasingly central, like sharing and distributed decision support systems within learning communities. This is the first example described as a significant moment of integration between LMS and other technologies that normally are not available in mainstream platforms.

V. DECISION SUPPORT SYSTEMS AND LMSS

In this section, a module of the platform that provides functionalities added in order to provide support to one of a partner, the local Developing Agency (Trentino Sviluppo S.p.A.) is presented. In e-learning settings, the evaluation of different alternatives regarding learning paths' proposal is nowadays crucial, due to the great attention devoted to the construction of learning objects (LO) available through Learning Management Systems (LMS). Learning processes are normally implemented through the interaction of the learner with a LMS and, in some cases, through the usage of learning, or e-learning, paths. A learning path, as referred inside a LMS, is represented by a set of LO mixed with other tools and services available in the LMS, like questionnaires, forums, wikis, FAQ etc. This combination of information chunks and services is devoted to obtain the educational objectives defined by an instructional designer.

While testing large scale implementation of virtual community systems, authors noticed that SCORM objects and pre-defined learning paths, are more and more important in educational settings today. The market is responding to this request, thanks to adequate technologies for the design, realization and delivery of these pre-constructed educational tools. SCORM packages themselves, if well designed, could be self-consistent learning paths. According to this scenario, educational institutions and specifically the industry rather than academy, are very often in front of the process of evaluating different possible learning paths, composed by different learning objects, composing different contents and representing different approaches and responses to the educational needs stated by the educational stakeholders. The criteria for choosing which alternative better fits with these needs are most of the time based on simple considerations (mainly cost of the learning objects), taken by people with no complete view of different aspects of the learning paths, not taking into consideration all the aspects that should be needed for such an important step.

E-learning has many advantages, but for sure the best application field of its pros is in presence of large numbers of users, where a wrong choice about the learning path to be offered could have serious consequences. In order to support the decision making process aiming at selecting the most suitable e-learning path(s), a multi-attribute, multi-expert model has been introduced, where several attributes are used for evaluating different e-learning paths, according to the rankings expressed by a group of experts. Then, a consensus modelling mechanism is introduced to find an agreement among the individual rankings. The multi-attribute evaluation is based on fuzzy TOPSIS while the consensual ranking is obtained through a constrained optimization model. Fuzzy logic in e-learning has been used according to different perspectives. Some fuzzy approaches to e-learning have been presented in [3], where fuzzy logic has been applied to the identification of e-learning design requirements and to select the most suitable e-learning service provider. Other approaches [4] use fuzzy inference to analyze students' way of working and group's behavior, while in other research areas fuzzy logic has been used to improve search capabilities of Learning Management Systems (LMSs) [5]. In the field of evaluation, under different perspectives the application of fuzzy logic to the evaluation of students' performances according to their profile [6], or to an evaluation teaching systems' quality [7] has been applied.

The same mechanism and the same attributes, or variations of them, can be applied to a different granularity of objects inside our platform. For example, very frequently in e-learning settings a teacher can use collaborative tools like forums or wikis to discuss over a topic. The comments of the users are often summarized or even pointed as "the best", the most representative response to the original post even coming from participants in form of a question. The provided model could be applied also inside these contexts, where a panel of experts (teachers, students or a mix of them) could evaluate the different alternatives (the different answers to a question) expressing linguistic values in correspondence of pre-defined appropriate vocabulary of linguistic labels for the attributes. In our opinion, e-learning systems (and virtual community systems) will need these extensions that go in the direction of cognitive computing, thus transforming the e-learning, passive environment (where actors simply download slide-ware) into an intelligente cognitive system able to support us in decisions related with our daily life, education included.

VI. CONCLUSIONS

The paper presented our point of view respect to the current state of evolution of LMSs, specifically their capabilities of reacting to new stimulus from end-users that require a deeper integration with the hosting information system. Our view is that customized platforms could perform largely better in these context rather than general purpose LMS. The research will be expanded with some extra comparison, but the empirical evidences collected so far seem to confirm that, when learning processes are not isolated islands inside the information system but core component of internal processes, LMSs provide a much higher rigidity and total cost of ownership. On the contrary, a customized platform, where the source code has been developed internally, could have its' Return on Investment exactly in these situations, furthermore providing extra advantages like seamless integration with the rest of the information system, greater customization capabilities and a much higher flexibility in adapting educational processes to the changing organizational needs.

Looking onwards, it rarely happens that we will witness a radical change in technology and business. It typically happens every 25 years or so, and it's happening now. What this will entail is mainly related with exponential learning, a process of exponential growth of training demand because new knowledge and skills must be delivered at a speed never seen before (see Industry 4.0 but also other community programs, cognitive managers, cognitive architecture engineers, cognitive system programming, etc.). So the paradigm should be extended, shifting from classrooms to communities, talking no longer of men *or* machines, but men *and* machines, then the technology will be an appendix extending the learning processes of individuals, enhancing their faculties and assisting them in the transformation of skills. This will happen through the definition, design and use of cognitive services that can be implemented in a platform like the one presented in this paper, that has already acquired and historicized its big data, but will have to offer a new set of cognitive services. We will be forced to respect two fundamental constraints: time and content, with contents that will have to be ready within the time learners will need them. Probably the services will be profiled for different users levels, such as learning professional and learning business consumer. We are on a turning point of training processes, a very challenging and important moment in which cognitive approaches will transform everything, and e-learning processes and platforms are not excluded.

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Learning Management Systems and the Integration with Social Media Services: A Case Study

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Learning Management Systems and the integration with social media services: a case study

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Abstract—The paper presents the experience of the author in designing, implementing and managing technology-enhanced learning settings of different nature, from high-school students to University students, to professional participants to blended courses and finally to public servants changing their traditional way of having life-long learning sessions. The common factor is a virtual community platform, called "Online Communities", that has been created from scratch in 1998 with the primordial idea of virtual communities and social interaction among different participants with different roles. In the paper, the role of social media-related services in the platform will be presented, together with some practical results derived from the comparison between educational services provided by social media, and social media services provided by e-Learning platform.

Keywords—Learning Management Systems, social media, virtual communities

I. Introduction

This paper presents a long-term experience as designer, manager and administrator of an e-Learning system (Learning Management System) used by the University of Trento. Since 1998, the self-built LMS has been devoted to the creation of virtual spaces for collaboration and interactions among participants, taking the final name of "Online Communities". Among the many services devoted to training settings, we managed the evolution of the system towards the provision of services and features oriented towards the interaction among participants within any virtual community created in the platform. This approach is, before its time, quite similar to the Web 2.0 and social media interaction spaces. Then after 2004 we started to see the incredible phenomenon of social media as we all know it, from Myspace to Second Life to Facebook and the rest.

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The incredible capacity of these social tools to attract the attention for any kind of social implications for our lives did not ignore the e-Learning world. In very short time, many teachers and educational organizations decide to integrate, if not to substitute their e-Learning tools with social media surrogates, more or less covering the educational needs, and the needs of appearing modern and "a la page" of most of us as educators.
While moving in this confusion of media, approaches and platforms, we had to face all the problems related to the integration of two different logics into a single environment (learning spaces and social media):

- A first problem was related with the creation / replication of features appreciated by users in the social media platforms. Not all these features, indeed, were useful for educational settings, but were perceived as a sort of "modernity" of the Learning Management System (LMS). If you did not have them, your platform was an outdated piece of software
- A second group of problems were the colleagues (teachers) fascinated by the quality, variety of service, quantity of stimulus and extensibility of social network platforms. Indeed, they decided to stop using whatever LMS the educational institution was providing, and moved all the materials and interactions with students using the social media (mainly Facebook). This has created a following problem, i.e., the loss of control of what was happening inside the institution in the e-Learning domain, with many autonomous and uncoordinated initiatives that, although they were an undoubtable enrichment of the discussion about technology-enhanced learning and social media, on the other hand they created a lot of confusion and misalignment of educational approaches and supports for students.
- A third problem, we had people that decided to use social media for what they are not, i.e., educational tools. Sophisticated questionnaires with automatic composition of tests, or SCORM-based learning objects, these are just two examples where a "fundamentalist" approach to omni-comprehensive usage of social media had some bad effect on the quality of the educational processes. Moreover, for different reasons, not everyone is comfortable turning their students lose on omnivorous social media like Facebook or Twitter.

- Last problem was related with those educators that decided to *ignore* social media for some specific educational settings. To ignore social dynamics inside technology-enhanced learning seems to be at least anachronistic nowadays.

Even in the presence of this variety of situations in the adoption of social media inside educational settings, we decided to extend our developed solution, named "On Line Communities" (OLC), with some ideas and services taken from social media world, but we especially customized existing tools of OLC in such a way that they could be comparable with some social media platforms' features. The system in its wholeness provides the idea of virtual spaces of collaboration and interaction, called "communities", as pillars of the interaction mechanisms among users. This revealed, in our opinion, on one side the limitations of traditional LMSs that were approaching new challenges emerging from social media with old solutions and metaphors heavily anchored to the idea of "class" instead of community, and on the other side the inappropriateness of social media to support educational activities.

When we enter into the problem of using computers in social network, we are somehow related with the theme of Computer Supported Collaborative Work. This topic has been widely debated [2] [3] [4], especially in the last decade. This area studies the idea of using ICT tools to perform and coordinate (collaborative) workgroup activities. One of the variations of this approach focuses on training, especially on e-Learning; in this case we talk about Computer Supported Collaborative Learning (CSCL). Many different pedagogical approaches to different disciplines require new approaches like learning by doing, learning by project, etc.: in these contexts, e-Learning systems with functionalities supporting cooperation and collaboration are very useful. The integration of e-Learning platforms and social media is closely related to the world of collaboration mediated by ICT (Computer-Supported Cooperative Work - CSCW). Thanks to the social earthquake represented Facebook®, Twitter®, Whatsapp®, Youtube® etc., the world of e-Learning needs to consider the expectation of users due to the social interaction that today is so common even in workplaces [1]: so we have three different needs (learning, managing tasks, collaboration) that hopefully should converge to one single platform, in order to avoid the use of many different platforms when the need is unified.

The paper will analyze the types of integration / modification that have been applied to a LMSs in order to get closer to social media services, evaluating through an empirical analysis the services provided by the two platforms (e-Learning, social media) and their impact on educational processes. The following chapter will deal with e-Learning and collaboration, where mechanisms similar to social network could be found. In the third chapter the connection of e-Learning and social media will be presented referring to the OLC implementation, while in the fourth chapter the empirical comparison between the most famous social network (Facebook) functionalities and what is provided by an LMS like OLC will be discussed.

2. E-LEARNING AND COLLABORATION

E-Learning became so popular thanks to many factors, like network availability, multimedia, increased power of client workstations, flexibility, low costs etc., but the role of software platforms like Moodle™, Docebo™, Dokeus™, Sakay™, Webct™ is clearly a central role. Web 2.0 and other collaborative paradigms (like social media or systems that support decisions) have become very popular among users, thus creating similar expectations in the educational fields. The evolution of distance learning sees the phenomenon of Massive Open Online Courses (MOOCs) and the respective platforms to manage them (like Coursera, EDX, Udacity etc.), where the massive inclusion of people into prestigious e-Learning paths is a great example of what technologies can do today. At the same time, this raises some questions about how software services can improve the educational experience of millions of users from all over the worlds. Usability, manageability, responsiveness, performance, scalability, modularity, just to mention some of the challenges this category of software is facing nowadays.

From a meta-architectural point of view, e-Learning platforms have based their pillars on the idea of "course", or "class", meaning that the basic container where relationships among users can be developed is a virtual place that resembles in some way what happens in any educational organization: collecting people in a (virtual) classroom. From our perspective, what clearly emerged from the evolution of latest years' educational settings and from our preliminary experiments, is the need of a different funding paradigm for software platform: the "community", or "virtual community".

In [7], Rheingold defined virtual communities as social aggregations that emerge from the Internet when enough people carry on public discussions long enough and with sufficient human feeling to form webs of personal relationships in cyberspace. In the implementation we created in our LMS, a virtual community is a container ready for didactic processes, but not only: anything that could be an aggregation of people around a scope using virtual spaces on the web like research teams, recreation groups, friends, secretariats, board of directors, colleagues etc. The core of the application is composed by some abstract entities, i.e., virtual communities as aggregation of people to which some services are available in order to obtain certain objectives.

"OnLine Communities" is the name of the web platform we started to create back in 1998 [8]. It is a web application devoted to pursue collaboration objectives, populated by people who communicate among each other, using a series of communication systems. The main characteristics of a virtual community could be summed up as follows:

- each community avails itself of a certain number of services
- services are embedded applications that enable the users to publish contents, exchange files, coordinate events, communicate in synchronous and asynchronous way etc.
- the potential services of a community are activated

by a manager of the community according to the needs, and the users of a community can use them with different rights and duties

- the communities can be aggregated into larger communities with hierarchic mechanisms and infinite nesting levels, but also in an arbitrary way into larger communities disregarding the possible position of a hierarchical structure
- all users are registered and no anonymous access is allowed

The complexity of managing virtual communities is objectively quite different from managing a course. It requires a different approach also in the management of roles/permissions related to people and role/permissions related to the service available. The building blocks of the platform are five classes: person, community, role, permission and profile, which is the combination of the roles and permissions for each user. The addition of some time-related services (like a full-fledged Project Management module with the implementation of the Critical Path Method – CPM) required to add the extra class "events", under which tasks and any other time-related object are managed. The interesting perspectives opened up by this paradigm shift are multifaceted:

A) Collaboration tasks are recognized as crucial in companies, and they share many services with educational tasks: for example, sharing files, aggregating people, sending emails, managing agendas, posting on forums etc. All these services are common to both environments, training and collaboration, very often duplicated in different platforms but substantially delivering the same (software) service to stakeholders

B) ICT teams tend to provide different solutions for similar problems: e-Learning is normally seen as something separated from the rest of the information system, not to be integrated. On the contrary, e-Learning platforms benefit from an integration with the rest of the information system in many aspects, from authentication to Human Resources integration, from social network integration to accounting, from directory services integration to email services etc.

C) Traditional LMSs, like Moodle™, are not easily adaptable to these needs, mainly because they are oriented to e-Learning, and their pillars are metaphors like "classroom", "class", "course", rather than other ideas more oriented to collaboration, like "community", "group", "team", "secretary", "board", "office", "department". The metaphor of "course" is not able to cover all the interactions that may take place within working groups, aggregative and collaborative structures that we define "virtual communities".

D) Social media like Facebook, Twitter, Youtube, etc. are not suitable for companies to solve these needs of internal collaboration and educational needs, as their large numbers and main objectives are not allowing small, "private" communities where collaboration can take place in a private, reserved, personalized space. The main objective of social media is "the more we are, the more we will interact", following very well-known multiplication laws like David Reed's law. The problem in this context is that this is not exactly what a company, or a public institution wants in most of the settings.

All these considerations are a perspective of evolution, if not a radical change, inside the architecture of software platforms for e-Learning, leading them to conquer others' prerogatives like collaboration spaces, videoconferencing, decision support systems, time/process/project management etc.

All these new topics for e-Learning blur the distinction between a collaboration process that is mainly unbalanced, i.e., the relationship between the teacher and the learner. It opens, on one side, a richer set of approaches to educational tasks, more devoted to collaboration and support to decision processes. On the other side, it changes the market perspectives of software platforms and even of information systems, where legacy and data-oriented applications are leaving the floor to software systems that manage unstructured data and informal knowledge, cooperation, collaboration and decision-making.

Given that a most detailed list of functionalities is beyond the aim of this paper, OLC supplies a series of articulated functionalities which we prefer to call 'services':

- 'Traditional' services: asynchronous (forum, agenda, upload and download of learning objects, newsgroup, notice-board, classroom management, management of course pamphlets and of users, etc.) and synchronous ones (chat).
- Integration services with external information systems (for example, the personnel information system of the organisation).
- Services for the fruition of 'offline' courses, i.e., courses already held and recorded, digitalised and made available to controlled communities of users (with the possibility to synchronise the video with slides using a webcast service SCORM compatible).
- Services for the creation of evaluation test, quizzes, polls etc.
- Statistics about the users' behaviour (using an internal data warehouse enriched by activity logs).
- Mobile services to support mobile learners, performing learning/collaboration activities directly through their mobile device.
- Support services for cooperative and collaborative online learning, i.e., services for sharing knowledge on a certain topic useful for collaborative learning (group learning that stems from the sharing of individual knowledge within the group itself) as well as for cooperative learning (group learning that stems from sharing tasks). For example, within this category we can list services such as blogging and wiki.

3. E-LEARNING AND SOCIAL MEDIA INTEGRATION: IS THAT EASY?

The early formulations of the concept of e-Learning 2.0

and its first implementations represented an attempt to replicate what online social media provide, like personal pages, walls, galleries of personal pictures, "friends". Curiously, while these networks were called "social", they had at the very center the subject, the individual, and what they created is a virtual world with a single subject at the center, and the social network looking at him/her. Even when providing LMSs with similar services, participants demonstrated their indifference, intolerance in using these services, or sometimes even the refuse to act on them. The lighter criticism was, as expected, "why should we use this if we already have….(one of the different online social media available)?". Probably, the question should be set in the opposite direction: why should we use a LMS instead of creating (for example) a Facebook page for the course?

After a period of usage of facilities comparable to e-Learning services inside a social network [9], students started to realize the separation between the two worlds. They started to suffer publication of common works, sort of being ashamed about their performance during exercises or workgroups. They were very reluctant to participate to discussion, even non-moderated discussions and they do not even publish their picture in the profile, because "they do not want to appear in the gallery of the community". In fig.1, you can see an example of a community of a course managed by OLC, were there is only one picture available for members' profile, the one of the teacher.

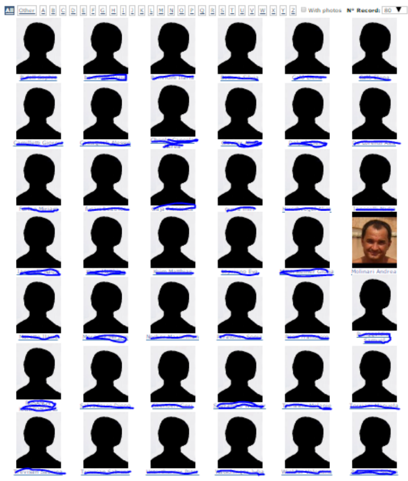

Fig1. Example of profile pictures in a community

Without forcing participants to upload their picture profile, in OLC only 2.4% of students have uploaded their picture profile, while we know that on social media, posting picture is one of the main reason for traffic and bandwidth allocation.

In general, many non-structured experiments of using social media in place of an LMS has been applied. But also this part has not been very successful in our experience. OLC at the moment is managing approx. 16.000 enrolled students (more than 35.000 with the graduated ones) and more than 5.000 live communities. Less than 0,5% of these communities have also a Facebook associated page, some colleagues started recently to attach a Whatsapp community, and very few others tried to use other parallel tools like WordPress, Myspace, Twitter accounts or similar options. The clear mental and cultural separation between the educational moment and the recreational, real-life, personal moment had a sort of revenge against the quick-and-dirty solution "let's use Facebook for our course": social media for fun, boring LMSs for learning. At the end of this winding awareness process, even if less sexy than using a famous social network, the LMS has been preferred and used along the course.

With a qualitative analysis conducted on 94 students and 24 teachers, the final motivation to prefer internal LMS services respect to social media was the integration with the rest of the Information System of the University: sharing calendars, single sign-on, dates of exams, virtual communities' services more specific than simple file repository. Another crucial factor that should be mentioned separately has been the use of SCORM-based learning objects: clearly, the availability of SCORM player connected with the e-Learning platform allowed them to sustain some intermediate parts of the course without having to switch platform, especially for the intermediate results.

In [1] authors suggest that cultural differences and the education system is a crucial factor in the use of social media as an online learning tool. In our university, we have students from many different countries, especially from Europe and East-Asia, but we cannot confirm this conviction of cultural differences.

Following these findings, trying to promote and improve OLC in order to include the best-of-breed services from social media, many drastic changes have been introduced into the platform, moving the focus from "community" to "user". As an example, when the user connects to the system, the user' personal home page and its services are presented, trying to create a personal learning space. Each user now has the opportunity to access to his/her personal page, which will contain personalized services. As a result, some interesting new services can be provided, for example:

1. access to communities where the user was registered;
2. view the most used services by each user;
3. access to contextual services for each community;
4. access to the personalized services;
5. add some services into the personal learning area.

At the end of the profound change in the services provided by OLC, we can now take out some considerations about final results, and the differences between these two worlds.

4. SOCIAL MEDIA AND LMS: OUR EXPERIENCE

As said, when decided to implement a "social network strategy" inside OLC, we had three choices in front of us, with pros and cons:

- Using social media as whole platform, dismissing OLC (or any other LMS)
  - PRO: great features, zero-time education for students, familiarity, no costs, no login /registration / access problems
  - CONS: no specific features for education, lot of unneeded features, dispersion of effort in another platform, some analytics specific for educational settings missing, full integration with institution's Information System, SCORM-based learning objects not usable
- Using OLC and social media together, each one for the best things available
  - PRO: best of both worlds, students probably more interested, sense of modernity to stakeholders, autonomy, customization for special needs, full integration with the institution's Information System
  - CONS: cost related to continuous switching contexts for students and teachers, confusion of roles and functionalities, overlapping of some functionalities, migration of data between the two environments when needed
- Encapsulate social media functionalities inside OLC
  - PRO: integrated view of services, integration with IS, one-platform-does-it-all, availability of logs, just-what-you-need functionalities from social media, best of both worlds, autonomy from social media dominance, availability of all data
  - CONS: students feel observed, not natural, social media features are much more tested, no contacts with outside world, cost and time for the implementation,

To complete the study, at the end of the process of adapting / enriching OLC with social media services, we provide preliminary, empirical evidences of the results derived from this integration. The following table compares the feature of the most famous social network used in educational contexts, Facebook™, with a comparable feature of our OLC platform. The column "Facebook Services" is taken from [6].

Clearly, there is an immense difference in terms of investments, end users involved and quality of the different features between the two situation, a sort of "David against Goliath" comparison, but the attempt is to clarify what functionalities are missing in an evolved LMS like "Online Communities" respect to top-notch social network platform. The idea is to understand which features an LMS should guarantee in order to compete, at least in the sense of "having the functionality" with world-wide, big players of the social media. In this table elaborated by the author, the column "judgement" is expressed respect to the usability of that feature in educational contexts, and it is absolutely an empirical evaluation, comments and feedback received in the past ten years this process of integration has been started. It is neither a technical nor a usability / aesthetic judgement of the feature, but refers to the availability of the feature and whether it is more or less adequate to educational settings. A positive or double positive value (+ or ++) is assigned when OLC has a feature that performed better in educational contexts respect to FB, an "==" when features (again, from an educational perspective) are more or less equivalent (teachers can do what they need or what is didactically valid), and finally is a negative or double negative when FB has a better feature, or a feature than our LMS does not present. Two final considerations:

- The label "Not relevant for education" refers to features in FB that are completely of out scope for educational context
- We have not evaluated all the features that are present in OLC, but not in FB. The scope of the empirical analysis was mono-directional, i.e. features from social media that are available in LMSs

5. CONCLUSIONS

In this paper, we described our experience in the design and implementation of a set of services for the management of activities within a virtual communities' platform that have some parallelism with what we do every day when using social media. In particular, we wanted to highlight how a modern LMS should provide features inherited, or simply copied by social media interaction style, but at the same time should customize and actualize these features into educational contexts. The paper presents first empiric results of an adaption work that started in 1998 with the creation of a LMS based on the metaphor of "virtual community", a sort of forefather of modern social media. Along the years, with many practical implementations of this platform in academic and industrial settings, with more than 150.000 users registered in these different contexts, we have accumulated an interesting spectrum of suggestions. First of all, it seems that for educational settings, LMSs enriched with specific features from social media are better than adaptions / customizations of social media for educational settings. Second, services in social media platform are by far better and usable than those available in LMSs, but less profitable for educational purposes. A very nice service like the wall (in FaceBook) is surely more charming for personal / recreational usage, but probably a less attractive but more effective service like a specific "educational path" service is more effective for learners. Third, LMSs should not delegate social tasks inside educational contexts to external platforms like social media: an integrated educational setting seems to be more efficient (even though less attractive) for learners, that probably don't want to be distracted by many disturbing elements when working on their training tasks. Next steps of this research are clearly oriented towards providing more quantitative analysis with structured interviews and lab sessions with side-to-side comparison.

Facebook services	Online Communities	Judgement
Facebook structure		
News Feed	News (customized per learning object, all the features and filters)	+
Friends	Community members	-
Wall	Educational Path Various history views in the different services	+
Timeline	Not that nice… – just educational events	--
Reactions	Specific forums and discussion services defined by the community admin	==
Messages and inbox	Whiteboard	==
Notifications	Notifications	==
Groups	Communities	++
Applications		
Events	Calendar, Agenda	-
Marketplace	Not relevant for education	n.a.
Notes	Notes	--
Places	"What Are You Studying" service	+
Platform	Application Program Interface	-
Facebook Questions	Questionnaires, polls, self-evaluation and similar services	++
Photos	File upload	--
Videos	Video features / SCORM	+
Facebook Paper	Blog	-
Facebook Mentions	Upload services	==
General features		
Facebook dynamic text/type	Accessibility features and skins	-
Credits	Not relevant for education	n.a.
Feature phones	Mobile version still in its infancy	--
Graph Search	Semantic technologies extensions (on the way)	--
IPv6	Not relevant for education	n.a.
Listen with Friends	Not relevant for education	n.a.
Live streaming	Video Conference services with streaming features	-
Mood faces	Not relevant for education	n.a.
Phone	Mobile version still in its infancy	--
Poke	Sticky notes services, to be expanded	-
Smartphone integration	Counting on mobile browsers	--
Subscribe	Sophisticated and multi-situation subscription features, like massive enrollments	++
Ticker	Ticker	==
URL shortener	Not relevant for education	n.a.
Verified Accounts	Not relevant for education	n.a.
Hash tagging Feature	Trivial internal search engine	--
"Say Thanks"	Not relevant for education	n.a.
Impressum	Not relevant for education	n.a.
Call to action button	Not relevant for education	n.a.

Table 1: empirical comparison between FB and OLC features

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Big Data and the Impact on E-Learning Platforms: A Case Study

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BIG DATA AND THE IMPACT ON E-LEARNING PLATFORM: A CASE STUDY

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The paper presents our experience in designing and implementing a mechanism to refactor the persistence layer of our virtual learning platform, named "Online Communities", in the perspective of collecting volumes of data compatible with big data tools and technologies. We will discuss the architectural and software solutions planned and experimented inside our virtual communities' platform to start moving towards the big data field, with an explanation of the technologies chosen, the changes in the architecture of the application, and the (big data) analytic tool for the real time analysis of users performances, while highlighting some related issues.

Keywords: e-learning, big data, LMS architecture

1 INTRODUCTION

In the past, various "waves" of attention and "hype" on technologies and solutions were related to Technology Enhanced Learning (TEL). Many of these hypes have revealed to be simply another buzzword, and have not been consolidated. Today's buzzword that has just started appearing in TEL is Big Data. The term refers to the huge amount of data coming from different data sources that becomes too large, complex and dynamic for any conventional data tools to capture, store, manage and analyse.

Big data approaches and technologies interest many different application fields, as an answer to the problem of managing what has been called "data deluge". The research activities in big data are aimed to find faster and more scalable solutions to store and process all data collected, instead of using traditional data warehousing approaches that are expensive, hard to design and to implement. Big data introduce two issues: how to address the problem of storing such a huge amount of data, and how analytics tools could be created for the problem of analysing these huge datasets, trying to find faster and more scalable solutions to store and process all data collected.

Characteristics of big data have been clearly identified through the "5 Vs" model, but nevertheless today many researchers and IT specialists are connecting this buzzword to any traditional database-oriented application with a (even remote) possibility of becoming "big". This could imply one risk: using traditional, relational DBMS tools and techniques could help the application to survive and even to be much less complicated than a "big data-aware" application, but in case of scaling to a real big data scenario, the application could fail and create a lot of issues, even if considering only its refactoring.

Since 1998 we have developed a Virtual Communities platform that aims at supporting collaborative and cooperative processes, thus being used also in the e-learning context. After 2005, according to the needs of some large public administrations, we started to consider the perspective of life-long learning, and the implications of this on the architectural design of the platform itself. With approx. 150.000 potential users and an average 6.000 unique accesses per day, the virtual communities platform is a fully operational large-scale application, with more than 500 tables in the relational persistence layers, and around four million lines of codes. This requires a great attention in terms of business continuity and performances when new customers or services are added. For example, life-long learning services evolved towards two main application fields: employees tracking records and post-SCORM educational paths [22]. Especially the second service, that we called "educational path", is collecting a lot of data regarding user's performances, but especially regarding user's actions.

User's actions are fine-grained set of logs regarding everything of relevance that the user does while interacting with the platform's objects and services. Originally, this meta-log service (other than what is already provided by the web application server) was created in order to avoid contestations from the employees. There were some behaviours associated with the certification of mandatory training that pushed the Public Administration to introduce extra logs in order to avoid discussions with "smart" employees. So logs became even bigger, from clicks and users' actions to logs of the SCORM player to logs of the educational path service itself.

User's actions have been our first point of contact with the world of big data: in the first version of the system, we used data warehouse – OLAP technologies. Other than cost of licenses and issues related with power users, it was clear that by using a state-of-the-art analytical tool, we could have reached the limits of the funding technologies of the platform, mostly related with scalability aspects. Thus we decided to consider new perspective in large datasets processing, meaning extraction, transformation and loading (ETL - extraction, transformation and loading) of this data into a convenient knowledge base, where this data could be supplied to decision makers through an analytic tool. This implied a radical change in the architecture of the application and the funding technologies especially (if not exclusively) in the persistence layer.

The paper will present our experience in designing and implementing this mechanism to refactor the persistence layer of our virtual learning platform, named "Online Communities". The experience of the authors has been in the direction of managing in a different way those flushes of data from the persistence of the virtual learning platform created for managing tens of thousands users in our region, both from Academy and Industry. After the design of the solution, we have implemented a traditional internal method for managing the first data source for big data, i.e., dedicated logs of the platform. With a potential of 150.000 users, the volume at the moment is still in the range of a high-end, non-critical database application, with approximately ten of thousand users using every day the platform for their e-learning tasks. When we added SCORM logging, the problem started to become much more complex. Furthermore, SCORM was not enough for some educational paths, especially outside University courses, and being aware of the limitations of the SCORM standard, we decided to implement a meta-SCORM service, that we called "educational paths". This service, in turn, increased noticeably the volume of data collected by our log services. Finally, mobile logging and specific actions on some services demonstrated the risks related to a traditional, DBMS-oriented persistence layer that should manage streams of data that are compatible with big data.

The paper will present a review of significant papers in the field of big data applied to Technology Enhanced Learning. The following chapter will present the test bed where we experimented the use of big data in e-learning, our self-made virtual communities platform called "Online Communities". The four chapter will summarize our experience in the integration of big data enabled technologies in the above settings.

2 BIG DATA AND TEL: STATE OF THE ART

Looking at the research field about big data and TEL, even if big data deals with the persistence of data generated by an application, the focus of researchers seems to ignore (to our knowledge) the architectural implications of big data on the software platform that should face big data scenarios. On the other hand, if we look at other application fields that imply big data approaches, there is clearly a great attention to these tools and technique due to the issues generated by the famous "5Vs" of big data (even 7 "Vs" for some observer like http://rob-livingstone.com/2013/06/big-data-or-black-hole/). In particular, of the different "Vs", these three are relevant for our argumentation:

- "Volume": it's exactly what it sounds like, the incredible amount of data collected around the world in different application scenarios, from social media to data regarding flights, from Internet of things and their sensors to Walmart and wholesalers tasks.
- "Variety": deals with the various forms that data can take, from structured tabular data, to unstructured data containing texts, images, emails, videos, spreadsheets, streaming media, complex BLOB objects like SCORM packages etc.
- "Velocity": the speed of data collection inside the platform, that in big data is another serious issue for applications

These characteristics have clearly demonstrated that traditional persistence layers based on RDBMS are outdated and probably not scalable enough. "Too big, too fast, too hard" is a very good representation of the difficulties that the relational model and the respective implementation in RDBMS are suffering [18]. Even if there are evidences of multi-petabyte databases around the world, this might not be big enough for most of the massive, Internet of Things applications aforementioned. Unfortunately, open source DBMS solutions are still lagging behind big commercial systems in terms of scalability. In general, it's on the "fast" and "hard" fronts where the relational approach does not fare well. One of the most significant problems is the import of raw data coming from big data sources into the native representation in the relational schema, before data can be queried. This limits the ability to handle some type of data, for example streaming data, and even if the database community has widely studied this specific issues, it's clear that streaming data do not fit well into the relational approach. If we translate this in the TEL field, most of the current Learning Management Systems (if not all of them) that are based on relational persistence layers, will clearly suffer if involved in big data-enabled contexts. A second order of problems comes from the support of engines respect to in-database statistics and modelling, again problematic because of massive quantities of data. In this case, massive parallelization of ETL algorithms would greatly help, but few cases are reported to have this attention of pre-processing data in preparation of analytical, decision-support oriented operations. Analytical tools such as SAS, R, or Matlab can support analysts with sophisticated functionalities, but again we have a scalability problem because most of the time these tools are limited to the working memory of the user's machine, and persistence tools have not these analysis methods out of the box [18]. In general, big data has stimulated a profound change in persistence architectures and tools, giving the floor to NOSQL technologies like columnar or graph databases, or frameworks like the Apache™ Hadoop® ecosystem. But the real question for the TEL is the following: do we really need big data technologies for e-learning settings, or is it just a way of climbing on the current ICT buzzword's bandwagon?

We had a closer look to the use cases of big data approaches and technologies in TEL. From an overlook of bibliography in the field, it seems that the focus of the current research in the field of big data for TEL is still in its infancy. The vast majority of the approaches and researches are focused on collecting data of learners' performance (whatever this could mean) and feed them is some analytical tool for educational decision makers at any level (from tutors to directors).

In [2], the author highlights 5 benefits of using big data inside e-learning contexts:

- Evaluation of courses' efficiency: data analysis allows to identify the type of teaching that is more effective for the objectives of the course of problem.
- Identification of areas for improvement of the educational activity: imagine to have a detailed log of uses of SCORM learning objects, in order to see why many students are taking too long to complete a module or task, and the implication on the re-design of the educational content according to this results. Large masses of users (like in Massive Open Online Courses) that use many SCORM objects and a system that records every mouse move, click and action on the object (for example, for a medical course), could quickly generate big data compatible data streams.
- Analysis of Web 2.0 / Learning 2.0 interaction of users in presence of social learning activities, with all the analytics deriving by this interaction.
- Information (detailed or aggregated) about the use of the educational path are immediately available, thus having a real-time (or nearly real-time) dashboard to control the situation on the courses, without waiting for the results of assessment tests where normally is too late for remedies..
- Based on these analysis, course designers could personalise courses according to students' performances, in a sort of prediction about the successes and failures of learners.

The main benefits of the collection and analysis of Big Data in e-learning, are mainly related with the possibility of obtaining useful information from this analysis in order to customize the learning experience based on the needs and learning styles of learners. Most of the bibliography of big data and TEL can therefore be labelled as "big data for learning analytics".

Learning analytics is the analysis of data coming from educational tasks performed by the learner, in order teachers, course designers and administrators of virtual learning environments to find unobserved and unpredicted patterns and infer new information for improving learning processes. So the main aim of learning analytics is to improve the learning experience and performance in blended or full-online courses. In [4], where an explanation of learning analytics is presented, the most basic unit of data for learning analytics is considered to be the "interaction", even if the authors correctly report the different definitions available and the lack of consensus on which interactions are relevant for effective learning. The similarity of this research to our approach is that, in order to have significant data for learning analytics, standard logs available from any web application are not enough. Data extraction and analysis required the development of a specific tool based on the idea the authors want to test, like we did in our experience.

In [1] the focus is mainly of interaction of learners with social media, thus allowing to rely on advanced artificial intelligence mechanisms to infer knowledge and interest. The idea is to assess the learner's knowledge level in different topics as well as recommend additional specific education related to his/her former studies in order to get a better/desired job. Clearly, when dealing with social media analysis and logs of actions, big data is a keyword. Other approaches [3] are trying to collect biophysical signals during learning processes regarding emotion detection: this approach is a sort of "humanization" of the Internet of Things (IoT), being IoT "one of the most promising fuels of big data expansion" [16].

In [5], other than recognizing learning analytics as a significant area of TEL, the author proposes an interesting analysis of "the technological, educational and political factors that have driven the development of analytics in educational settings". The emergence of learning analytics, originated in the 20th century, is associated with the development of data-driven analytics, the rise of learning-focused perspectives and the influence of national economic concerns. The relationships between learning analytics, educational data mining and academic analytics are presented, thus assigning a central role to learning analytics even for the future challenges of the education field.

In [6], another source for big data in TEL is presented, i.e., the services of LMSs that fall under the label of e-Learning 2.0, nowadays well established and widely accepted. Comparing the different generations of e-Learning (1.0 and 2.0), and looking at the perspectives of the Web 3.0 / e-Learning 3.0, the authors survey some existing predictions for e-Learning 3.0 and finally provide their own. In particular, Machine Learning and Data Mining are identified as major driving forces for the Web 3.0, and therefore for the development of e-Learning 3.0. Many LMSs platforms have together with traditional services like sync/async communication or file repository, other 2.0 services like forums, blogs, wikis, FAQ etc. These services constitute an important part of interaction with students and among students, and therefore could be an interesting place where to extract information about learning behaviors. Web 2.0 interaction analysis is another field of application for big data tools and techniques, according to the impressive volumes of data collected every minute.

To conclude, the potential recognized for learning analytics [9] [10] is to track students' learning, to reveal patterns in their learning behaviors, or to identify patterns that put students under risk of failures. Learning analytics have another important end-user, i.e. the decision makers of the educational institution, that could take advantage of analytics to reform and supporting educational programs and activities with the aim of improving teaching and learning processes, and even organizations' educational strategies [11] [12]. Besides, there is an increasing attention for learning analytics as an instrument to improve learning processes, with the respective pedagogically implications and inputs [13]. Many LMSs are adopting learning analytics tools at the classroom level, thus providing both teachers and learners some benefits from learning analytics data [14][15].

3. THE TESTBED: "ONLINE COMMUNITIES"

The source of inspiration for big data analysis in e-learning is a virtual communities management platform entirely and autonomously created by our research team, starting since 1998. The approach used in most of the communities managed by the platform regards what is called "blended" approach, i.e. an e-learning mixed between frontal and online education training, asynchronous and synchronous, with online tutoring and frontal work sessions, all supported by our "Online Communities" system, of which, around the end of the 90s, the Faculty of Economics of the University of Trento has decided to adopt, followed by other public and private institutions. Currently, "Online Communities" (OC from now on) is mainly used outside the university campus, serving approximately 50.000 users from different public and private customers against approximately 15.000 students in our University.

OC is a dynamic web application, based on the metaphor of the virtual learning community, which ensures the cooperative organization of work in groups of users called "Community". A virtual community is defined as a space of communication shared by a group of people, not only related to educational aspects. Every community has at least one coordinator and participants that are not anonymous. It is natural to imagine a virtual community as an aggregation of individuals made possible thanks to computers; an extension in the virtual learning environments is the class in which the courses take place. The system is designed from the ground up within the Laboratory of Maieutics working group - Department of Industrial Engineering of the University of Trento, and is able to support the needs of a broad group of users (teacher, student, tutor, lecturer, external consultants, supervisor, dean, counselor, secretary, board member etc.), customizable within the context in which the system is used (for example in a business organization we will have different roles respect to the university, as president, secretary, director, administrative, board of director etc.).

The participants in the system are not anonymous, and have a number of roles; each role brings with it specific rights and duties. Therefore, the enrolled users participate in a series of communities, fulfilling different roles in each of them. The communities are also characterized by a series of events that correspond to the active involvement of members in different moments. OC was released outside of test environments in 1998 as a working prototype, then reached through different evolution steps its maturity in early 2005, but counting on a long experimentation on a limited number of courses started at the end of 1998. Since September 2005, the system is in operation at the University of Trento, involving tens of thousands of users, and has become an everyday tool for the teaching of many teachers. It represents the technology infrastructure used officially by some faculties of the university of Trento for testing and supporting new forms of teaching based on the techniques and the methods of e-learning. In 2007, the Autonomous Province of Trento decided to adopt it as its platform to deliver e-learning for its approx. 20.000 users. Then the Chamber of Commerce of Trento and the Chamber of Commerce of Bolzano adopted the platform and extended it to the affiliated enterprises, where we have just for the Province of Trento approx. 55.000 enterprises with the respective users.

The platform enables the members of any community to collaborate using multiple computer services (blog, wiki, chat, video conferencing, forums, file sharing, diaries , diaries, etc.). These services are used in areas collaboratively, both in the training, given the apparent closeness between the two environments. It 'also clear that, talking about continuing education and lifelong learning, the boundary between training and collaboration is increasingly being blurred when dealing with adults involved in the workplace. The logic of a virtual community platform considers any combination of people, brought together in a virtual place (hence "virtual community") for various purposes.

4. BIG DATA TECHNOLOGIES AND “ONLINE COMMUNITIES” PLATFORM INTEGRATION

In general, there a several elements of data gathering and manipulation that push our virtual learning environment towards big data, and that increase the need of a structural change of LMSs architecture towards approaches and technologies:

- Traditional Weblogs, being the application a web-based software
- internal logs of usage of the platform, the so-called “digital breadcrumbs”, that track the learner’s journey throughout the entire learning experience;
- Mobile logs, where data about mobile learning actions are collected
- Service logs, users’ actions on the different elements of the platform like documents, forums, blogs, FAQ etc.
- logs from the SCORM player, normally an external entity respect to the core services of the platform, with the records of the SCORM objects’ execution
- Tin-CAN API calls, in case the platform is connected or acting as a LRS

Recently, a further set of new ideas in e-learning could increase the need of a structural change of LMS architecture towards approaches and technologies connected with big data:

- Massive Open Online courses (MOOCs), by definition a generator of high volumes of data
- Life-long learning, an old buzzword of e-learning that is still valid and interesting and, most of all, is another generator of big data, specifically along time
- Serious games that will use materials inside the platform, thus generating a relevant dataset related with users’ performances

From the analysis we made in a test case, the interaction of users generate 2GB of data per month only for the high-level users’ actions log, just for 2.000 users/day. It’s clear that the overall picture could become much more compelling for any LMS involved with hundreds of thousands participants following intensive MOOCs. Tasks are recorded both for educational and security reasons, being the logging tasks involved in the recording of mouse clicks and SCORM-based material actions. Being SCORM logging not enough for some educational paths, according to the known limitations of SCORM standard, we decided to implement a meta-SCORM service, where more SCORM packages could be used in an educational path, mixing them with other services provided by the platform (like Wikis, FAQs, forums etc.) in a unique view called “educational path”. In this scenario, we have logs of the platform for clicks and users’ actions, logs from the SCORM player, and logs from the educational path service. From the potential amount of data generated by these actions, we started to imagine our big data approach to the platform. Our attention has been concentrated on projects parallel to our group, specifically a semantic big data integration pipeline created by the University of Trento’s start-up OKKAM.

In Figure 1, a graphical representation of the process of preparing proper data source for big data integration and analysis is presented. The first step is the selection of the data from the persistence of OC. This persistence is a typical big data data source, with structured (RDBMS) and unstructured (file, SCORM objects, blog/forum posts, wikis etc.) data created inside the platform. The idea in the project is to separate this data from the rest of the online platform, in order to create the background for analytics. So, in a sense, this is a typical ETL process that is present in any data warehouse / OLAP / Data Mining solution. In the future, using Open Refine as an ETL tool, we are ready to include also external data sources not included in the OC namespace.

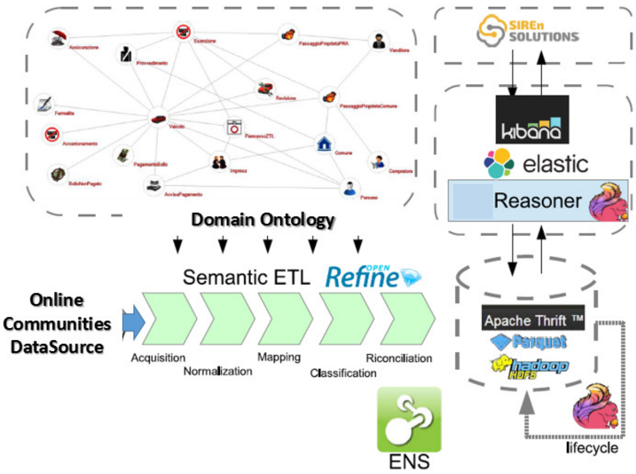

Figure 2. Overview of the process of preparing big data for analytical tools

Most of this data are coming from the first data source we used in our experimentation due to its affinity with big data data sources, the aforementioned “Actions”. It collects all data coming from users’ interactions with any OC object or service. It is a sort of “sensor” introduced inside the source code of the platform in any place is needed the software to capture an “action” from the user interface. This is of course a relevant enrichment of the logs recorded by the web application server, and has been used for many different purposes. Due to volume issues, the system at the moment is blocked on collecting only some types of events, to a certain granularity defined by the system administrator. This choice has not been a design choice, but a performance-related one. From the early experimentations, it was clear that the amount of data could have compromised the capacity of the DBMS to stand data acquisition pace and volumes: a typical “Velocity” and “Volume” big data problem.

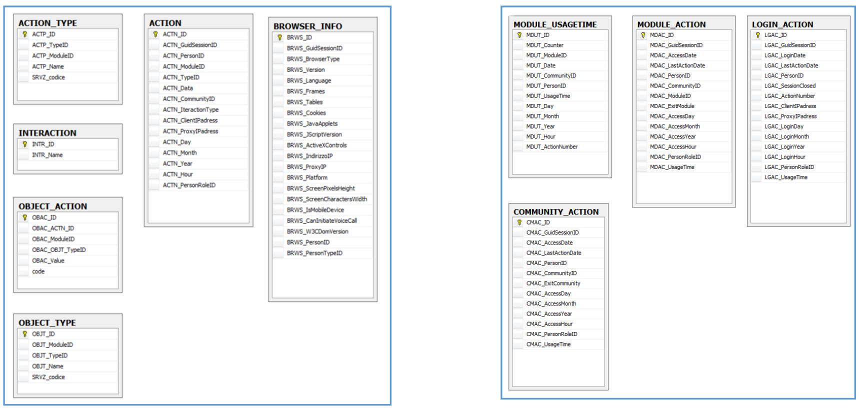

Figure 3. data structures for big data analysis in “Online Communities”

To manage all these aspects of data cleaning and integration, we enhanced Open Refine, a tool which allows for cleaning, transforming, mapping the data to the defined ontology, and crossing tables with related decoding tables. Once data are cleaned and normalized, they are moved through the pipeline towards a special process we call “okkamization”. This process is not relevant for the argumentation: more details can be found in [19]. In short, “okkamization” is a process of assigning persistence and unique identifiers to entities inside contents (to be able to connect them across different data sources), OC adopts an entity-centric platform developed in the Okkam EU-funded project. Okkam approach provides a solution to the problem of uniquely identifying entities inside contents, and we used OKKAM semantic technologies to identify entities inside our persistence layer.

The OKKAM main technology, named Entity Name System (ENS), profiles entities and supply a persistent identifier, called OKKAMid, to any entity included in the data source. This allows to provide a deeper connection between entities inside the content, inside the platform and outside the platform. Once the entity in the LMS has been profiled, the respective OkkamId has been created and the original content has been labelled with the OkkamId, it is possible to connect any content where the different occurrences of the same entity have been used inside the LMS, and also connecting OKKAMids to existing identifiers which have been assigned to any other content outside the learning platform, for example the web or social networks. Furthermore, a context-based ontology has been added to the platform, thus allowing to add new functionalities extensions to our virtual community platform thanks to the inference processes available through a reasoner, thus substituting the business logic of the application.

During the “okkamization” process, relevant entities are therefore identified and classified according to the Okkam Conceptual Model [20]. The process selects a subset of columns of the data source providing sufficient identification criteria for the considered type of entity, and submit queries to a purposely configured instance of the Entity Name System. If a query finds a matching entity (the ENS returns a URI and positive matching decision) than we consider the target entity as identified. When there are no positive matching candidates, a new OkkamID is created for that entity in the ENS, enabling its reuse in the following iterations. Once the cycles of interaction with the ENS are complete and the largest possible number of entities is okkamized, data are exported through the RDF to allow following requests of reasoning on the knowledge base. Having reconciled the identity of entities mentioned in different sources through the Entity Name System, we proceed gathering and integrating them easily relying on a distributed process implemented with Apache Flink. The generated dataset, representing a first version of the knowledge base, is serialized using Apache Thrift, and stored using Apache Parquet. In the experimentation described here [21] where the same pipeline has been applied to a different context with different data sources, experimental verification showed performances compatible (with adequate hardware) to big data settings.

The next step in the pipeline is the execution of reasoning tasks which materialize implicit knowledge to support learning analytics. For the moment, this reasoning is limited to basic inference regarding actions performed on certain parts and services of the platform, but the mechanism is ready for larger application scenarios. When the inference process is complete and new knowledge is inferred, a set of administrative routines is executed to load and transform part of the knowledge base to feed applications databases and indexes. In our case, we process the data pool to generate a set of Elastic- Search indexes used by the Siren Solution KiBi plugin for Kibana. The result is an adaptive dashboard that allows for a seamless exploratory analysis of the data where different visual elements update according to the current selected element (Figure 4). Further, thanks to inference processes we can materialize information elements that are useful for the decision makers and for tax assessment in the car sector. At the end of the process we produce JSON objects to be indexed in ElasticSearch and create in SirenSolutions KiBI dashboards (Fig. 4)

5. CONCLUSIONS

The paper presented the architectural and software solutions that have been designed and experimented in TEL settings to start moving towards the big data field, specifically in virtual communities used for e-learning. The biggest issues of experimenting big data approaches and tools came from the technical structure of the platform used for collecting data. The persistence layer, originally created using traditional RDBMS and Object-relational Mapping – ORM tools, was clearly not ready to face big data, especially for the “Volume” and “Variety” of data implied in the management of learning Virtual Communities. The paper presented the technical direction taken in order to face this problem, together with some early results. Further studies and experimentation are needed, considering also the limited amount of data used as a test respect to big data volumes (8GB of dataset collected in 4 months of interaction recordings), but the first findings demonstrate how important is an evolution of current, DBMS-centric persistence layers of Learning Management Systems.

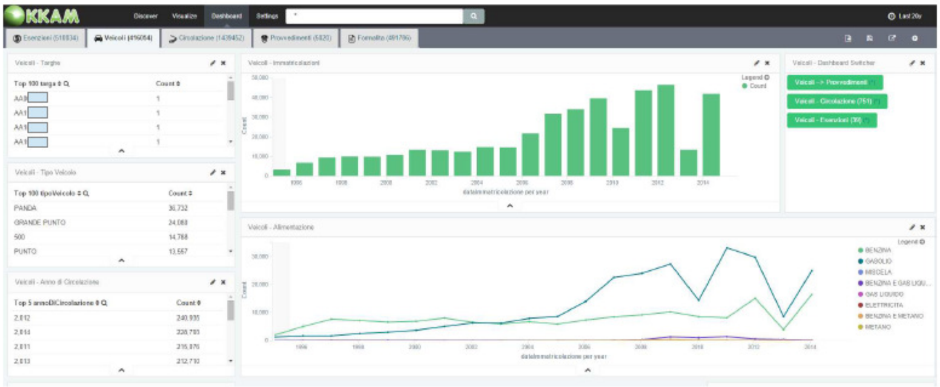

Figure 4. a snapshot of the analytical tool for big data analysis in "Online Communities"

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Publication XII

Molinari A.
Supporting Decision-Making Processes in Virtual Learning Environments

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SUPPORTING DECISION-MAKING PROCESSES IN VIRTUAL LEARNING ENVIRONMENTS

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Decision-making pervades our daily working tasks, and information systems should provide adequate support for this. Many tools have been created, from specific Decision Support Systems (DSS) to business intelligence tools, to various services provided by software platforms that originally have another scope. In this paper, we present a different perspective of integration between DSS-based tools and the information system of the organization, specifically virtual learning environments (VLE).
There are trivial examples of usage of DSS tools inside learning contexts, like the evaluation processes performed for educational purposes, but other usage of DSS-based tools are less trivial although very useful. This is especially true when the virtual learning environment is used to support not only educational tasks, but also collaborative and community-based processes. Examples of this integration between DSS-based tools and VLE are evaluating the various candidates for a job position, supporting evaluators in a public tender, evaluating project proposals that have been uploaded in the platform, assigning a prize respect to documents uploaded in a forum, evaluating the best contribution for a wiki item etc. In all these cases, the platform should provide the end-user (the expert / evaluator) with a set of tools that help:

a) aggregating grades / votes / "likes" and any other form of value expression using a richer set of mathematical tools, even when these grades are expressed in linguistic form;
b) aggregating the evaluation coming from different experts with different background and initial positions, but that with a VLE and appropriate consensus management tools can reach a more shared evaluation community.

This paper describes the different settings where multi-criteria, multi-agent tools can be useful inside collaborative environments oriented to educational tasks, with an example of application inside a VLE created by the University of Trento.

Keywords: E-learning, virtual Learning environment, decision support systems.

1 INTRODUCTION

Computers today play a central role in decision-making processes, by the presence of hardware and software tools devoted specifically to these tasks. Decision support systems, under different names or implementation, are present as software tools in every information system, from trivial spreadsheet-based models prepared by single users, to sofisticated mathematical-oriented software tool like data mining, OLAP or custom-made systems to support management and executives in their decision processes. In the end, decision-making tasks are pervading our life, with tools that provide us suggestions and information as adequate support for this. The advent of mobile technologies has opened a new, specific field of research for mobile decision support systems[1].

In learning contexts, there are plenty of situations where the usage of DSS tools is rather obvious, like the evaluation processes performed for educational purposes, but other usage of DSS-based tools are less trivial although very useful. This is especially true when the virtual learning environment is used to support not only educational tasks, but also collaborative and community-based processes. Examples of this integration between DSS-based tools and VLE are evaluating the various candidates for a job position, supporting evaluators in a public tender, evaluating project proposals that have been uploaded in the platform, assigning a prize respect to documents uploaded in a forum, evaluating the best contribution for a wiki item etc. In all these cases, the platform should provide the end-user (the expert / evaluator) with a set of tools that help:

a) aggregating grades / votes / "likes" and any other form of value expression using a richer set of mathematical tools, even when these grades are expressed in linguistic form;

b) aggregating the evaluation coming from different experts with different background and initial positions, but that thanks to a VLE and an appropriate consensus management tool, can reach a more shared evaluation.

Other interesting examples of these application fields are those situations where a reputation attribute must be derived from the evaluation of an experts' panel respect to the contribution of different learners. The voting mechanism in a forum, the selection of a wiki item's proposal respect to different proposals made by learners, or the item added to the FAQ by different contributors and evaluated by a team of experts (teachers or simply other participants to the learning community), these are examples of DSS techniques to e-learning settings. There are different moments in the usage of an LMS where an (semi) automated help to take decisions could be very useful, for every role involved.

Nevertheless, the support to decisions inside Learning Management Systems (LMSs) is, according to our review, rather poor, in contrast with a consistent bibliography on methods supporting decisions in learning and collaborative environment.

This paper describes how a set of decision support techniques has been integrated into services provided by a Learning Management System, specifically multi-criteria, multi-agent tools useful inside collaborative environments oriented to educational tasks. We will present the design and implementation of a library of tools that allow to extend platform's services in order to provide support to decisions taken by the user of the platform in different contexts. The common ground for this library is a multi-criteria, multi-expert model where several attributes are collected regarding different alternatives, and the opinions of different experts about that alternatives are collected and then aggregated using the model. Accordingly, a multi-attribute method is worth to be used and a consensus modeling mechanism helps in finding the agreement on evaluation carried out by the team of experts. In the model, we will base our evaluation on fuzzy TOPSIS and other techniques that can be configured by a skilled administration depending oon the objectives of the evaluation process.

The paper is organized as follows. In section 2 we present a short overview of the state-of-the-art in applying DSS techniques to e-learning settings. Section 3 describes the software platform used to implement and experiment the use of these tools, while section 4 presents the details of the services where DSS extensions have been added. Section 5 will shortly present the conclusions.

2 SUPPORTING DECISIONS IN E-LEARNING: STATE OF THE ART

In this section we present a short overview of the main research lines that see mathematical methods applied to e-learning settings. Specifically, we are interested in multicriteria decision making problems in the presence of multiple experts, where emphasis is especially on the methods supporting consensus in group decision making, and the applications of fuzzy sets to multicriteria decision making methods which are used to describe vague linguistic evaluations of the experts. These methods allow, in our opinion, to capture, represent and compute in a more comprehensive way the diversity of opinions in a team of decision makers, and at the same time to compute an aggregated value that represents the final result. In e-learning settings, the evaluation of different alternatives is very frequent and relates with different contexts: for example, the evaluation process typical of educational paths, the evaluation of study materials, courses, students' performance, the agreement on learning strategies, the choice of learning objects based on experts' (teachers and tutors) evaluation, or the ranking of candidates in a selection process, or the evaluation of contributions of users into social media discussions.
Many techniques have been used in research projects, and the following paragraphs will argument why we chose some of them and which ones are used in our system. Technically, the selected methods have been implemented in software libraries that are integrated into the different services provided by the system. Some examples of the integration of these modules will be presented in section 4.

The first technique included in the DSS library is TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution), first developed by Hwang and Yoon [8], a method that is quite popular when dealing with multiple attribute decision making problems. TOPSIS simultaneously considers the distances to the positive and negative ideal solution regarding each alternative, and selects the most relative closeness to the ideal solution and the farthest one from the negative ideal solution. The method is also used for its relative simplicity of calculus: ituses the shortest distance from the ideal solution and the longest distance from the negative ideal solution. The set of alternatives is compared according to the criteria in an evaluation matrix, that is normalized, then weighted normalized, and so ideal and negative ideal solutions are determined. Finally, distances of each alternative from the ideal and negative ideal solutions are computed, the separation measures are obtained, and the alternatives are ranked.

Many changes and extensions have been development since 1981, mostly focusing on the normalization of the evaluation matrix, determination of the ideal and negative ideal solutions and the distance of alternatives from the ideal and negative ideal solutions. Another thread for TOPSIS extension are proposed in order to deal with multicriteria group decision making and decision making under fuzzy environment. For example, the authors of [2] review the literature on methodologies and applications of the TOPSIS method until 2012, and recommend future research directions in the TOPSIS methodology.

Related to TOPSIS, inside our LMS we decided to implement a library of functions related with the Analytic Hierarchy Process (AHP). This method has received a lot of attention since its development, and nowadays it is one of the most popular methods applied in multicriteria decision making. Similarly to TOPSIS, a significant amount or research has been conducted to propose extensions and modifications to AHP. Many papers that are proposing mathematical models for the evaluation of e-learning products and their components involve AHP, and one of the main threads of research refers to fuzzy extensions.

AHP foundation is to structure a problem into a hierarchy, proceeding with pairwise comparison matrices of objects from one level of the hierarchy with respect to an object from the upper level of the hierarchy. Pairwise comparison matrices of objects are checked in terms of consistency (i.e. consistency of the expert's preferences), and priorities of objects are obtained from the matrices. Finally, the priorities are aggregated into the overall priorities of the decision making alternatives, and then a ranking process on these is applied. AHP is a very debated methodology, especially the aspect of consistency of the matrices: for example, in [10] an analysis of proportionality between existing consistency indices in the AHP method is presented, while in [11], a method for achieving matrix consistency in the AHP is proposed. In general, we suggest [9], where the main methodological developments in the AHP since its inception until 2010 are presented.

The application of AHP in e-learning settings exists, though in different directions. To evaluate the criteria affecting the quality of distance e-learning, in [12] the AHP method is used together with consistent fuzzy preference relations. Similarly, in [13], AHP has been applied to evaluate five practices of a given teaching platform from the perspective of knowledge management. In [14], a model for selecting a e-learning platform suitable for organizations using the AHP method is proposed. In [15], a consistent literature review about course website quality has been conducted, with the objectives of generating criteria suitable for measuring course website quality. This is probably not exactly related with the objectives of including mathematical techniques inside a web platform, but it is an interesting application case, together with [16]. An extension of AHP method with fuzzy approach and triangular fuzzy numbers has been proposed in [17], in order to obtain the relative weights of course website quality criteria between high and low online learning experience groups. The authors propose an approach based on the fuzzy AHP method and critical success factors to evaluate e-learning systems by universities and educational institutes.

Fuzzy logic is another interesting research area that inspired our development, and that is significanty present in e-learning research field. Some approaches have been presented in [3], where fuzzy logic has been applied to the identification of e-learning design requirements and to select the most suitable e-learning service provider. Other approaches [4] use fuzzy inference to analyze students' way of working and group's behavior, while in [5] fuzzy logic has been used to improve search capabilities of Learning Management Systems (LMSs). In the field of evaluation, under different perspectives we find the application of fuzzy logic to the evaluation of students' performances according to their profile [6], or to an evaluation teaching systems' quality [7].

Supporting decision making in e-learning environment have been proposed through different approaches: for example, in [18] a fuzzy multicriteria group decision support software has been developed. This software allows users to choose between two fuzzy inference methods and three different membership functions describing linguistic terms. The decision makers are helped to determine the main criteria, sub-criteria and their weights, as well as the performance of the alternatives according to each criterion. The software can be applied to multi-purpose decision making processes, such as evaluating performance of students, teachers, journals, employees or assessing projects, journals, etc., and was used to assess the performance of research assistants at Marmara University in Turkey.

We conclude this section addressing the we used as an inspiration, and that is partially included in our platform. FuzzME™ is a tool for creating fuzzy models of multiple-criteria evaluation and decision making. It was developed at the Faculty of Science at Palacký University Olomouc: see [19] for details. In fig.1, the user interface of the Fuzzme software in the stand-alone version.

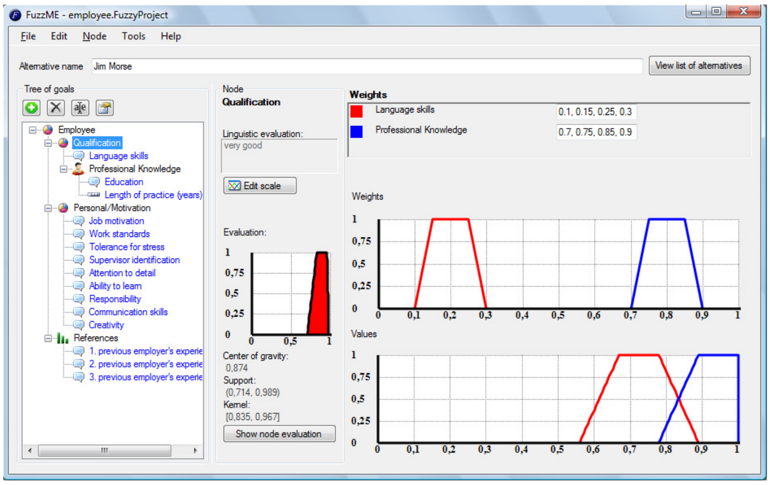

Fig.1 The Fuzzme™ software and its end-user interface

The inclusion of FuzzME software inside our platform relates with both quantitative and qualitative criteria that are available in the platform for the aggregation of partial evaluations. Different methods are available:Fuzzy weighted average, Fuzzy OWA operators, Fuzzified WOWA operator, Fuzzy Choquet integral and Fuzzy expert system. At the moment, Fuzzy weighted average and Fuzzy OWA operators have been included in the development of DSS-based services of our e-learning platform.

3 THE APPLICATION ENVIRONMENT

At the time of the sperimentation, it was clear that most of the DSS techniques presented in the previous section would have been useless if applied only to tradional educational settings: too complicated for the decision-maker (most of the time, a teacher), too complex to adapt existing LMSs for the purpose. The orientation of LMSs to support prevalently educational tasks were limiting the possibility to use their services in more flexible and collaborative contexts. This prevented also the integration of these tools with the rest of the enterprise's information system. In the end, what emerged from our early attempts was that e-learning is normally seen inside organizations as a separate world from the rest of the information system. However, when the needs of the organization turn into collaboration needs, many services of an e-learning platform would be very useful if not the solution: for example, file repository, forums, wikis, FAQ, tickets, video-conference etc. The problem is that converting an LMS from a mere repository of educational material to a tool devoted to integration, collaboration, cooperation between virtual communities would have been too complicated, at least with platforms that (as said) have educational needs as main target.

Our idea was the following: extending e-learning tools to other contexts greatly expands the possibilities for e-learning platforms to become a crucial component of the information system, not a remote set of service seen as an external body. However, a simple adaptation of the platform to collaboration needs, or simply re-assembling different tools in "patchwork" solutions demonstrated many limits: just consider the problem of single sign-on, or the need to create a community that is not related to the idea of "class", "course", "module" or similar educational containers. In general, this means for organizations to intervene heavily on e-learning solutions with customizations, often distorting and hence losing or compromising compatibility with future releases, or devoting considerable efforts to maintain it.

In these corporate contexts, it is essential to have advanced tools that support activities not limited to simple training delivery, but that reduce space and time barriers and enable collaboration "anytime - anywhere". Examples of these needs are: planning and time management, managing events related to the activities of the community, decision support and process evaluation, ticketing and help desk, cooperative writing, social collaboration and so on. Similarly, with the increase of complexity, tools for collaboration, sharing and distributed decision support within the communities are becoming increasingly central.

In this section we present the software solution developed by our research group to overcome this issues, specifically the integration of DSS-based services inside educational-oriented software platforms. This solution, called "Online Communities", has been entirely developed fromscratch at

University of Trento, to support blended teaching, starting from 1999-2000 by the Faculty of Economics. At the time, infact, there were no Moodle™ or other relevant FOSS systems available, and WebCT™ / Blackboard™ were out of reach. After the first 5 years conducted with the first implementation of the system, completely devoted to support typical educational tasks (download slides, forums, chat, administrative messages, exams etc.), our team focused on carrying out a new platform based on a new approach and new pillars.These are some elements that convinced us to modify the approach:

- The didactics of an university are not only built as a set of studies and tests, but these activities are inevitably intertwined with the university's organization and its information system. In an academic context, not everything concerns teaching: for example, the entire Faculty is more than a container of degree courses, and a degree course is more than a container of lectures.
- Models of teaching / learning (such as learning by problems, learning by projects, cooperative learning and their combinations) can hardly be connected to an e-Course, especially when the software treats everything as something related to teaching / learning;
- The needs for cooperation within the academic environments is pervasive and extended to all the activities of the context in which didactic takes place;
- The didactic scenario is changing in organizative terms, under the effects of new regulations or decisions made by academic institutions, and these changes will inevitably influence the LMS functionalities.

To answer these needs we decided to revolutionize the whole architecture of the plaform, from the persistence layer (a tradional RBDM) to the services provided to even the therminology used by the platform. We substitute the funding metaphor or "course" with the metaphor of "community": the atomic container of users' activities and interaction should have been a "community", non just a "course" / "class" or "module". The new metaphor contributed to this complete refactoring of the system, which had at least three basic characteristics: a) generalized enough to extend the application field from e-learning to cooperative environments, b) suitable to support the cooperation processes c) capable of properly modelling the organizational needs of an educational institution.

As said, the system that arose, called "Online Communities", started in 2003 and is up and running since February 2005, constantly evolving thanks to research and end-users/customers contributions and stimulus. Over the last years the system has evolved into a platform to support collaboration and cooperation tasks. The new implementation preserved certain basic features of earlier versions, while also extending its functions to allow new business perspectives outside the educational scope. Today we have many different partners and customers, outside academic context, that regularly use the platform, with a total of approx. 100.000 end users.

In short, the basic container of the platform is a (virtual) community, a virtual space shared by groups of individuals who have a common goal. A community's virtual space can be simple or complex; for example it can contain further virtual communities, thus establishing a hierarchical "parent-child" relationship. The (virtual) community space can be open, accessible to anyone, or it can be restricted, with access reserved only to some people authorized by the community administrator. The users can have different roles with associated rights and duties, which may vary according to the use of communication services activated in the community. The system maintains the consistency of the whole social environment of the virtual communities which are active at a given time, in that it provides users of a community with a range of on-demand services that can be activated and used in accordance with the permissions granted and the roles assigned.

Managing virtual communities is different from managing course, and requires a different approach in several component of the platform, especially in the management of communities, roles and permissions. Here follows a list of the main characteristics of a community:

- each Community provides a certain number of services to members;
- services are general applications that enable users to perform needed actions inside the virtual space (synchronous and asynchronous communication, contents publishing, file exchange, events and time management, social interaction etc.)
- communities can be of different types with different aims, not necessarely related with educational tasks: recreation, research, tourism, public discussion, cuisine, union, professional or whatever else the platform administrator will allow. The communities can be aggregated into larger communities with hierarchic mechanisms and infinite nesting levels.
- services could be differents for different classes or instances of community, and are activated by community administrator according to specific needs

- users may have different rights and duties according to the assigned role inside that community (admin, moderator, teacher, member of the board of director, secretary, president, participant etc.), and may play different roles in different communities
- Only registered users are admitted: no anonimity is allowed in Online Communities, even though it is technically feasible.

Nowadays, the relation between our Virtual Communities platform and the hosting information system of the educational institutions is at the center of our reseach and development plans. At the moment, e-Learning platforms seem to be built to act in a restricted circle made up by only teachers, tutors and students. Therefore, the community is a container ready for didactic processes. Thanks to the extensions added, some of which are described in this paper, we have extended the range of users profitably using our platform, and at the same time keeping the educational usage of it: research teams, recreation groups, friends, secretariats, board of directors, chess players groups, colleagues, anything that could be an aggregation of people around a scope using virtual spaces.

4 RESULTS

In order to support the decision making process that could happen at different levels inside a virtual community, we implemented inside "Online communities" a set of advanced components taken from research in the field of decision support systems, related with distributed consensus management and multi-criteria evaluations. The introduction of components from the field of soft computing inside a full-fledged eLearning platform is quite unique to our knowledge, and this further expands and evolves the application field of our platform from simple contexts related with teaching to all those contexts where support to decision-making in presence of several experts / evaluators and multiple evaluation criteria is needed.

The initial stimulus came from the request to support the decision making process aiming at selecting the most suitable eLearning path(s) for certain students. We introduced a multi-attribute, multi-expert model where several attributes are used for evaluating different eLearning paths, according to the rankings expressed by a group of experts [20]. This multi-attribute evaluation is based on fuzzy TOPSIS. Then, we added a consensus modelling mechanism in order to find the agreement among the individual rankings. This is obtained through a constrained optimization model.

The implemention is a generalized tool for supporting and providing "Online Communities" services with some primitives (APIs) to be used in different contexts. We are experimenting some application fields of these methods through the extension of already available services. This allows the platform to do the following.

- Choose the type of model to be used, according to the needs of the administrator of the community and according to the decision processes to be implemented. Because this step requires an adequate background and knowledge ofthe best approach to be applied in that specific context, this is the crucial moment for the entire use of the tool. The administrator should have quite a robust mathematical background, or the instructions provided by the platform are very clear, or finally (and this is the road we are following) the system provides a set of templates of models classified according to specific situations and contexts. For example, using linguistic (fuzzy) operators is apparently natural for human operators, but the effects related to some parameters (alpha-cut, triangular of trapezoidal fuzzy numbers etc.) must be clearly managed as they influence the final results.
- Set the parameters of the module, through an interface that again must face a problem of clarity of language and awareness of the effects of the single parameter on the whole result.
- Set number and attributes of experts (fig.2), that subsequently will become members of the community where the decision process will be held, and therefore will take advantage of all the services (mainly communication and file sharing services) that the platform/community will provide.
- Set the criteria needed for the implementation of the decision process (fig.3).

This is just to mention the main actions, repeating the fact that the configuration phase is the most delicate one. The platform, according to the parameters, prepares the interface for acquiring input from experts via web, thus facilitating the decision and enabling a quicker decision process. In our early experiments conducted together with the Trentino Local Development Agency, a process for the evaluation of public tenders regarding spin-off financing required almost six months of lead time mainly spent in organizing meetings among evaluators, collecting and aggregating their judgment.

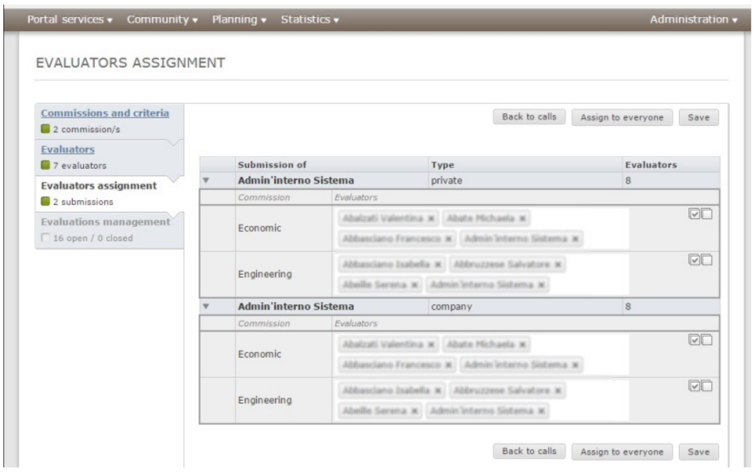

Fig.2 Setting the commission members and evaluation criteria

Thanks to the usage of "Online Communities" platform, its collaboration and management tools, and the application of the DSS model, all the process of collecting proposals, involving evaluators, collecting their evaluation according to the model proposed, aggregating results and formulating the final ranking required less than three weeks. Most of all, vis-à-vis sections have been limited to an initial session to meet each other and share the evaluation criteria, and the final meeting for the formal approval of the ranking.

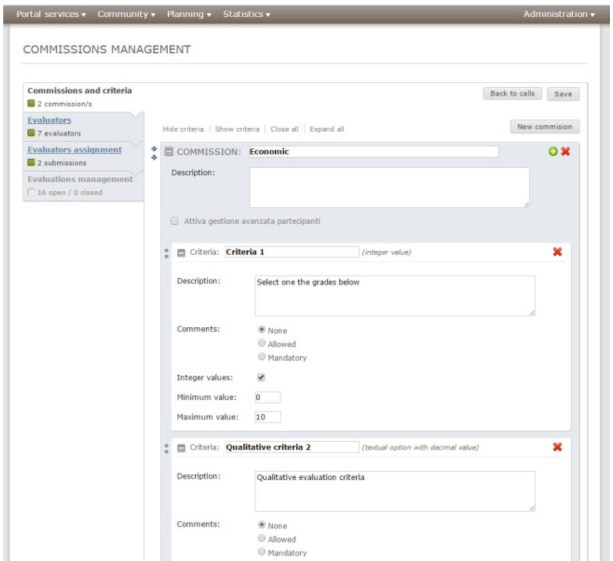

Fig.3 Managing evaluation criteria in a multi-critera, multi-expert context

The DSS engine uses a two-stage decision making process, where in the first stage each expert evaluates alternative paths using a TOPSIS-based approach, assuming that the scores are linguistically expressed. The computations of individual rankings are carried out representing linguistic labels as positive fuzzy numbers. The second stage is devoted to the description of the consensus modelling process aiming at finding the group ranking according to the minimization of a distance function.

The DSS module includes a set of modules with different but coordinated objectives:

- a module for estimating the experts' individual assessments expressed by linguistic variables represented by fuzzy numbers triangular / trapezoidal;
- an algebra for the treatment of language assessments and a corresponding mechanism linguistic approximation based on the distance between fuzzy numbers;
- an algorithm for the representation of individual preferences (fuzzy binary relations) aimed at introducing an order of preference among alternatives;
- operators of media defined on linguistic information represented by fuzzy numbers: average weighted fuzzy, fuzzy OWA, Choquet fuzzy integral;
- models for decisions / assessments multi-criteria based AHP and Topsis;
- a module for the representation of processes of reaching consensus in the presence of individual judgments expressed by linguistic preference relations.

As a use case, in a situation where an educational institution should evaluate different proposals for educational paths, the attributes introduced in the model have been the following: a) clarity of language b) completeness c) adequacy of literature d) length of learning objects e) length of learning path f) structure of educational paths g) appropriateness of LO h) appropriateness of evaluation methods.In the following picture, an example of proposed educational paths according to the evaluation of a commission that used Online communities to suggest.

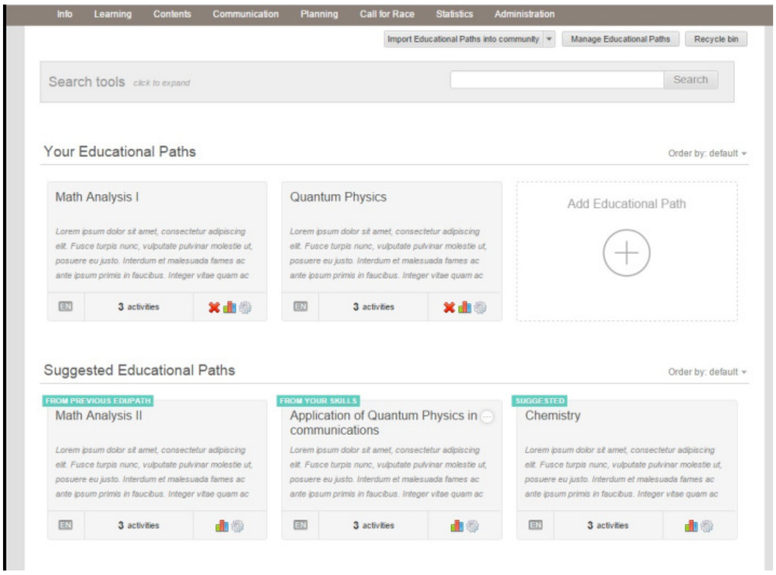

Fig.4 Educational paths proposed according to the multi-criteria module

Regarding the use made by users of our DSS extensions, the DSS library has been integrated, or is in the process of being integrated in many different services that are normally used by community members for the following purposes:

a) the selection of several existing proposals today to cover routes of online learning, which is crucial because of the great attention paid to the construction of the learning object (LO) available through the LMS
b) evaluating the performance of the various participants in a training
c) the evaluation of applications for admission to a training / competition
d) the evaluation of post made by various users on a forum in order to view or discard their contributions
e) The evaluation of contributions alternative to the definition of items in a wiki, in the presence of various contributions added by the participants in which there is, by a group of experts (the same community or communities outside) the need to choose the one that will be the final contribution

f) the internal assessment in a community that, in the face of a series of contributions, should be the end result of the contribution, then this in a perspective of self-regulation of the community in the logic of the community
g) the evaluation of different activities within the platform to be able to reward the best, for example in connection with the "Polls" of COMOL
h) the evaluation of proposed projects to a panel (for example in the presence of notices where the various questions collected through COMOL)
i) assessment of proposal documentation from internal and / or external to a virtual community
j) various forms of voting and opinion expressed by participants in the virtual community on matters to be working in the community.

5 CONCLUSIONS

The paper presented how decision-making processes could be integrated inside e-learning settings to support educational processes, and how a virtual community approach could allow users to switch from traditional learning/training tasks to decision-supported tasks. Even educational institution and the respective actors have today many decisional tasks, and these tasks are most of the time conducted or supported by technologies. The starting point of the DSS tools developed is our virtual community platform, created and developed along the years to support collaborative tasks. The most remarkable novelty of our approach consists in proposing a mixed procedure which permits to combine individual ranking, as carried in a multi-attribute setting by each member of a group of experts, with a linear constrained optimization process whose purpose is to determine a distance-based group consensual ranking. This approach could be reused and applied in many different collaborative contexts and services provided by our platform, thus extending the possibities of application of LMS outside the strict learning environment. This allow us to integrate the platform inside institutions' information system not just as a tool support e-learning, but as an integrated tools that supporto collaboration and cooperation processes.

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