An application framework for the systematic construction of multimedia-based Collaborative Complex Learning Resources

A doctoral dissertation submitted to the Doctoral programme in Network and Information Technologies of the

Universitat Oberta de Catalunya

in partial fulfillment of the requirements for the degree of Doctor in Network and Information Technologies

Doctoral candidate: David Gañán Jiménez

Doctoral thesis supervisors: Dr. Santi Caballé and Dr. Jordi Conesa

January 26, 2015

Acknowledgments

I would like to gratefully acknowledge the supervision and guidance of Dr. Santi Caballé and Dr. Jordi Conesa during this work.

I will be forever indebted to my parents for their understanding, endless patience and encouragement when it was most required.

Abstract

Despite their demonstrated potential through a range of early studies, on-line collaborative learning systems do not yet have the impact that many believe is possible. In particular, collaborative learning approaches cannot be readily applied to every e-learning experience, since they require a degree of presence and/or collaboration which may be difficult to achieve. In addition, collaborative learning systems often lack the challenging resources and tools required to fully support collaborations, making the experience unattractive to end-users and discouraging progression. Whilst the learner might expect to control the collaborative experience, often it is the collaborative experience that controls and limits the learner. As a result, collaborative learning resources can lack authentic interactivity, user empowerment and balanced levels of challenge, thus having a negative effect in learner motivation and engagement.

To overcome these deficiencies, this thesis work proposes the provision of software infrastructure to support new types of pedagogically augmented collaborative learning methodologies and resources by means of an innovative application framework called Virtualized Collaborative Sessions Framework (VCSF). The VCSF helps meet challenging pedagogical requirements in online collaborative learning, such as increasing student's engagement and learning performance during the collaboration. In turn, the systematic application of the VCSF platform, enriched with semantic technologies, enables e-learning developers to leverage successful collaborative learning experiences in a software reuse fashion while saving development time and effort. The framework has been prototyped and successfully tested in real environments, thus showing the software reuse capability and the pedagogical benefits of the VCSF approach.

The VCSF exploits a new paradigm named Collaborative Complex Learning Objects (CC-LO): a special type of Learning Object which aims to leverage the knowledge elicited during live sessions of collaborative learning, augmented with author-generated information, to produce interactive and attractive resources to be experienced and played by learners. During the CC-LO execution, learners can observe how avatars discuss and collaborate, how discussion threads grow, and how knowledge is constructed, refined and consolidated. Furthermore, learners can interact with the CC-LO in order to modify some parameters observing the consequences and assessing their understanding. Then, the CC-LO concept is extended with the definition of Collaborative Complex Learning Resources (CC-LR), which are customizable CC-LOs with new capabilities, such as cognitive assessment and emotional awareness, that open a window towards an authentic social interaction and learning experience through accountability and constructive feedback. The CC-LR approach is created, edited, executed and fully managed by the VCSF tools.

In addition, the VCSF platform extensively leverages standards and defines new ones. In particular, a new ontology called Collaborative Session Conceptual Schema (CS^2 for short) has been defined in order to enhance the portability and interoperability with other e-learning systems. The intrinsic extensibility of the system enables the interaction with many kinds of collaborative sources; the only requirement is to create a conversion mapping from the source

model into the CS^2 model, which is the common standard format used as the input for the platform.

Finally, multimedia and networking technologies are found an important support for education and make the presentation of learning materials easier to be adapted to different learning goals. From this motivation, the VCSF makes an extensive use of multimedia resources, including images, videos and text-to-speech audios, etc., and is flexible enough to be extended with more complex and specific multimedia requirements. From a pedagogical perspective, the VCSF flexibility becomes essential for delivering personalized learning materials to students with different learning styles and needs, as well as allowing students to learn more effectively and increase their motivation and engagement in the learning process as certain studies confirm.

In order to validate this thesis outcomes, the VCSF framework was extensively tested and evaluated in several higher education institutions and in different contexts of e-learning and blended learning, with the collaboration of distinct types of roles, including students, professors (both technical and not technical) and developers. These evaluation studies allowed for the validation of the VCSF purposes and objectives, and also provided valuable feedback in order to improve the prototype developments and move forward to future steps of research.

List of main contributions

The relevance of the research conducted by the Doctoral candidate (from now on "the candidate" is supported by more than 25 research contributions to several journals, conferences, project deliverables and other dissemination channels. This section shows the main contributions resulting of the thesis work.

The three most relevant contributions of the thesis are the following (indexed in ISI-JCR):

- **Gañán, D.**, Caballé, S., Conesa, J., Xhafa, F. (2015). *An Application Framework to Systematically Develop Complex Learning Resources Based on Collaborative Knowledge Engineering*. International Journal of Applied Mathematics and Computer Science (AMCS). To be published in Vol. 25, No. 2. University of Zielona Góra Press. ISSN: 1641-876X. IF: 1.390, Q1: 45/250 (JCR-2013 SE).
- Caballé, S., **Gañán, D.**, Gómez-Cazorla, M., Conesa. J., Rius, A., Santanach, F. (2014). *Experiences with Engineering Education at the Open University of Catalonia by the Virtualization of Live Collaborative Learning*. International Journal of Engineering Education (IJEE), Vol. 30, No. 3, pp. 663–674. TEMPUS Publication. ISSN: 0949-149X. IF: 0.360, Q4: 74/87 (JCR-2013 SE).
- Caballé, S., **Gañan, D.**, Dunwell, I., Pierri, A., Daradoumis, T. (2012). *CC-LO: Embedding Interactivity, Challenge and Empowerment into Collaborative Learning Sessions*. Journal of Universal Computer Science (J.UCS), Vol. 18, No. 4, pp. 25-43. Verlag der Technischen Universität Graz. DOI: 10.3217/jucs-017-01-0025. ISSN: 0948-695X. IF: 0.762, Q3: 54/100 (JCR-2012 SE).

The candidate also collaborated in other journal publications indexed in ISI-JCR (3 articles) and SCOPUS (1 article):

- Caballé, S., Mora, N., Feidakis, M., **Gañán, D.**, Conesa, J., Daradoumis, T., Prieto, J. (2014). *CC-LR: Providing Interactive, Challenging and Attractive Collaborative Complex Learning Resources.* Journal of Computer Assisted Learning (JCAL), Vol. 30, No. 1, pp. 51–67. Wiley. DOI: 10.1111/jcal.12021. ISSN: 0266-4909. IF: 1.023, Q2: 61/219 Category: EDUCATION & EDUCATIONAL RESEARCH (JCR-2013 SSE).
- Feidakis, M., Caballé, S., Daradoumis T., **Gañán, D.**, Conesa, J. (2014). *Providing emotion awareness and affective feedback to virtualized collaborative learning scenarios*. International Journal of Continuing Engineering Education and Life-Long Learning (IJCEELL), Vol. 24, No. 2, pp. 141-167. Inderscience. ISSN: 1560-4624. Indexed in: SCOPUS (Elsevier), Compendex (Elsevier), Inspec, Scirus.
- Feidakis, M., Daradoumis, T., Caballé, S., Conesa, J., **Gañán, D.** (2013). *A Dual-Modal System that Evaluates User's Emotions in Virtual Learning Environments and Responds Affectively*. Journal of Universal Computer Science (J.UCS), Vol. 19, No. 11, pp. 1638-1660. Verlag der Technischen Universität Graz. ISSN: 0948-695X. IF: 0.401, Q4: 89/102, Category: COMPUTER SCIENCE, THEORY & METHODS (JCR-2013 SE).
- Conesa, J., Caballé, S., **Gañán, D.**, Prieto, J. (2012). *Exploiting the Semantic Web to Represent Information from On-line Collaborative Learning*. International Journal of Computational Intelligence Systems (IJCIS), Vol. 5, No. 4, pp. 653-667. Atlantis Press. DOI: 10.1080/18756891.2012.718111. ISSN: 1875-6883. IF: 0.451, Q4: 108/121, Category: COMPUTER SCIENCE, ARTIFICIAL INTELLIGENCE (JCR-2013 SE).

In addition, the most relevant contributions published in conference proceedings by IEEE Computer Society are shown next with the candidate as the first and corresponding author:

- **Gañán, D.**, Caballé, S., Conesa, J., Barolli, L., Oda, T. (2014). *Evaluation of Using Software Infrastructure and Multimedia Technologies for the Creation of Complex Learning Resources*. In proceedings of the Sixth International Conference on Intelligent Networking and Collaborative Systems, pp. 457-462. IEEE Computer Society. ISBN: 978-1-4799-6387-4/14.
- **Gañán, D.**, Caballé, S., Conesa, J., Barolli, L., Kulla, E., Spaho, E. (2014). *A Systematic Review of Multimedia Resources to Support Teaching and Learning in Virtual Environments.* In proceedings of the 8th International Conference on Complex, Intelligent and Software Intensive Systems. IEEE Computer Society, pp. 249-256. ISBN: 978-0-7695-5094-7/13.
- **Gañán, D.**, Caballé, S., Conesa, J. (2013). *Towards Software Infrastructure for the Systematic Virtualization of Collaborative Learning Sessions*. In proceedings of the Fifth International Conference on Intelligent Networking and Collaborative Systems, pp. 422-429. IEEE Computer Society. ISBN: 978-0-7695-4988-0/13.

The candidate also published 9 more contributions in conference proceedings by IEEE Computer Society. They can be found in the References section: [10][13][14][15][16][17][18][19] and [20].

Finally, the candidate has collaborated with several research projects over the last years. These collaborations helped him to improve his skills as a researcher in a great deal, but they are out of the thesis scope. For this reason, such contributions are not listed in this section though they were included in the References section, labeled as “Other candidate's scientific papers and reports” [21] – [28].

Index

1. Introduction

1.1. Introduction to Collaborative Learning

Computer-Supported Collaborative Learning (CSCL) is a mature research field in the educational domain dedicated to improve teaching and learning through the introduction of modern ICT [29]. Learning collaboratively is represented by a set of educational approaches, involving joint intellectual effort by learners, or learners and teachers together [30]. Collaborative learning activities vary widely, though most of them are centered upon student's exploration or application of the course material, not simply the teacher's presentation or explication of it.

However, many researchers [30][31][32] argue that students must be meaningfully engaged in the CSCL resources for effective collaborative learning to occur. A lack of engagement in on-line collaborative learning content can be attributed to the lack of (i) real interactivity (in many cases the only interaction available is to click on the next button to obtain the next message in a discussion forum); (ii) challenging collaborative tools, instead of tools which fail to stimulate learners, making the collaborative experience unattractive and discouraging progression; and (iii) empowerment, as learner expects to be in control of their own collaborative learning.

Other reasons that can affect the engagement in popular collaborative learning technologies, such as discussion forums, are: (i) large number of contributions, which are hard to follow by students and tutors; (ii) dispersion of knowledge, which is hard to separate from the straw, and is usually unordered; and (iii) text-based contributions, which are tedious to read[9]. On the other hand, discussion forums associated with an academic course exist are usually close and forgotten, even deleted, at the end of the course, thus the collaborative knowledge generated in the discussion is lost or hard to reuse in further courses.

Finally, current Learning Management Systems (LMS) do not support a straightforward integration of modern pedagogical models and methodologies nor the corresponding complex learning resources yielded [33]. Instead, great development efforts must be made to integrate these resources into LMSs, most of times in an ad hoc fashion, with very inefficient results in terms of productivity, quality and cost [34][35]. Further, LMS developers have no opportunities to leverage computational experiences of on-line collaborative learning designed to meet modern and changing pedagogical requirements, hence the knowledge reuse capacity in this field is rather low [36].

The purpose of the research conducted in this thesis is to propose solutions to overcome the above mentioned limitations. In particular, the provision of a software infrastructure to support new types of pedagogically augmented collaborative learning methodologies and resources by means of an innovative application framework [52] called Virtualized Collaborative Sessions Framework (VCSF). The VCSF supports the entire process of creation, management and execution of Collaborative Complex Learning Resources (CC-LR) [4] from any LMS and collaborative learning tool. As part of the process, the VCSF leverages Web semantic technologies [7] to enable e-learning software developers to embed many types of successful collaborative learning experience into different LMSs in a software reuse and systematic fashion. The ultimate aim is to provide online collaborative learning with software reuse capability from the systematical application of our software framework approach as well as the resulting pedagogical benefits, such as increasing students' engagement and learning performance.

The rest of this section is structured as follows: section 1.2 presents the state of the art in the research field and section 1.3 summarizes the object of research and the main contributions of this work. The structure of the remaining chapters in this thesis is presented in section 1.4.

1.2. State of the art

In this section, a brief overview of each of the technologies and paradigms related to this work is presented, namely (i) Computer-Supported Collaborative Learning, (ii) Collaborative Complex Learning Resources; (iii) Learning Management Systems; (iv) software infrastructure for collaborative learning; (v) technology support for collaborative learning, and (vi) Semantic technologies. This overview will serve as background for setting the main goals of this research, which are defined at the end of this section, becoming the very rationale of the software infrastructure approach for collaborative learning presented in this work.

1.2.1. Computer-Supported Collaborative Learning

Computer-Supported Collaborative Learning (CSCL) is one of the most influencing research paradigms dedicated to improve teaching and learning with the help of modern information and communication technology [29][37][38][39]. Collaborative or group learning refers to instructional methods where students are encouraged to work together on learning tasks. As an example, Project-based Collaborative Learning proves to be a very successful method to that end [31]. Therefore, CSCL applications aim to create virtual collaborative learning environments where students, teachers, tutors, etc., are able to cooperate with each other in order to accomplish a common learning goal.

To achieve this goal, CSCL applications provide support to three essential aspects of cooperation, namely coordination, collaboration and communication, with communication being the base for reaching coordination and collaboration [40][36]. Collaboration and communication might be synchronous or asynchronous. The former means cooperation at the same time with the shared resources not typically having a lifespan beyond the sharing while the latter means cooperation at different times being the shared resource stored in a persistent support.

1.2.2. Collaborative Complex Learning Resources

Collaborative Complex Learning Resources (CC-LR) were defined in [4] as modern pedagogically augmented learning resources based on the Collaborative Complex Learning Object (CC-LO) approach, which was first presented and discussed in [3]. This innovative concept of CC-LO was justified by setting up two research questions about what makes a Learning Object (LO) [41] collaborative and what makes a LO complex, which cannot be easily answered by current standard learning objects. The key differentiators from the standard LO include multiple levels of abstraction from pedagogic context, learners, and representational medium (complexity), as well as intrinsic support for interaction across the object (collaboration) [33] [42]. To accommodate the above concepts with the model co-proposed by the candidate [3], first, a CC-LO was embedded into a new software system called Virtualized

Collaborative Session (VCS) [11] with the aim to register live collaboration sessions and augment them by alternative flows, additional content, assessment, etc., during an authoring phase (subsequent to the registration phase). The VCS is made to be compatible and interoperable with broad collaborative sessions, such as chats and discussion forums [7], in order to create specific types of CC-LO (e.g. Storyboard Learning Object (SLO)) [3]. Therefore, the VCS system converts source data from the live collaboration into standard data format and creates specific SLOs, containing information about scenes, characters, and other artifacts used during the later visualization of this learning object. The result is an interactive and animated storyboard where learners can observe how knowledge is constructed, refined and consolidated (see figure 1).

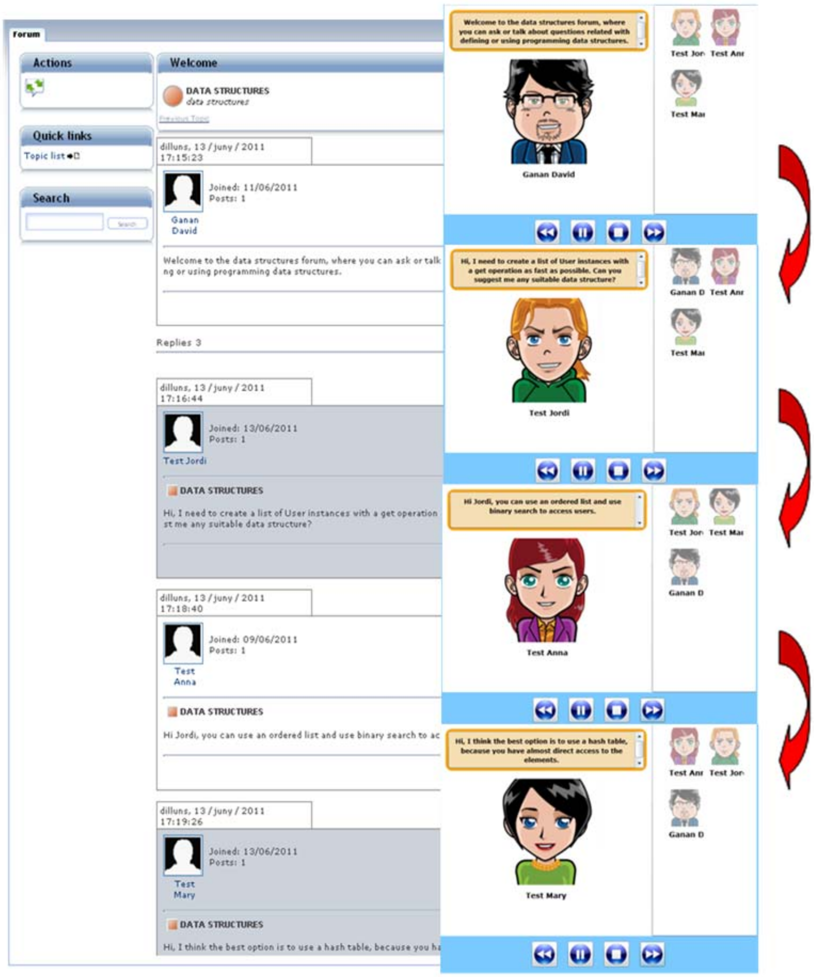


Figure 1 - Screenshot of the VCS system showing a SLO with a discussion evolving overtime, produced by the virtualization of a live text-based collaborative session performed in a web forum.

Then, the CC-LO approach was extended towards the invention of CC-LR as complex learning material that is used, adapted and reused extensively in academic courses beyond the original collaboration [4]. To this end, the CC-LOs are edited by the VCS system to include complex aspects of the learning process, such as alternative paths, cognitive assessment and emotional awareness. Finally, the CC-LOs are packed and stored as CC-LR for further reuse so that future learners can leverage the benefits from past sessions of live collaborative learning enriched with high quotes of interaction, challenge and empowerment. In particular, two important extensions of the CC-LO approach were exploited when proposing the new CC-LR: cognitive assessment [16] and emotional awareness [15] (see figure 2).

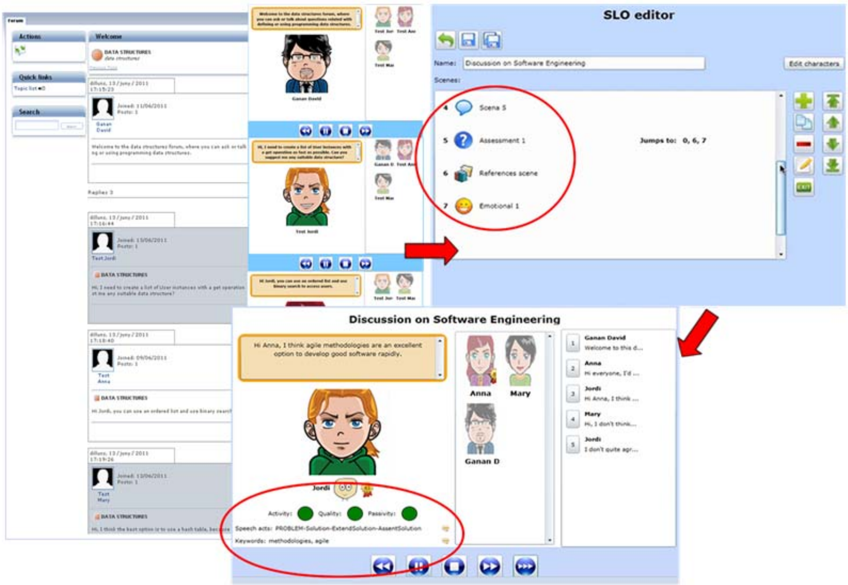


Figure 2 - The process of producing, managing and storing a CC-LR by the VCS system from a CC-LO, incorporating different types of scenes and author information, such as cognitive and emotional information of the original participant and contributions.

1.2.3. Learning Management Systems

Learning Management Systems (LMS) are software packages to enable the management of educational content and also integrate tools that support most of groupware needs, such as e-mail, discussion forums, chat, virtual classrooms, and so on [43]. Over the last years, a great amount of full-fledged Web-based LMS systems have appeared in the marketplace [44][45] offering designers and instructors, generic and powerful user-friendly layouts for the easy and rapid creation and organization of courses and activities, which can then be customized to the tutors' needs, learner's profile and interests, and to specific pedagogical goals.

Representative LMS systems are Moodle (http://moodle.org), Blackboard (http://www.blackboard.com), Sakai http://www.sakaiproject.org), and others, such as the Intelligent Web Teacher (IWT) [46], and the UOC Virtual Campus[1], which all are being extensively adopted by educational organizations to help both educators create effective online learning communities, and educational institutions to highly customize the system to suit their pedagogical needs, and technological requirements.

Despite the great support of LMS systems to important areas such as communication, collaboration and assessment [36], very few of them are focused specifically on collaborative learning, given that they support collaboration as another learning option. Another common drawback is the lack of interoperability (e.g. Moodle is entirely written in PHP, and Sakai in Java), thus making the applications dependent from the programming language, underlying infrastructure, and so on.

Moreover, current popular LMS platforms, such as Moodle [47], are evolving by exposing certain aspects of their functionality externally and separating content from tools. However,

[1] The Open University of Catalonia (UOC) is located in Barcelona, Spain. Through its Virtual Campus, the UOC offers fully distance education over the Internet to 50,000 students.

they still focus strongly on learning administration rather than on the learner [48] and are unable to offer the expected degree of flexibility, interoperability, scalability and reusability as the key challenges for the next generation of the LMS platforms.

1.2.4. Software infrastructure for engineering collaborative learning applications

Generic platforms, frameworks and components are normally developed for the construction of complex software systems through the reuse technique [36][49][50][40][52]. This approach has been successfully applied to different domains thus providing applications of increased quality, and reduced cost and development time [53][54].

In particular, application frameworks promote a standard structure for developing software applications and tools. Programmers find it much simpler to develop automatic creation tools when using a standard framework, since this defines the underlying code structure of the application in advance. Developers usually use object-oriented programming techniques to implement frameworks such that the unique parts of an application can simply inherit from pre-existing classes in the framework [50]. Application frameworks became popular with the rise of graphical user interfaces (GUIs) and Web applications, which alleviate the overhead associated with common activities by providing libraries for database access, template frameworks and session management, and therefore promoting code reuse [41]. The outcome of this thesis work follows this application framework approach.

However, a revision of the latest research to provide framework support for the development of applications within the field of CSCL domain shows that the results are still scarce (see [55] and [56] for an extensive overview of related work). Main focus is still on leveraging the great research efforts and technological advances within the general Computer-Supported Cooperative Work (CSCW) domain [57][58][59][60][61]. These approaches provide exhaustive support for cooperative work, such as group and workflow management, group editing, document sharing and many types of both synchronous and asynchronous communication [58]. However, many of them are not even prepared to support essential collaborative learning features, such as collaborative knowledge building and scaffolding as well as specific monitoring and assessment of the learning process [31]. Representative researchers [32] argue whether intrinsic CSCL requirements should be considered from the very beginning of the development and not as an extension to experimented CSCL tools for work [62].

Among the efforts that are currently being made by different consortia and initiatives around the world, there exist a variety of frameworks in the form of standard specifications and guidelines for e-learning platforms [48][55]: the IMS Abstract Framework (www.imsglobal.org/specifications.html) loosely identifies and represents the core components and interfaces of an e-learning system. The E-Learning Framework (ELF: www.elframework.org) illustrates e-learning systems common functionalities. Similarly, the Open Knowledge Initiative (OKI: www.okiproject.org) defines service layers for developing e-learning platforms. The common approach among these emergent standards is to modularize functionality, usually defining the following groupings [56]: application services (educational domain dependent that provide the functionality required by agents, such as content management and assessment); common services (provide lower-level functionality upon which educational-domain services and users depend, such as authentication, archiving and service directory); core infrastructure services (cross-domain set of services, such as lookup, policy, replica management and scheduler).

1.2.5. Technological approach for enhancing collaborative learning applications

Technologists have made many attempts to provide better tools for content creation and management, and for the execution of learning resources to educators, but the transition from the role of content creator to moderator generates inherent resistance in the educator [48]. In particular, CSCL tools commonly focus on the provision of design aids to educators, which seek to ensure best-practice in pedagogy by the software and its user interface [63]. This has the potential to address the common concern in technology-supported learning of technologists, rather than educators, taking a lead role [64] by lowering the technological skills required to create and implement scenarios.

The research drive here is to create CSCL tools that are abstracted from low-level technical implementation. However the concept of a CSCL tool embeddable within different LMS, demands to realize it in practice. Such demand arises from the evolving nature of technology and its increasing ability to facilitate various learning styles and content items. Therefore, the transfer of pedagogic content between technologies requires some ability to adapt this content autonomously to meet the capability of the system.

1.2.6. Semantic knowledge engineering technologies for learning

There has been a great effort in the Semantic Web community in order to provide specifications, standards and ontologies to facilitate semantic processes in learning [65][66]. The difficulties of the current standards and specifications for defining learning objects unambiguous specifications pose a serious problem in its adoption to semantic approaches [67]. Several ontologies have been created to define learning objects unambiguously. The more representative of them are [68][69][70][71][72].

Semantic approaches related to the definition and implementation of learning processes in the field of CSCL include [73], which defines an ontological framework to describe the common semantics needed for the implementation of collaborative learning environments. [51] also proposes the use of educational patterns in a Domain Specific Language fashion in order to specify and reuse processes that occur repeatedly in learning environments, providing a good alternative to model and reuse learning processes. Similarly, [74][75] use ontologies in a model driven approach in order to use a standard vocabulary to specify learning artifacts and mechanisms to automatically implement such artifacts in different LMS. In a higher level of abstraction, the authors in [14] propose a framework that supports bottom-up learning processes, such as support registration, management, and sharing methods. They also create high-level elements, such as courseware and e-learning tools, with remarkable benefits of ubiquity and interoperability, in line with tutors needs and requirements. Indeed, with a well-defined ontology structure, collaborative learning can accumulate the knowledge representation of learning objects and their use, including participant background, instruction designs, learning activities and outcomes, etc. [73].

To sum up, current attempts fail in providing appropriate response to the two main objectives of our research: (i) provision of software infrastructure to support advanced types of pedagogically augmented collaborative learning resources, and (ii) enable LMS developers to systematically reuse successful collaborative learning sessions and the generated knowledge. To this end, this thesis work presents a methodological approach to validate our VCSF approach aimed to yield more effective and quality pedagogically augmented CSCL applications while saving development time and effort.

1.3. Object of research

Considering all the above, current attempts fail in providing appropriate response to the main objectives of this thesis:

- Provision of a software infrastructure to create and support advanced types of pedagogically augmented CC-LRs coming from CC-LOs, thus increasing interaction, challenge and empowerment.
- Provide flexible mechanisms to facilitate the addition of further functionalities into the framework and CC-LOs in the future.
- Enable LMSs to systematically reuse successful collaborative learning sessions by means of CC-LOs.
- Leverage multimedia technologies to enhance and improve the collaborative learning experience.
- Provide authoring tools to simplify the task of creating and modifying CC-LOs and CC-LRs, especially for teachers without technological skills.
- Promote the use of eLearning standards in order to enhance interoperability and portability of learning systems and applications.

To this end, next section presents the main contributions of this thesis, which report on the development and validation steps of the VCSF framework aimed at yielding more effective and quality pedagogically-augmented CSCL applications while saving development time and effort.

1.4. Structure of the thesis

The rest of this thesis report is structured as follows. Section 2 presents a summary of the three main contributions of this thesis work, while Section 3 shows the main conclusions and results obtained as well as highlights future directions of research. Finally, Appendix A includes the letter of acceptance of one of the main publications, and Appendix B includes the program committees were the candidate has participated or will participate in the near future.

2. Contributions of the thesis

The main contributions of this thesis are included below. The versions given in this thesis are post prints as the authors do not have permission to distribute the published papers.

2.1. CC-LO: Embedding Interactivity, Challenge and Empowerment into Collaborative Learning Sessions

Caballé, S., **Gañan, D.**, Dunwell, I., Pierri, A., Daradoumis, T. (2012). *CC-LO: Embedding Interactivity, Challenge and Empowerment into Collaborative Learning Sessions*. Journal of Universal Computer Science (J.UCS), Vol. 18, No. 4, pp. 25-43. Verlag der Technischen Universität Graz. DOI: 10.3217/jucs-017-01-0025. ISSN: 0948-695X. IF: 0.762, Q3: 54/100 (JCR-2012 SE).

Despite their demonstrated potential through a range of early studies, on-line collaborative learning systems do not yet have the impact that many believe is possible. In particular, collaborative learning approaches cannot be readily applied to every e-learning experience, since they require a degree of presence and/or collaboration which may be difficult to achieve. In addition, collaborative learning systems often lack the challenging resources and tools required to fully support collaborations, making the experience unattractive to end-users and discouraging progression. Whilst the learner might expect to control the collaborative experience, often it is the collaborative experience that controls and limits the learner. As a result, collaborative learning resources can lack authentic interactivity, user empowerment and balanced levels of challenge, thus having a negative effect in learner motivation and engagement. In order to overcome the above deficiencies, this contribution proposes a new paradigm named Collaborative Complex Learning Objects (CC-LO): a special type of Learning Object which aims to leverage the knowledge elicited during live sessions of collaborative learning, augmented with author generated information, to produce interactive and attractive resources to be experienced and played by learners. During CC-LO execution, learners can observe how avatars discuss and collaborate, how discussion threads grow, and how knowledge is constructed, refined and consolidated. Furthermore, learners can interact with the CC-LO in order to modify some parameters observing the consequences and assessing their understanding.

Overall, this contribution presents the CC-LO approach as a new paradigm to provide collaborative tools, which are challenging and attractive resources that enable learners to interact with the content, thus increasing their motivation and engagement in the learning process.

Journal of Universal Computer Science, vol. 18, no. 1 (2012), 25-43
submitted: 15/7/11, accepted: 9/12/11, appeared: 1/1/12 © J.UCS

CC-LO: Embedding Interactivity, Challenge and Empowerment into Collaborative Learning Sessions

Santi Caballé, David Gañán
(Open University of Catalonia, eLearn Center, Barcelona, Spain
{scaballe, dganan}@uoc.edu)

Ian Dunwell
(Coventry University, Serious Games Institute, Coventry, United Kingdom
IDunwell@cad.coventry.ac.uk)

Anna Pierri
(Modelli Matematici e Applicazioni (MoMA, SpA), Baronissi, Italy
pierri@momanet.it)

Thanasis Daradoumis
(University of the Aegean, Dept. of Cultural Technology and Communication
Mytilene, Lesvos, Greece
daradoumis@aegean.gr)

Abstract: Despite their demonstrated potential through a range of early studies, on-line collaborative learning systems do not yet have the impact that many believe is possible. In particular, collaborative learning approaches cannot be readily applied to every e-learning experience, since they require a degree of presence and/or collaboration which may be difficult to achieve. In addition, collaborative learning systems often lack the challenging resources and tools required to fully support collaborations, making the experience unattractive to end-users and discouraging progression. Whilst the learner might expect to control the collaborative experience, often it is the collaborative experience that controls and limits the learner. As a result, collaborative learning resources can lack authentic interactivity, user empowerment and balanced levels of challenge, thus having a negative effect in learner motivation and engagement. To overcome these deficiencies, we propose a new paradigm named Collaborative Complex Learning Objects (CC-LO): a special type of Learning Object which aims to leverage the knowledge elicited during live sessions of collaborative learning, augmented with author-generated information, to produce interactive and attractive resources to be experienced and played by learners. During CC-LO execution, learners can observe how avatars discuss and collaborate, how discussion threads grow, and how knowledge is constructed, refined and consolidated. Furthermore, learners can interact with the CC-LO in order to modify some parameters observing the consequences and assessing their understanding. The research reported in this paper was undertaken within the European Framework 7 project ALICE (Adaptive Learning via Intuitive/Interactive, Collaborative and Emotional Systems).

Keywords: Collaborative Learning, Collaborative Complex Learning Objects, Virtualized Collaborative Sessions, On-line Discussions
Categories: K.3.1, L.1.2, L.3.0, L.3.6

1 Introduction

On-line collaborative learning is a mature research field in the educational domain dedicated to improving teaching and learning through the introduction of modern ICT [Dillenbourg, 1999]. Collaborative learning is represented by a set of educational approaches, involving joint intellectual effort by learners, or learners and teachers together [Goodsell, 1992]. Collaborative learning activities vary widely, though most of them are centred upon students' exploration or application of the course material, not simply the teacher's presentation or explication of it. However, many researchers [Dillenbourg, 1999; Goodsell, 1992; Stahl, 2006] argue that students must be meaningfully engaged in the learning resources for effective learning to occur. Such a lack of engagement is especially evident in collaborative learning content, and can be attributed to the lack of (i) real interactivity (in many cases the only interaction available is to click on the "next" button to obtain the next message in a discussion forum); (ii) challenging collaborative tools, which fail to stimulate learners, making the collaborative experience unattractive and discouraging progression; and (iii) empowerment, as learner expects to be in control of their own collaborative learning.

To overcome these and other related deficiencies, Learning Objects (LOs) have received much attention in recent years as technology that enables educational elements to be repackaged and reused far more readily than was previously the case [Littlejohn, 2003; Friesen, 2004; Polsani, 1997; Wiley, 2001]. In particular, the emergence of the Internet as a medium for educators, with its capacity to reach large audiences and bring together content from a wide range of sources, has been of significant interest. The initial definition of an LO is given [see Gerard, 1967] as self-contained and reusable elements of learning. More recently, the IEEE Learning Technology Standards Committee provided the following working definition: Learning Objects are defined as any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning. Common themes from literature include:

- A need for a minimalistic approach to individual LOs. The greater a larger learning process (e.g. a training course) can be decomposed into individual LOs, and the more succinct these LOs and their constituent elements are, the greater their potential for repurposing.
- A focus on repurposability. The ultimate purpose of deconstructing a larger learning process into individual LOs is to facilitate straightforward repurposing of the individual elements to form part of other learning processes and pedagogic approaches [Polsani, 1997].
- Technical compatibility and format consideration. An increasing issue, as technology advances, is the transition towards new media for education, such as virtual worlds and collaborative online environments. As well as the pedagogic considerations that must be attached to this transition, technical consideration must also be afforded to how elements may transition from one collaborative online environment to another. This composability has long been a goal of virtual environment designers [Zyda, 2005], and the adoption of common formats for the representation of virtual content is increasingly enabling it to be moved seamlessly between game engines and virtual world platforms.

- Freedom in the definition of content. Content itself can be any form of media, as long as it is attached to an educational context [Kaldoudi, 2009], a definition which includes resources that have not been initially developed for educational purposes. Ultimately, content must be defined by the creator of an LO, not the end user: this is the nature of repurposement. Technological and pedagogic compatibility are not necessarily harmonious [Zyda, 2005] and the need is upon the designer of both the content and overarching system to ensure compromise is reached.

As the concept of the LO becomes well-defined and broadly accepted, an extension of this definition is needed to address the requirements of learners in collaborative scenarios, pedagogically designed with reference to the concepts of social and collaborative learning [Vygotsky, 1978; Bandura, 1979; Collazos, 2007]. The key differentiators from the standard LO include multiple levels of abstraction from pedagogic context, learners, and representational medium (complexity), as well as intrinsic support for interaction across the object (collaboration). Hence, extending the LO paradigm we reach the notion of "Collaborative Complex Learning Object (CC-LO)" [Caballé, 2011] by asking two fundamental questions: what makes a learning object complex, and what enables a learning object to be collaborative?

In order to define a CC-LO we consider first what makes a collaborative learning object. There are two principle ways in which collaboration occurs, collaboration in the formation of the object, and collaboration in its active use [Fuentes, 2008]:

- Collaboration in creation: Several platforms exist for the collaborative creation of LOs by educators. This can adopt a principle of segregated responsibility, whereby individuals are responsible for various elements of an object (e.g., independent designers for educational materials and assessment methods), or shared responsibility, whereby educators play a role in peer-reviewing and adapting content. [Boskic, 2003] describes the critical nature of this role, though discusses how it may extend to the perception of LO use and reuse in general, rather than best-practice for creation. [Vargo, 2003] address how such evaluation may be automated, concluding this remains most effective when implemented in a synergistic fashion with the educators.
- Collaboration in use: A collaborative learning object in this sense is capable of responding to and facilitating interaction by multiple simultaneous learners. It is hence a communication medium, through which learning objectives are achieved by the collaboration and social learning environment it forms [Collazos, 2007]. However, this simple notion brings with it a host of questions: the object must embed pedagogy and assessment to conform to the expectations of a standard LO [Wiley, 2001]. It must simultaneously accommodate multiple interactions and shared space, whilst also supporting the need for other groups of learners to approach it in different times and reuse it. [Farrell, 2004] describe the concept of dynamic creation of learning objects, in this case we see the emergence of a methodology whereby the learning object becomes analogous the object-orientation metaphor: it has a class (an overarching definition), and instances (multiple creations of that object with its different states in flux).

Of these two components, despite in inherent interdependence (a collaborative learning object allowed to evolve is effectively being recreated over time), the latter is of greatest interest and relevance to the social pedagogies [Bandura, 1979]. A true collaborative learning object in this sense is one which supports this collaboration between learners and the subsequent emergence of societal groups to create the shifts in social norms required for behavioural and attitudinal change.

The second consideration in defining a CC-LO is what makes a 'complex' learning object. The chief sources of may be defined with respect to pedagogy as well as the technical complex implications these pedagogic affordances imply, as follows:

- Applicability: A trait common to pedagogic as well as technical consideration is how widely an LO can be repurposed across technical domains. A CC-LO, under this definition, has the capacity to be deployed into an online collaborative environment as an encapsulation of learning activity, assessment, and integration. The learning activity could be through direct interaction with the learning object in a virtual incarnation (e.g., an object could be given physical form as a Virtual Scientific Experiment (VSE)). Further applicability to content rating systems is also a worthy consideration [Kumar, 2005].
- Evaluability: Following on from the need for content rating and assessment in order to provide adequate selection tool for educators, CC-LOs must support evaluability in pedagogic and technical terms [Ertl, 2010]. A key principle in the definition of any learning object is the implicit co-relationship between education and assessment, and a learning object must provide the interface to not only assess its users [Leal, 2011], but also to provide comparative evaluation for the purposes of repurposement selection. For a holistic view, this needs to come from the learner as well as the educator.
- Internal dynamicism: [Valderrama, 2005] describe the concept of creating learning objects which are themselves able to adapt to context. These 'intelligent' LOs are able to adapt to their content autonomously, removing the need for the end-user to undertake substantial repurposing work. We describe in [Section 2] the concept of a virtual collaborative session: in these sessions CC-LOs are instanced and evolved over time, but retain the capacity to reset to an initial state to allow their reuse with other groups of learners. Any form of adaptivity implies a core template and source exists, and our definition of a CC-LO here suggests a need for the ability to define CC-LOs in time-independent states (the core repurposable LO), and time-dependant states (following learner interaction and evolution). We refer to this as internal dynamicism, as the state of a CC-LO must adapt to collaborations, yet be supported by a core instance of the CC-LO from which these dynamic versions evolve.
- Composability. Virtual environments have long spoke of the need for content to be more easily composable [Macedonia, 1997]. Frequently, objects are created which are explicitly linked to a single learning environment through their singularity in technical implementation, and failure to dissociate learning objectives from implementation issues. A CC-LO in this sense must be defined in broader and platform-nonspecific terms.

In practice, these paradigms lead to common attributes specific to CC-LOs:

- Augmentation with author-generated information. This can take multiple forms:
  - Questions & answers: discursively-generated information can help evaluators assess indirectly the strengths and weaknesses of a CC-LO.
  - Alternative flows: internal dynamicism supports non-linear paths through CC-LOs.
  - Assessments: since flow is not linear, assessment must track the path of the learner through the CC-LO and provide relevant assessment.
  - Dependencies: applicability and composability are required to take the form of either interdependencies with other CC-LOs, dependencies on other simple LOs, or dependences upon the learning environment.
- They are animated and evolve over time. The forms of animation can be simple, such as movies or comic strips, allowing learners to observe how avatars discuss and collaborate and how knowledge is constructed, refined and consolidated. Alternatively, this animation can be a more sophisticated virtual simulation. In all cases, the animation should be composable.
- They are interactive. Learners can interact to modify some parameters, observing the consequences and assess their understanding. This implies they are instantiable – learners have their own instance of a CC-LO which can either be disposed of, or integrated into the initial CC-LO after a learning activity.

In order to accommodate these concepts, under the model proposed by this article a CC-LO is embedded into a Virtualized Collaborative Session (VCS) [Caballé, 2011]. A VCS is a registered collaboration session augmented by alternative flows, additional content, assessment, etc., during an authoring phase (subsequent to the registration phase). The VCS can be interactive and animated (by movies or comic strips) and learners can observe how knowledge is constructed, refined and consolidated. In this context, CC-LOs also include assessment, collaboration and communication features to enrich the learning experience provided by the VCS. The VCS containing the CC-LOs is eventually packed and stored as learning objects for further reuse so that individual learners can leverage the benefits from live sessions of collaborative learning enriched with high quotes of interaction, challenge and empowerment.

Focusing specifically on the objectives of the European Framework 7 project ALICE[1], in this article we uncover the notion and nature of this new CC-LO paradigm. To this end, [Section 2] provides a description of the scope and aims set for this research, alongside a concise discussion of the methodological background for the creation, management and execution of CC-LOs. [Section 3] presents a methodological approach with the aim of validating this definition of the notion and nature of a CC-LO through the development of a prototype VCS system which enables the embedding of CC-LOs. The prototype components are then technically tested by a proof of concept in [Section 4] along with a discussion on the results achieved. [Section 5] concludes the paper by highlighting the key concepts covered in this contribution and outlining ongoing and future work.

---

[1] ALICE project web site: http://www.aliceproject.eu

2 Aims and Background

A key aim of this research was to review the main processes and concepts of the new paradigm of CC-LO, and advocate guidelines for the use of CC-LOs both within the ALICE project and by educators on a wider scale. In this section, we first describe the goals of the ALICE project related to this research work and then we present existing work that help understand and use the concepts related to the CC-LO.

2.1 The ALICE Project

The general objective of ALICE (Adaptive Learning via Intuitive/Interactive, Collaborative and Emotional Systems) is to build an innovative adaptive environment for e-learning combining personalization, collaboration and simulation aspects with an affective/emotional based approach, able to contribute towards overcoming the existing limitations of current e-learning systems and content. The proposed environment is to be interactive, challenging and context aware, whilst realising learners' demands of empowerment, social identity, and authentic learning experiences.

The ALICE starting point is an existing e-Learning platform, Intelligent Web Teacher (IWT) [Capuano, 2009] already developed to exploit experiences and know-how gained through several EC projects. IWT seeks to customize the learning experience through understanding of real learner needs and preferences, whilst ensuring extensibility and flexibility at content, pedagogic and service levels. With respect to the basic aspects of collaboration, the project pursues a broad set of objectives related to collaborative learning. ALICE studies in depth themes surrounding collaborative learning in situations where learners have to develop specific skills (e.g. communication, problem solving, decision making, etc.) and collaborative activities can increase learning efficacy. However, collaborative learning approaches cannot be applied in every e-learning experience as they require a degree of presence. Consequently, a paradigm is required to reuse, in formal, informal or intentional learning contexts, the knowledge elicited during collaborative learning activities. Furthermore, this approach must sustain the advantages achieved through such an approach after the closure of the live sessions, preserving aspects such as social interactions, conversational processes and the evolution of discussion threads.

In order to achieve the aforementioned goal, the paradigm of CC-LO is proposed and defined as special types of learning objects embedded into VCSs, obtained by registering live collaborative sessions executed in Web-based environments, and augmenting (during an authoring phase) the tracked data with author-generated information (questions & answers, alternative flows, assessments, dependencies, etc.) to define attractive interactive resources experienced by learners through several different experiences. During the CC-LO execution, a VCS is animated in such a way (using movie or comic strips metaphors) that learners can observe how avatars discuss and collaborate about one or more topics, how discussion threads grow, and how knowledge is constructed, refined and consolidated. Furthermore, learners can interact with the CC-LO in order to modify some parameters observing the consequences and assess their understanding.

2.2 Related Work

A range of methods for creating, managing, and executing learning objects exist and may be applied to the case of CC-LOs. Dynamic assembly of learning objects has gained increased focus as technological capacity to manage and deploy in real-time becomes increasingly viable [Farrell, 2004]. Therefore creation is not restricted to offline development and instructor-led pedagogic design. However, ensuring quality and a usable end-product remains a concern for automated construction techniques.

Particularly, if dynamicism extends to the learning session itself, inconsistencies in learner experience may potentially arise. Furthermore, management of LOs becomes an increasingly demanding task in the face of dynamicism, as LOs may evolve over time, invalidating attempts to index and categorize them effectively. This is particularly true of a collaborative LO, and hence the virtual collaborative session is defined in our research [see Section 3] as a means to control this evolution and afford dynamicism. In general terms, learning object-based systems have met with most success in subject areas such as information technology, in part because there is little established content for these topics, as well as constant evolution in the state-of-the-art, and in part due to the fact educators within these disciplines are more ready to engage with technology [Abernethy, 2005]. Reaching core areas such as literacy and numeracy is a more demanding task both due to the nature of the subject matter, and the experience of educators working within the area.

Commonly, methods for creating learning objects have centered on mining existing information to construct learning objects autonomously [Rajendra, 2004]. The inherent appeal of this process is its ability to capitalize on the large volumes of semantic data present on the web and create educational material whilst requiring a minimum of involvement from educators. Some semantically-annotated sources [Auer, 2007], are particularly appealing sources of educational material. Validation of data from such a source remains a key concern, although these repositories are drawing increased attention as the veracity of peer-created data sources on the web is increasingly shown [Margaryan, 2007; Wang, 2010]. Participatory techniques have also been used for LO creation. These build upon the use of the creation process itself as a means for learning, instilling learners with increased engagement as a result of deeper engagement within the educational process [Abad, 2008]. However, the composability of these learning objects may prove a concern, as students are not best-placed to act as pedagogic designers thus requiring the resulting learning objects careful validation and development to ensure quality.

Early Learning Content Management Systems (LCMS) were closely integrated into existing e-Learning configurations as extensions or additions to content acquisition and control systems [Meinel, 2002]. More recently, the management of learning objects has benefited significantly from the application of semantic technology [Su, 2008]. Similarly, methods to extrapolate semantic relationships by direct and automated analysis of learning objects also exist, having been explored [Taibi, 2007]. This can be achieved through the use of content representation models, such as the Sharable Content Object Reference Model (SCORM), to enable the provision of a wide range of comparators. Peer-to-peer (P2P) approaches to learning object management have also been shown to have benefits in load distribution [Prakash, 2009], though bring with them the concerns common to peer-to-peer configurations around security and validity. Once adequately addressed through infrastructural design, a P2P management approach has strong long-term potential, and is of particular relevance to collaborative learning objects and CC-LOs since ownership must be carefully considered and assigned when deploying and devising learning objects for peer input and use.

An early review of repositories based on Learning Object Metadata (LOM) demonstrated significant advances in global standards for representation [Neven, 2002], and these have continued throughout the past decade. Yet the principal issue in the uptake of tools for LO creation and use remains in facilitating end-user involvement. Technologists have made many attempts to provide tools for content creation, management, and execution to educators [Mosley, 2005], however uptake remains limited. Fundamentally, though LO systems have the potential to make the teaching process less time-intensive in the development of course content, they transition the educator from the role of content creator to moderator, and hence generate some inherent resistance. Overcoming this requires that methods to better involve educators and allow their collaborative input are provided. Although LOM-based repositories offer strong potential to support independent learners working solely through e-Learning systems [Dinis, 2009; Leal, 2011], their use as a basis for tutor-led or collaborative activities requires much research [McGreal, 2006]. It is a consequence of this need that the notion of the CC-LO is explored within this paper.

The execution of learning objects has previously been achieved through methods such as the SCORM Run-Time Environment (RTE) [Costagliola, 2006]. The RTE defines a model by which LOs can be launched within a Learning Management System (LMS) and interchange data, allowing for user customization and adaptivity. The platform-independent nature of the system at the core allows for interfaces to be designed using server-side web scripting languages allowing for a high degree of dynamicism in the end-user interface and toolset. Evolution of learning objects over time is also supported across a range of formats, such as video learning objects [Fadde, 2009]. Overall, creating learning objects in an executable form represents a step-change in the context and autonomy in which they can be deployed, and reflects the transition of LOs from pedagogic material to semantic data constructs.

From the above approaches, methodologies for creating, managing, and executing CC-LOs can be largely grouped under three headings:

- Educator-centric: the educator assumes the role of author, moderator, and deployer of the CC-LO.
- Technology-centric: creation, management, and execution are handled by technology. Technology-centric case focuses on situations where an element of artificial intelligence or intelligent filtering is applied in lieu of a human expert.
- Learner-centric: these methods advocate techniques such as participatory design to allow learners to be involved in the creation and management of CC-LOs.

3 Research Methodology

This section presents a methodological approach to validate our definition of the notion and nature of CC-LOs by addressing the requirements of learners in collaborative scenarios, pedagogically designed with reference to the concept of collaborative learning. To this end, we first identify the notion of the "Virtualized Collaborative Session (VCS)" as an event in which CC-LOs are played and consumed by learners. Then, a newly created VCS system enabling the virtualization of collaborative sessions is presented to support the creation, management and execution of CC-LO. The realization of this system is reported from the requirements that conducted the development of a VCS prototype where CC-LOs are embedded. Finally, for validation purposes, a proof of concept of this approach is given that examines the embedding of a CC-LO into the VCS prototype, as well as the results of technical testing based on a set of indicators incorporated to measure and analyze user response.

3.1 Definition and Purpose of Virtualized Collaborative Sessions

Perhaps the best definition of a VCS can be achieved through analogy to a computer program. In this analogy, the learning objects exist as objects within the code, and the VCS is the overall execution of the program. As it runs, learning objects are created, evolve over time, and are subsequently disposed of. At termination, the evolved states of the learning objects are disposed of, and the VCS becomes ready to 'run' with new instances of CC-LOs from their initial templates, repeating the learning cycle to a new group of learners. This idea of the VCS is illustrated in [Fig. 1].

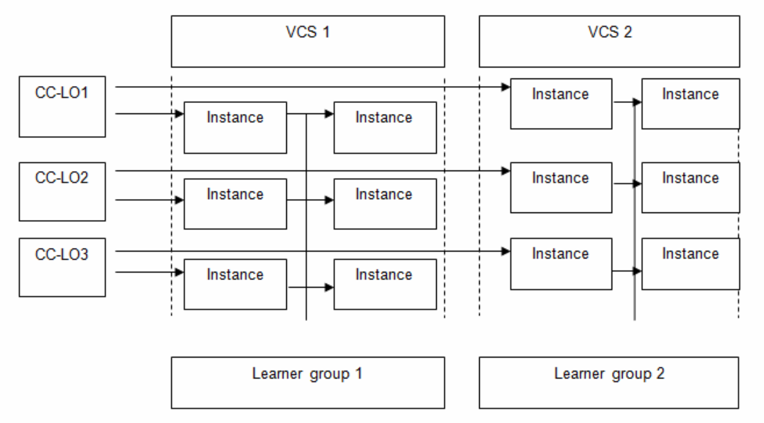


Figure 1: Execution of CC-LO instances within VCS programs

From this view, we capitalize on the instantiability of CC-LOs to facilitate multiple collaborative sessions in which CC-LOs evolve but remain reusable and reinstantiable for a second learner group. There are some notable considerations and benefits from this time-evolution, such as that the CC-LO can encapsulate the learning requirements on both pedagogic and technical levels, whilst retaining repurposability and reusability. Furthermore, as the VCS itself is not constrained to a single technical platform, compatibility with different platforms, such as forums and chats, can be facilitated through a driver interface (i.e., converter) to the CC-LO which, through middleware, converts it into the technical format required for representation within a given online collaborative environment.

3.2 Realization of the VCS System

Based on the above requirements, it becomes possible to propose some key guidelines for realizing a VCS system [Fig. 2]. The main feature of a VCS system is to be compatible with different kinds of chat messaging, forums or more general collaborative sessions to create CC-LOs. For this purpose, the input of VCS system is a file containing the collaborative session data in a common format called Collaborative Session Markup Language (CSML) based on XML. The CSML specifies an ontology named Collaborative Session Conceptual Schema (CS^2) that allows for modeling and representing knowledge about Web-based collaborative sessions [Conesa, 2011].

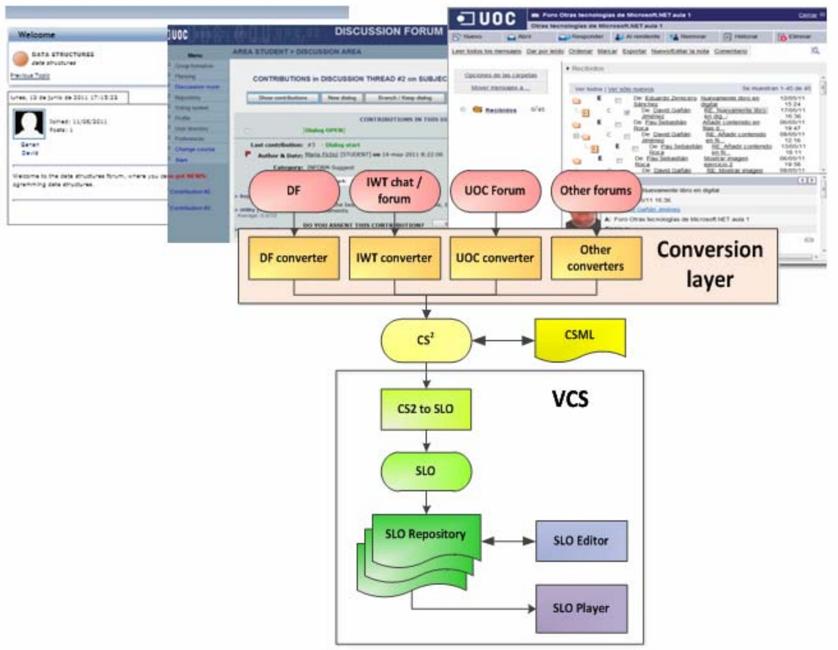


Figure 2: Architecture of the VCS system. The system is compatible with multiple forums and chats by specific converters

A first approach to a VCS system is depicted in [Fig. 2]. The process of conversion between the source of collaborative session data and CSML is done by a specific converter, which is different for each kind of source (i.e., the data model of a forum). Then, the VCS system processes data in CSML format and creates a complex learning object named Storyboard Learning Object (SLO), containing information about scenes, characters, and other artifacts used during the later visualization of this learning object. The SLO is editable by the use of a tool (SLO Editor), which allows for changing scene order, adding or removing content, adding assessment scenes, defining workflow, etc. Finally, the viewer tool (SLO Player) enables students and moderators to see the virtualized collaborative session in an interactive but read-only way. While the edition capabilities are still under development, the current status of our VCS prototype fully supports the viewer tool [Caballé, 2011].

Overall, the VCS transforms a live discussion forum into an animated storyboard and produces an event in which SLOs are played and consumed by learners, sessions evolve ("animate") over time, and the ultimate end-user interactions with SLOs are handled. As a result, the VCS becomes an attractive learning resource so that learners become more motivated and engaged in the collaborative activities [Fig. 3].

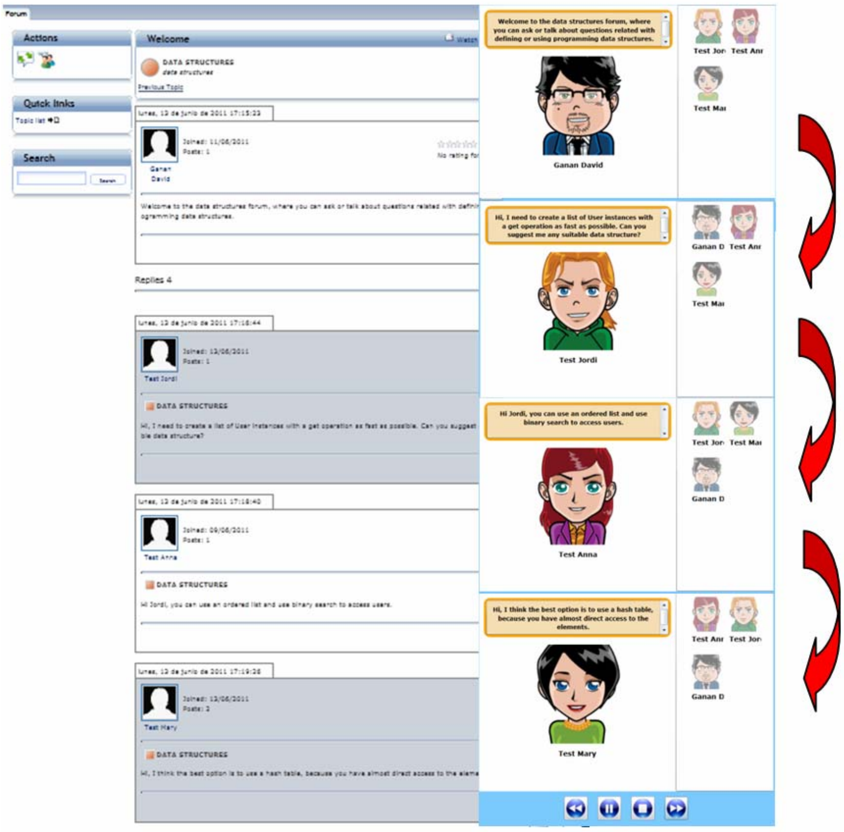


Figure 3: Sequence of snapshots of a CC-LO evolving over time after the virtualization of a live collaborative session. Four contributions of the text-based discussion are converted by the VCS prototype into an animated storyboard (SLO) supported by a text-to-voice engine

The extracted knowledge need to be represented by using typical standards of Semantic Web, such as: RDF, RDFS, OWL and SKOS [see, Fahad, 2011]. Simple Knowledge Organization System (SKOS)[2] is a family of formal languages designed for representation of thesauri, classification schemes and taxonomies.

---

[2] http://www.w3.org/2004/02/skos/

In the SKOS ontology each individual is a Concept [Fig. 4]. A Concept can have a label (skos:prefLabel) and one or more synonyms (skos:altLabel). Hierarchical relationships between concepts can be expressed through the properties skos:narrower (that links a concept to a more specific one) and skos:broader (that links a concept to a more generic one), while a simple correlation is expressed through skos:related .

A sequence of mapping steps transforms the fuzzy lattice, into a semantic technologies compliant representation. [see, Granitzer, 2011].

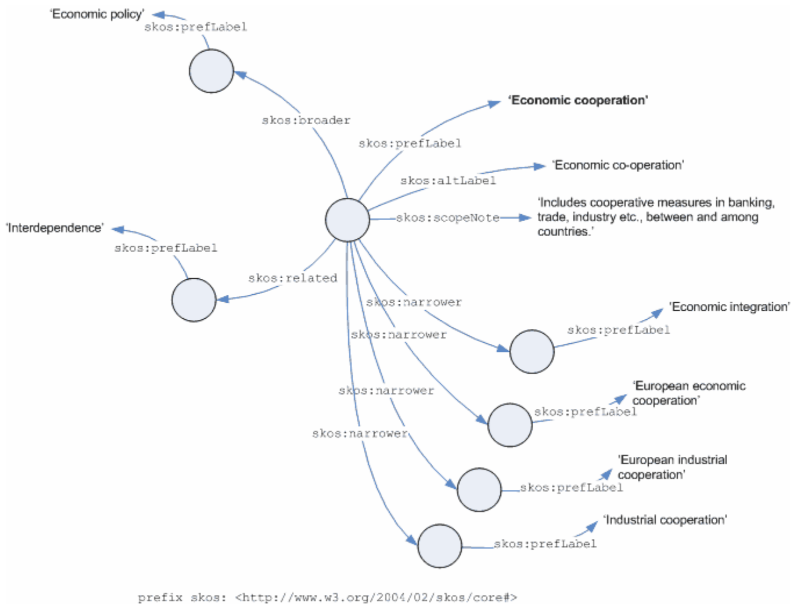


Figure 4: Example of use of SKOS

4 Experimentation and Validation

For experimentation and validation purposes, a proof of concept of the VCS prototype with an embedded CC-LO/SLO was developed [Fig. 3]. Firstly, the data source of a live collaborative learning session was derived from the IWT forums [Section 2.1], which are typically used to support in-class collaborative learning activities based on discussion. Then, following the process of modeling and representing forum data mentioned in [Section 3.2], a specific converter was built to turn the data model of the IWT forums into CSML representation [see, Conesa, 2011 and Fig. 2]. From the CSML representation, the VCS prototype generated an animated SLO showing how people discussed and collaborated, how discussion threads grew and how knowledge was constructed, refined and consolidated.

The design of the experiment consisted of three user assessments of the prototype with the aim to evaluate the proof of concept. The first at the Open University of Catalonia (Site A), the second at Coventry University Serious Games Institute (Site

B), and the third at the company Modelli Matematici e Applicazioni (Site C).

On all sites, a group of three types of testers were formed to provide three different evaluation perspectives, namely pedagogical, technical and usability. Thus, from the pedagogical perspective, domain experts (i.e., researcher and teacher in e-learning) were chosen; from the technical perspective, skilled technicians (i.e. developers with experience in e-learning systems) were selected; finally, novice users (i.e., students with experience in e-learning systems) performed testing on the VCS prototype to provide a usability perspective. Hence, each pilot site prepared a group of three testers, each of each type. Finally, the testing was run in each pilot site and by each tester by using different data input and running several executions of the prototype. The aim was to validate the concept of CC-LO by the next four indicators of interest asked to the VCS testers at the end of each test:

1. Build automatically an effective draft storyboard (CC-LO/SLO) from a threaded discussion coming from a forum. Score on scale 0-5 and open comments.
2. The VCS prototype allows non-expert users to build a CC-LO/SLO (i.e., in a friendly way and efficiently). Score on scale 0-5.
3. Create, edit, manage, store and playback the generated storyboard. Score on scale 0-5 and open comments.
4. The VCS prototype allows users to observe how knowledge is constructed. Score on scale 0-5 and open comments

		Indicators of interest				
	Testers	**#1**	**#2**	**#3**	**#4**	**Total (M)**
Site A	# Expert	4	4	2	2	3.0
	# Technician	5	4	4	3	4.0
	# Novice	5	4	4	2	3.8
Site B	# Expert	5	3	3	2	3.3
	# Technician	5	4	4	2	3.8
	# Novice	5	5	3	1	3.5
Site C	# Expert	5	5	4	3	4.3
	# Technician	5	4	3	4	4.0
	# Novice	5	3	4	4	4.0
	Total M(SD)	4.9(0.3)	4.0(0.7)	3.4(0.7)	2.6(1.0)	**3.7(0.4)**

Table 1: Mean (M) and Standard Deviation (SD) statistics in the 0-5 scale

4.1 Quantitative and Qualitative Results

This section presents a brief discussion on the data collected from the aforementioned subjective assessment performed at both sites on the VCS prototype.

[Tab. 1] shows, on the one hand, some basic statistics of the quantitative marks on the scale 0-5 scored by all testers for each of the four indicators of interest considered. Each tester performed 5 executions in a row before providing the scores.

On the other hand, [Tab. 2] shows an extract of qualitative results from those indicators with open comments provided by the testers after the test in questionnaires.

Indicators of interest with open comments	**Testers' open comments (type of the tester: E: Expert; T: Technician; N: Novice)**
Build automatically an effective draft storyboard from a threaded discussion coming from a forum.	"I could watch the storyboard very easily, it was exciting!" (N, Site A) "The automatically created SLO follows the same structure as the threaded discussion" (T, Site A) "To test fully [the system] would need to be compatible with all our existing forum content" (E, Site B) "Why can't I see people's real faces?" (N, Site B) "It looks very nice to build a story from a forum in this way." (N, Site C) "The draft SLO should be larger to be tested appropriately" (E, Site A)
Create, edit, manage, store and playback the generated storyboard.	"I could control the storyboard with the play, pause, stop, back and forward controls and playback the discussion many times." (N, Site A) "...felt like features for editing were lacking, but playback and storage worked fine" (E, Site B) "To test fully [the system] would need to be compatible with all our existing forum content" (E, Site B) "For complicated stuff... [it] might be better if I could advance the discussion pressing a key rather than keep pausing" (N, Site B) "The storyboard player could be more clear" (N, Site C) "Yes, it was possible to observe some knowledge building but it still misses the editor tool to remove some scenes that cause noise" (E, Site A) "The player only gives a sequential view of the knowledge" (T, Site A)
VCS prototype allows users to observe how knowledge is constructed.	"It is interesting and easier to follow a discussion though I could not observe knowledge construction" (N, Site A) "...would be great on a mobile device" (T, Site B) "Why would I store it instead of just making it again every time?" (N, Site B) "The management of the created SLO is not immediate to understand and the Playback should be improved" (T, Site C) "It was interesting to me to see how a discussion progressed but the built knowledge is not quantifiable." (E, Site C)

Table 2: Excerpt of the questionnaires on the 3 commented indicators #1, #3 and #4

4.2 Discussion

At site A, from the quantitative results, we can see that whilst the total score is promising, it is limited as the VCS prototype currently offers the player tool only. In particular, indicators #3 and #4 were scored low by the expert tester [see Tab. 1]. According to this tester's comments [see Tab. 2], since the prototype could not still offer all its potential regarding the edition of the storyboard, this in turn limited the improvement of the storyboard-based discussion. Novice's quantitative scores were also low for indicator #4. According to his comments, he reported a failure to observe a noticeable improvement of knowledge building from the text-based discussion. Finally, the technician tester scored the prototype well, and commented positively on the automatic transformation of the threaded discussion into a SLO, considering also the lack of edition capabilities of the SLO, which is currently a work-in-progress.

At Site B, an open group discussion was held between expert, technician and novice, moderated by the researcher, following all other data collection activities. Tension between novice and technical expert was evident for several aspects of the system: the novice feeling the system "lacked clarity of description", whilst the technician disagreed, suggesting the system was "completely clear". One aspect here might be that the creation of the SLO is fully automated, and therefore a novice user is unaware of this underlying functionality, instead experiencing only the high-level playback of the VCS. Therefore, in the testing at Site B, the novice failed to engage with this aspect of the system instead focusing on visual aspects (e.g. "Why can't I see people's real faces?"), and failing to appreciate the benefits of creating the SLO ("Why would I store it…"). Results for indicator #4 reinforce this finding, with expert and technician feeling the process was too transparent, and the novice failing to observe the relationship between use of the tool and knowledge creation. This presents something of a paradox: on the one hand, much investment in SLO creation emphasizes the need to make the process as simple as possible for the novice user, however, in this case the degree of abstraction is so great supplemental materials or explanation may be required for novices to understand this component of the system.

At site C, experimentation highlighted that further work remains to be done. In particular, the story management, and absence of an edit phase, suggested that although the system has a good potential it may be still improved. For example, participants suggested it could be useful if the avatars have different voices at least between male and female, allowing more access to users with vision impairments as well as enhancing immersion for general users. Site C reported that major efforts must be done in order to give more emphasis on indicator #4 to observe how the knowledge related to a specific topic is constructed. Expert users noted that the knowledge extracted by the storyboard is not quantifiable. Hence, at this stage the prototype seemed to be more interesting from the technological rather than methodological point of view.

However, it should be noted, from the data collected from novice users at all sites, the potential of the VCS player tool is evident, providing a step forward through the provision of an attractive resource which motivated and engaged the tester in discussion. The technician and novice at Site B also suggested the system would have particular potential for mobile devices, as the visual representation of the discussion fits well to a small screen and would be particularly beneficial due to the difficulties of reading large volumes of web-forum text on such a device.

In summary, the results of the tests reported here are not conclusive due to their exploratory nature. A recurring theme is the difficulty in balancing ease-of-use and transparency against the need to provide the user with an understanding of the underlying process and its value. Future work, therefore, will address not only the increased incorporation of key features and functionality based on the findings of this study, but also explore how better to convey the underlying process and principles to novices, supporting them in developing their understanding of the use and application of CC-LOs. This is fundamental to applying the main processes and concepts of the new paradigm of the CC-LO, as well as providing guidelines for their use by educators on a wide scale.

Previous related studies [Caballé, 2011b] investigated in a conceptual framework for modeling interactions from live collaborative activities. The results showed an improvement of the collaborative learning process in terms fostering student participation and enhancing individual performance. The current approach differs from previous initiatives by considering virtualized instead of live collaboration as the grounds for the study. Virtualization provides further benefits towards the learner's engagement, such as reusability of the knowledge elicited during the collaboration, more real interaction, and empowerment of the collaborative experience from attractive and challenging learning resources. This may provide a significant step forward in the development of current e-learning systems and applications.

5 Conclusions and Ongoing Work

This paper has detailed research work undertaken within the European Framework 7 project ALICE, a project devoted to providing on-line collaborative learning with authentic interactivity, challenging tools and user empowerment, with the ultimate aim to influence learner motivation and engagement. To this end, a new type of LO called CC-LO has been introduced, embedded into a VCS system that registers live collaborative sessions and produces an animated storyboard (SLO) such that learners can observe how people discuss and collaborate, and how knowledge is constructed. The development of this VCS prototype has been reported from a methodological research view. The notion and nature of the CC-LO is finally validated by running extensive tests on a proof of concept of the VCS system that embeds a CC-LO. These validation activities were carried out following the same methodological procedures in several international sites with different perspectives and expectations towards the research presented in this paper. Ongoing work includes the evaluation of the VCS prototype in the real context of learning of the Open University of Catalonia. Intensive experimentation and validation activities will be conducted in on-line courses in order to provide attractive and challenging CC-LOs to support the collaborative learning activities, in particular in-class discussions. Moreover, current work within the ALICE project is the development of an editor tool to augment the VCS system with author-generated information. For instance, e-assessment scenes will be added to the VCS, such as tests (with optional jumps to storyboard scenes) as well as supporting videos, to be connected with scene parts according to the dialogue timeline. As a result, tutors will be provided with edition capabilities of the SLOs, such as cutting scenes, modifying involved characters, selecting emotional states, dialogues and connected concepts.

Acknowledgements

This work has been supported by the European Commission under the Collaborative Project ALICE ”Adaptive Learning via Intuitive/Interactive, Collaborative and Emotional System”, VII Framework Programme, Theme ICT-2009.4.2 (Technology-Enhanced Learning), Grant Agreement n. 257639.

References

[Abad, 2008] Abad, C.L.: Learning through creating learning objects: experiences with a class project in a distributed systems course. 13th annual conference on Innovation and technology in computer science education. ACM: 255-259, 2008.

[Abernethy, 2005] Abernethy, K., Treu, K., Piegari, G., & Reichgelt, H.: A learning object repository in support of introductory IT courses. 6th conference on Information technology education. ACM: 223-227, 2005.

[Auer, 2007] Auer, S., Bizer, C., Lehmann, J., Kobilarov, G., Cyganiak, R., & Ives, Z.: DBpedia: a nucleus for a web of open data. 6th semantic web conference. Springer-Verlag: 722-735, 2007.

[Bandura, 1979] Bandura, A.: Social learning theory. New York: General Learning Press, 1979.

[Boskic, 2003] Boskic, N.: Learning Objects Design: What do Educators Think about the Quality and Reusability of Learning Objects? Third IEEE International Conference on Advanced Learning Technologies, 2003.

[Caballé, 2011a] Caballé, S., Dunwell, I., Pierri, A., Zurolo, F., Gañán, D., Daradoumis, Th. Mora, N.: Towards Collaborative Complex Learning Objects by the Virtualization of Collaborative Sessions. 4th World Summit on the Knowledge Society, Springer, 2011.

[Caballé, 2011b] Caballé, S., Daradoumis, T., Xhafa X., Juan, A.: Providing Effective Feedback, Monitoring and Evaluation to On-line Collaborative Learning Discussions. Computers in Human Behavior, 27(4), 1372–1381, 2011

[Capuano, 2009] Capuano, N. Miranda, S. and Orciuoli, O.: IWT: A Semantic Web-based Educational System. IV Workshop of the Working Group on AI & E-Learning, AI*IA: 11-16, 2009.

[Collazos, 2007] Collazos, C.A., Guerrero, L.A., Pino, J.A., Ochoa, S.F., Stahl, G.: Designing Collaborative Learning Environments Using Digital Games. Journal of Universal Computer Science, 13(7), 1022-1032, 2007.

[Conesa, 2011] Conesa, J., Caballé, S., Gañán, D., Prieto, J.: CS2: An Ontology to Model and Represent Collaborative Learning Data. 4th World Summit on the Knowledge Society, Springer, 2011.

[Costagliola, 2006] Costagliola, G., F. Ferrucci, Fuccella, V.: Scorm run-time environment as a service. 6th international conference on Web engineering. ACM: 103-110, 2006.

[Dillenbourg, 1999] Dillenbourg, P. (ed.): What do you mean by “Collaborative Learning”? Collaborative learning, Cognitive and computational approaches, 1-19, Oxford: Elsevier Science, 1999.

[Dinis, 2009] Dinis, P., da Silva A.R.: Application Scenarios for the Learning Objects Pool. Journal of Universal Computer Science, 15(7), 1455-1471, 2009.

[Ertl, 2010] Ertl, B., Ebner, K., Kikis-Papadakis, K.: evaluation of e-Learning. International Journal of Knowledge Society Research, 1(3), 31-43, 2010.

[Fadde, 2009] Fadde, P. J.: Evolution of a Video-Learning Object Format, eLearn 2009(3), 2009.

[Fahad, 2011] Fahad, M., Moalla, N., Bouras, A., Qadir,M., Farukh, M.: Towards Classification of Web Ontologies for the Emerging Semantic Web, Journal of Universal Computer Science, 17(7), 1021-1043, 2011.

[Farrell, 2004] Farrell, R., Liburd, S. D., & Thomas, J. C.: Dynamic assembly of learning objects. 13th International World Wide Web Conference on Alternate Track Papers (pp. 162-169). New York: ACM Press, 2004.

[Friesen, 2004] Friesen, N.: Three objections to learning objects and e-learning standards. In R. McGreal (Ed.), Online education using learning objects (pp. 59-70). London: Routledge, 2004.

[Fuentes, 2008] Fuentes, L. M., Arteaga, J. M. and lvarez Rodriguez, F.: A Methodology for Design Collaborative Learning Objects. 8th IEEE International Conference on Advanced Learning Technologies, 2008.

[Gerard, 1967] Gerard, R.W.: Shaping the mind: Computers in education, In N. A. Sciences, Applied Science and Technological Progress, 1967.

[Granitzer, 2011] Granitzer, M., Lindstaedt, S.: Semantic Web:Theory and Application, Journal of Universal Computer Science, 17(7), 981-983, 2011.[Goodsell, 1992] Goodsell, A., Maher, M., Tinto, V., Leigh Snith, B. and MacGregor, J.: Collaborative Learning: A Sourcebook for Higher Education. Pennsylvania State University: National Center on Postsecondary Teaching, Learning, and Assessment, 1992.

[Kaldoudi, 2009] Kaldoudi, E.: Balasubramaniam, C. and Bamidis, P.D, Content Repurposing: Definition of Repurposing Reasons and Procedures, deliverables of the project “mEducator: Multi-type Content Repurposing and Sharing in Medical Education”, EC, 2009.

[Kumar, 2005] Kumar, V., J. C. Nesbit and Han, K..: Rating learning object quality with distributed Bayesian belief networks. 5th IEEE International Conference on Advanced Learning Technologies, 2005.

[Leal, 2011] Leal, J.P., Queirós, R.: Integrating the LMS in Service Oriented eLearning Systems. International Journal of Knowledge Society Research, 2(2), 1-12, 2011.

[Littlejohn, 2003] Littlejohn, A.: Reusing online resources. A sustainable approach to e-learning. London: Kogan Page, 2003.

[Macedonia, 1997] Macedonia, M. and Zyda, M.: A Taxonomy for Networked Virtual Environments. IEEE MultiMedia 4(1): 48-56, 1997.

[Margaryan, 2007] Margaryan, A., Littlejohn, A.: Community dimensions of learning object repositories. World Conference on Educational Multimedia, Hypermedia and Telecommunications, 2007.

[McGreal, 2006] McGreal, R.: Online education using learning objects. London, New York, Routledge, 2006.

[Meinel, 2002] Meinel, C., Sack, H. and Schillings, V.: Course management in the twinkle of an eye - LCMS: a professional course management system. 30th annual ACM SIGUCCS conference on User services. ACM: 281-283, 2002

[Mosley, 2005] Mosley, P.: A taxonomy for learning object technology. J. Comput. Small Coll. 20(3): 204-216, 2005.

[Neven, 2002] Neven, F. and Duval, E.: Reusable learning objects: a survey of LOM-based repositories. Tenth ACM international conference on Multimedia. ACM: 291-294, 2002.

[Polsani, 1997] Polsani, R. P.: Use and abuse of reusable learning objects. Journal of Digital Information, Volume, 164, 1997.

[Prakash, 2009] Prakash, L.S., Saini, D.K. and Kutti, N.S.: Integrating EduLearn learning content man-agement system (LCMS) with cooperating learning object repositories (LORs) in a peer to peer (P2P) architectural framework." SIGSOFT Softw. Eng. Notes 34(3): 1-7, 2009.

[Rajendra, 2004] Rajendra G., Singh, R.G., Bernard, M., Gardler, R.: Creating sharable learning objects from existing digital course content. 31st International Symposium on Computer Architecture, ACM: 8, 2004.

[Stahl, 2006] Stahl, G.: Group Cognition: Computer Support for Building Collaborative Knowledge. Acting with Technology Series. MIT Press, 2006.

[Su, 2008] Su, L., S. Yang, Li, Y., Cheng, X., Huang, R.: Semantic-Oriented Ubiquitous Learning Object Management System SULOMS. 32nd Annual IEEE In-ternational Computer Software and Applications Conference, IEEE CS: 801-806, 2008.

[Taibi, 2007] Taibi, D., Gentile, M., Fulantelli, G., Allegra, M.: Revealing semantic relations in learning object structure, 7th WSEAS International Conference on Applied Informatics and Communications, 246-251, 2007.

[Valderrama, 2005] Valderrama, R.P., Ocana, L.B. & Sheremetov, L.B.: Development of intelligent reusable learning objects for web-based education systems, Expert Systems with Applications, 28, 273–283, 2005.

[Vargo, 2003] Vargo, J., Nesbit, J., Belfer, K., & Archambault, A.: Learning object evaluation: Computer-mediated collaboration and inter-rater reliability. International Journal of Computers and Applications, 25(3), 198-205, 2003.

[Vygotsky, 1978] Vygotsky, L.S.: Mind in Society: The development of higher order psychological processes. Cambridge and London: Harvard University Press, 1978.

[Wang, 2010] Wang Y., Zhu M., Qu L., Spaniol M. and Weikum, G.: Timely YAGO: harvesting, querying, and visualizing temporal knowledge from Wikipedia. 13th International Conference on Extending Database Technology, ACM: 697-700, 2010.

[Wiley, 2001] Wiley, A. D.: Connecting learning objects to instructional design theory: A definition, a metaphor and a taxonomy. In D. A. Wiley (Ed.), The instructional use of learning objects Bloomington: Association for Educational Communications and technology, 2001.

[Zyda, 2005] Zyda, M.: From visual simulation to virtual reality to games. IEEE Computer, 2005.

2.2. Experiences with Engineering Education at the Open University of Catalonia by the Virtualization of Live Collaborative Learning

Caballé, S., **Gañán, D.**, Gómez-Cazorla, M., Conesa. J., Rius, A., Santanach, F. (2014). *Experiences with Engineering Education at the Open University of Catalonia by the Virtualization of Live Collaborative Learning*. International Journal of Engineering Education (IJEE), Vol. 30, No. 3, pp. 663–674. TEMPUS Publication. ISSN: 0949-149X. IF: 0.360, Q4: 74/87 (JCR-2013 SE).

In the previous contribution (see Section 2.1), a new type of learning object named Collaborative Complex Learning Object (CC-LO) is presented in support for teaching and learning engineering by the virtualization of live collaborative sessions, with the aim to leverage the knowledge elicited during the collaboration and produce interactive and attractive resources to be played by learners. This type of pedagogically and technologically augmented learning resources is able to overcome endemic problems found in collaborative learning of on-line engineering courses, such as lack of authentic interactivity, user empowerment, social identity and challenge, thus having a positive effect in learner engagement. In this contribution, the experiences gained in the production, deployment, experimentation and validation of the CC-LO approach are reported from the live collaborative sessions occurring in real on-line engineering courses of the Open University of Catalonia (UOC). The ultimate goal is to evaluate and validate how the CC-LO approach can support engineering education at the UOC, and in particular observe the impact in the collaborative learning performance during the on-line discussions. The novelty of this paper is the integration of the CC-LO approach into the actual phpBB-based Web forums that support specific engineering courses at the UOC and in particular their in-class discussion processes and collaborative activities.

Overall, this contribution reports on the experiences gained in the production, development, experimentation and validation of the CC-LO approach from live collaborative sessions occurring in real on-line engineering courses of the Open University of Catalonia (UOC).

International Journal of Engineering Education Vol. 30, No. 3, pp. 663–674, 2014
Printed in Great Britain
0949-149X/91 $3.00+0.00

Experiences at the Open University of Catalonia with the Virtualization of Live Collaborative Learning in Support for Engineering Education*

SANTI CABALLÉ, DAVID GAÑÁN, MÀRIUS GÓMEZ, JORDI CONESA, ÀNGELS RIUS and FRANCESC SANTANACH
Open University of Catalonia, Dept. of Computer Science, Multimedia, and Telecommunication Rambla Poblenou, 156. 08018 Barcelona, Spain. E-mail: {scaballe, dganan, mgomezcaz, jconesac, mriusg, fsantanach}@uoc.edu

In previous research we proposed a new type of learning object named Collaborative Complex Learning Object (CC-LO) in support for teaching and learning engineering education by the virtualization of live collaborative sessions, with the aim to leverage the knowledge elicited during the collaboration and produce interactive and attractive resources to be played by learners. We claim this type of pedagogically and technologically augmented learning resources is able to overcome endemic problems found in collaborative learning of on-line engineering courses, such as lack of authentic interactivity, user empowerment, social identity and challenge, thus having a positive effect in learner engagement. In this paper we report on the experiences gained in the production, deployment, experimentation and validation of the CC-LO approach from the live collaborative sessions occurring in real on-line engineering courses of the Open University of Catalonia (UOC). The ultimate goal is to evaluate and validate how our approach can support engineering education at the UOC, and in particular observe the impact in the collaborative learning performance during the on-line discussions. The novelty of this paper is the integration of our approach into the actual phpBB-based Web forums that support specific engineering courses at the UOC and in particular their in-class discussion processes and collaborative activities.

Keywords: engineering education; live collaborative learning; discussion forum; collaborative complex learning object; virtualized collaborative sessions; learning engagement; Open University of Catalonia

1. Introduction

The Open University of Catalonia (UOC)[1] is the first virtual university in Spain. The UOC offers a great variety of graduate and post-graduate degrees, including a wide selection of courses on engineering education in the fields of Computer and Software Engineering. Since its creation the UOC has continuously innovated both in methodological and technological aspects related to e-Learning, and in particular Computer-Supported Collaborative Learning (CSCL) [1, 2]. CSCL activities at the UOC vary widely, though most of them are centered upon students' exploration or application of the course material through in-class formal discussions, being of the most interest for engineering students [1]. Given the added value of asynchronous collaborative learning [3], the UOC have incorporated on-line discussions as one of the pillars of its pedagogical model, and in particular of the engineering education programs. To this end, great efforts are being made to develop adequate on-line tools to specifically support engineering curricula by focusing on essential aspects of the on-line discussion process, which include students' monitoring and evaluation as well as engagement in the collaborative learning process.

However, following many researchers' claims [1–3] we argue that our students must be meaningfully engaged in the learning resources and tools for effective collaborative learning to occur. Such a lack of engagement is especially evident at the UOC and can be attributed to the lack of (i) real interactivity (in many cases the only interaction available is to click on the "next" button to obtain the next message in a discussion forum); (ii) challenging collaborative tools, instead of tools which fail to stimulate learners, making the collaborative experience unattractive and discouraging progression; and (iii) empowerment, as learner expects to be in control of their own collaborative learning.

In addition, current technologies in the form of Web forums that support virtual discussions sessions of our engineering education courses show important limitations, such as (i) the discussion is based on a long list of messages, sometimes with technical jargon, which is hard to follow by engineering students and tedious to monitor by tutors and moderators; (ii) after the collaborative activity is over the discussion is not available anymore and

[1] The Open University of Catalonia is located in Barcelona, Spain. The UOC offers distance education through the Internet since 1994. Currently, about 60,000 students and 3,700 lecturers are involved in 8,300 online classrooms from about 100 graduate, post-graduate and doctorate programs in a wide range of academic disciplines. The UOC is found at http://www.uoc.edu

* Accepted 20 October 2013.

the collaborative knowledge produced is lost; (iii) in-class discussions are scheduled in certain points of the course and no opportunities for formal collaboration are found in between; (iv) usual text-formatted posts are far from real-life discussions and physical participation, thus chances for social benefits from actual collaboration are not available. All these deficiencies lead to rudimentary and little attractive collaborative learning practices as well as lack of interest, thus having a negative effect on learners' self-motivation and engagement in their learning process.

In order to overcome these and other related limitations and deficiencies, in previous research we reported on a new collaborative learning methodology called Collaborative Complex Learning Object (CC-LO) through the development of a system prototype called Virtualized Collaborative Session (VCS) that enables the embedding and execution of the new CC-LO [4]. The VCS platform allows for the virtualization and registration of live collaborative sessions, which can be augmented by alternative learning paths, additional content, etc., during an authoring phase in order to produce interactive and attractive resources to be experienced and played by learners. During the CC-LO execution, learners can observe how avatars discuss and collaborate, how discussion threads grow, and how knowledge is constructed, refined and consolidated. The registered CC-LOs are eventually packed and stored for further reuse, enriching live sessions of collaborative learning with balanced levels of interaction, challenge and empowerment [5, 18]. The VCS system and the whole approach were specifically tested for supporting the collaborative processes underlying engineering education courses by using an external Web-based discussion tool [5].

In this paper, we leverage the CC-LO approach to enhance and improve the collaborative learning experienced at UOC by integrating the VCS platform specifically into the internal forum tool extensively used at UOC to support the in-class discussions sessions occurring in the virtual classrooms of an engineering course. An exhaustive evaluation and validation process is reported that shows an increase of learners' engagement during the learning process and in particular observes the impact in learning performance during the discussions.

The paper is structured as follows: Section 2 presents related work with concepts and technologies used in later sections. In section 3, we present a research methodology to empirically demonstrate the educational value of the CC-LO approach at UOC and the benefits for UOC learners through the integration of the VCS system into the UOC standard web forums. Section 4 evaluates and validates the approach by an analytical data discussion and interpretation of the effects of virtualizing the discussion sessions in our real context of learning. Section 5 concludes the paper by highlighting the key results achieved and outlining ongoing and future work.

2. Aims and background

In [4] and [5] a new issue and concept, called "collaborative complex learning object" (CC-LO), was presented and discussed. The notion of this new concept was set off from the known concept of "learning object" (LO) [6]) and an extension of it was proposed. The reason and purpose of this new notion was justified by setting up two research questions about what makes a LO collaborative and what makes a LO complex, that current standard learning objects are not able to respond. The answer to these two questions set the basis to provide the key differentiations between LO and CC-LO as well as the need to define and include multiple levels of abstraction from pedagogic context, learners, and representational medium (complexity), as well as intrinsic support for interaction across the object (collaboration). To this end, existing methods for creating, managing, executing and easily access [7] LO were found and examined with respect to how they may be applied to the case of CC-LOs.

After this preliminary research, examples of CC-LOs were addressed to obtain the requirements of learners in collaborative scenarios, pedagogically designed with reference to the concepts of social and collaborative learning emerging from the theories of [8] and [9]. As a consequence, the concept of the "virtualized collaborative session" (VCS) was identified as an event in which CC-LOs can be applied and consumed by learners, how these sessions evolve ("animate") over time, and how the ultimate end-user interactions with CC-LOs can be handled [4] Finally, the issue of how CC-LOs might be created through either the extension of existing tools or creation of proprietary tools was addressed in the same research which seeks to allow for their formation (either through bespoke creation or repurposing of existing LOs/CC-LOs).

A first approach to a VCS system is depicted in Fig. 1 (see also [4] for further details). The VCS is intended to be compatible with collaborative sessions in general, such as chats and forums, in order to create CC-LO as general as possible. For this purpose, the input of VCS system is a file containing the collaborative session data in a common format called Collaborative Session Markup Language (CSML) based on XML [10].

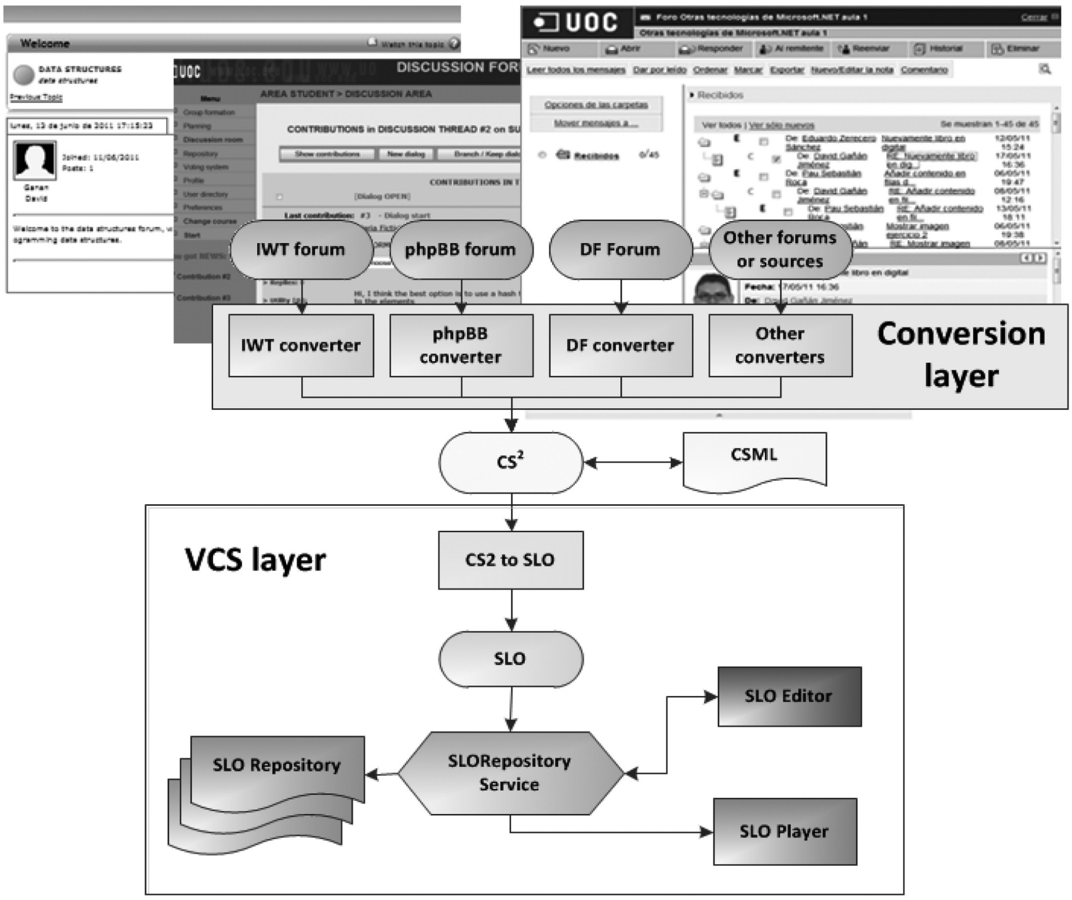


Fig. 1. Architecture of the VCS system.

The CSML specifies an ontology named Collaborative Session Conceptual Schema (CS^2) that allows for modeling and representing knowledge about Web-based collaborative sessions [10]. The CSML is based on SIOC specification (see Fig. 2) so it contains some of the elements defined on this and other related specifications like FOAF (Friend of a friend) or Dublin Core (see [10] for a extensive review of them).

The process of conversion between the source of collaborative session data and CSML is done by a specific converter (see Fig. 1), which is different for each kind of source (i.e., the data model of a forum). Then, the VCS system processes data in CSML format and creates a specific CC-LO named Storyboard Learning Object (SLO) [4], containing information about scenes, characters, and other artifacts used during the later visualization of this learning object. SLOs are editable by the use of an editor tool (SLO Editor), which allows for changing scenes order, adding or removing content, adding assessment scenes, defining workflow, etc. Finally, the viewer tool (SLO Player) enables students and moderators to see the virtualized collaborative session in an interactive but read-only way. While the editing capabilities are still under development, the current status of our VCS prototype fully supports the viewer tool (see more information in [4]).

Overall, the VCS transforms a live discussion forum into an animated storyboard and produces an event in which SLOs are played and consumed by learners, sessions evolve (‘‘animate’’) over time, and the ultimate end-user interactions with SLOs are handled (Fig. 3). As a result, the VCS becomes an attractive learning resource to increase the learners' engagement in the collaborative activities [5].

The VCS system has been successfully integrated with different web forum tools, such as IWT [11] and the Discussion Forum tool [12]. In this paper we proceed, firstly, with integrating the VCS specifically into the UOC standard web forum tool supporting the in-class formal discussions sessions occurring in the on-line classrooms. The UOC and its new Virtual Campus has recently upgraded the standard forum tool to a phpBB-based web forum. phpBB (phpbb.com) is a free flat-forum bulletin

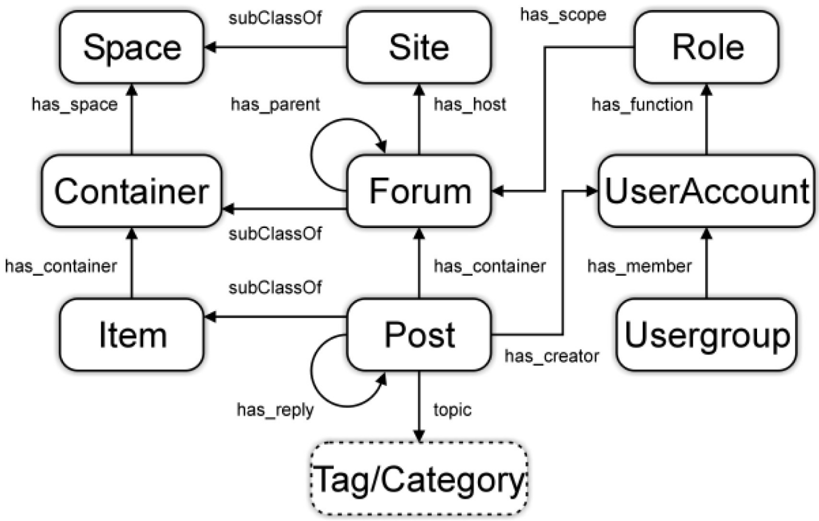


Fig. 2. SIOC core ontology classes.

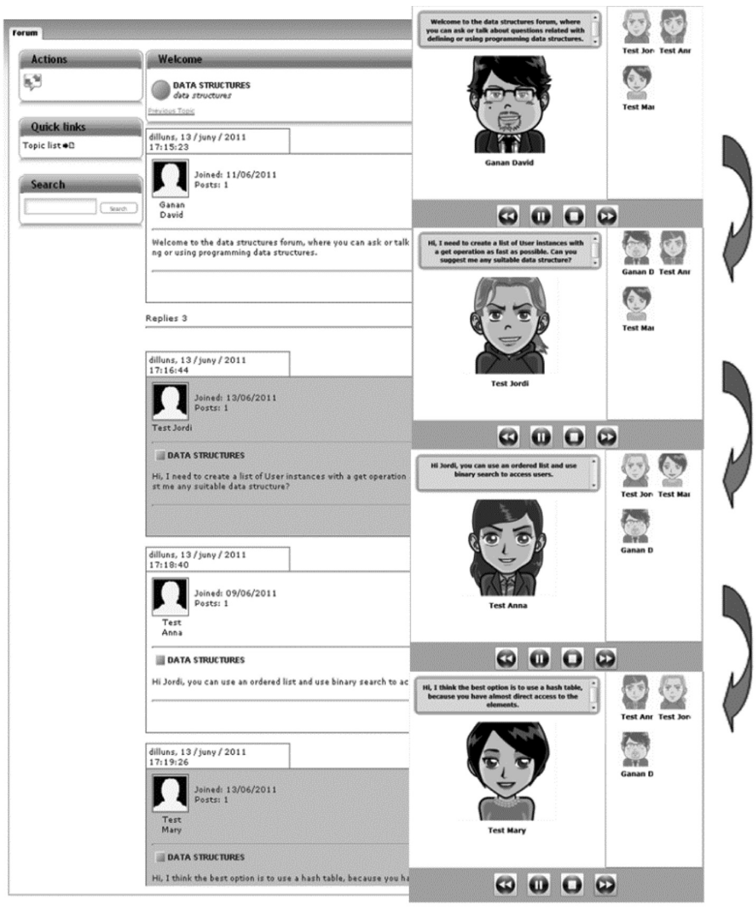


Fig. 3. Sequence of screenshots of the VCS embedding a CC-LO/SLO with a discussion

board software solution that offers a great complement of features and is highly customizable and configurable while maintaining efficiency and ease of use. However, phpBB is considered yet another web forum tool with standard functionalities to support discussion. Secondly, the results produced from this technological integration were experimented to validate the impact of the virtualization of live sessions of UOC's in-class discussions in complex dimensions of the collaborative learning process, such as participatory behavior and motivation, as well as technical aspects of the VCS tool (e.g., usability) and worthiness.

3. Research methodology

This section presents a comprehensive experimentation study describing all activities that were undertaken during the experimentation of the requirement scenario (see Section 2). For this scenario, first the prototyping activities of integrating the VCS system into the standard Web-based discussion tool (i.e. phpBB forum tool) of an engineering course at UOC are described. Then, a complete empirical study is reported that includes details on the goals and hypotheses, the method (including number and type of participants, apparatus and stimuli, and procedure). The standard structure presented is based on the APA guidelines to report empirical results (see [14]). Experimental results are discussed in Section 4 to evaluate and validate the VCS system [13].

3.1 VCS prototyping on UOC forums

Following the VCS architecture (see Fig. 1), the integration between the phpBB forums and the VCS was enabled by developing a specific Converter which read the phpBB database directly (phpBB Converter). The main problem found in the integration was that the IWT and the VCS system were installed in separated servers, which prevented the direct access to the database in the UOC installation of phpBB forums. To remedy this situation, we implemented an additional service on the UOC servers that returned collaborative sessions data in JavaScript Object Notation (JSON) format. Then the phpBB Converter was implemented and installed in the VCS server which recovered that JSON data and transformed it into CS^2 data model.

The conversion strategy starts with the user's request for generating an SLO from a discussion session supported by the UOC's phpBB web forum, and then, by involving the following VCS components: CS2 to SLO, VCS Creator, UOC Converter (i.e. phpBB Converter) and finally the SLO Player (see Fig. 1). Eventually, the user can watch the generated SLO (Fig. 4).

3.2 Research goals and hypotheses

The goal of this scenario is to virtualize live discussion sessions of UOC to produce storyboard learning objects embedded in an attractive learning resource (VCS) to be experienced and played by UOC learners. During the resource execution, learners observe how avatars discuss and collaborate, how discussion threads grow, and how knowledge is constructed, refined and consolidated (see Section 2). The VCS version used for the experimentation allowed for virtualizing live collaborative sessions at the same time they occur and no augmentation or

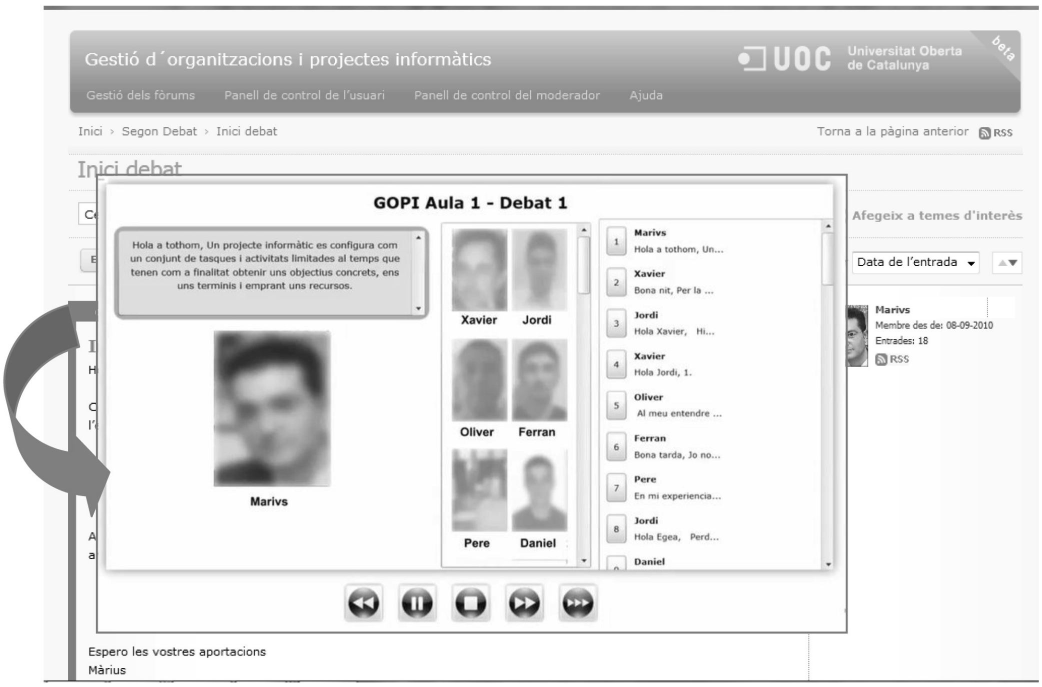


Fig. 4. Screenshot of the virtualization of the discussion supported by the UOC's phpBB web forum into a storyboard (SLO) created by the VCS tool (facial images have been faded and surnames have been removed for private reasons).

management of the virtualization process was available. Hence the virtualization process kept providing a live collaborative learning session in a different format.

The goals and hypotheses formulated for this scenario are related to this version of the VCS prototype. In particular, the usability and functionality of the VCS tool to play and observe the UOC text-based discussions supported in a multimedia attractive format. To this end, an experiment was run to pilot this scenario at UOC in support for a formal in-class assignment of collaborative learning based on a discussion. In this experiment, the VCS acted as the distinctive complement to the underlying phpBB forum tool. Next, the goals and hypotheses are formulated.

Goals

G1: To build a system able to build a SLO from a threaded discussion (coming from the phpBB forum).
G2: To employ the VCS in online courses in order to enhance the teaching/learning process.
G3: To identify possible ways of improving further the utility of the VCS in online courses.
G4: To create, store and playback the generated SLO through a user friendly interface.
G5: To build (automatically) a draft SLO from a discussion session effectively.
G6: To build (automatically) a draft SLO from a collaborative activity efficiently.

Hypotheses

H1: The VCS prototype allows non-expert users to build and use a SLO (i.e., in a friendly way and efficiently).
H2: Use of VCS contributes to significantly improve students' emotions and motivation.
H3: Use of VCS contributes to significantly increase students' activity levels, both in individual and collaborative activities.
H4: Use of VCS contributes to significantly improve students' understanding of key concepts and results.
H5: VCS is considered as a worthy educational resource by students.

3.3 Method

Following the APA guidelines to report empirical results proposed by [14], information about the participants, the apparatus used for experimentation and the procedure of the experiment are provided in this subsection.

3.3.1 Participants

In order to evaluate the prototype of the VCS and analyze its effects in the UOC discussion processes, the sample of the experiment consisted of 55 undergraduated students enrolled in the course Organization Management and Computer Science Projects from the Computing Engineering degree at the UOC. Two in-class discussions were scheduled in the course and for the sake of our experiment.

From 55 students who started the course, 47 (85%) participated in the first discussion forming the control group for this experiment. Then, 40 students (72%) participated also in the second discussion forming the experimental group. Finally, only 29 (53%) fully completed the experiment by submitting a final questionnaire, thus forming the actual sample. The rest of students (8) chose not to participate or dropped out before the first discussion and the course for personal reasons. Therefore, considering 35% dropout ratio is usual in the last third of the academic term when the experience was completed, the actual participation in the experience was as high as 82%, thus quite representative.

The students were supervised by a tutor, who was assigned to the classroom as the official lecturer teaching the whole course.

3.3.2 Apparatus and stimuli

Students from the experimental classroom were required to use the standard text-based phpBB forums equipped with the multimedia-based VCS tool (see Fig. 4) to support the formal collaborative assignment (i.e. in-class discussion).

After the in-class discussion assignment, the students were required to fill in a questionnaire, which included the following 6 sections: (i) identification data (names and username); (ii) open questions about the knowledge acquired during the discussion; (iii) test-based evaluation of the VCS as a valuable resource; (iv) test-based evaluation on the usability of the system; (v) test-based evaluation on the emotional state when using the system; (vi) a test-based evaluation of the questionnaire. All sections had a final field to express suggestions and further comments about aspects not represented in the questions. The questionnaire's sections (ii) through (v) were considered for the purpose of our study.

For qualitative statistical analysis, we summarized the open answers in the questionnaire. For the quantitative statistical analysis we employed basic statistics, such as Mean (M), Standard Deviation (SD) and Median (Md). We complemented this quantitative analysis by employing accepted statistical procedures [15], such as Chi-square (X^2), so as to compare the observed scores to the expected scores.

For the Section (iv) (usability of the forum tools with the VCS and without it) we used the System Usability Scale (SUS) developed by [16] which contains 10 items and a 5 point Likert scale to state the level of agreement or disagreement. SUS is generally used after the respondent had an opportunity to use the system being evaluated. SUS scores have a range of 0 to 100 with an average score of 68, obtained from 500 studies. A score above 68 would be considered above average and anything below 68 is below average. A score above 80.3 is considered an A (the top 10% of scores). Scoring at the mean score of 68 gets a C and anything below 51 is an F (putting the score in the bottom 15%).

Finally, Section (v) of the questionnaire was concerned about the "emotional state" of students when using the new system, which included the Computer Emotion Scale (CES) [17]. The aim was to investigate students' emotions when using the forum tool equipped with the VCS. CES scale is used to measure emotions related to learning new computer software by means of 12 items describing four emotions:

- Happiness ("When I used the tool, I felt satisfied/excited/curious.")
- Sadness ("When I used the tool, I felt disheartened/dispirited.")
- Anxiety ("When I used the tool, I felt anxious/insecure/helpless/nervous.")
- Anger ("When I used the tool, I felt irritable/frustrated/angry.")

The answer categories in this section of the questionnaire are "None of the time", "Some of the time", "Most of the time" or "All of the time.

The data from this experience was collected by means of the web-based phpBB forums supporting the discussions in the virtual classroom of UOC. As mentioned, quantitative and qualitative data were collected from questionnaires containing quantitative and qualitative questions. The answer categories varied between rating scales, multiple choice or open answers.

Regarding the rating scales, for the majority of the quantitative questions we used the 5 point Likert scale, so that students could state their level of agreement or disagreement. The rating scale ranged from "I strongly disagree" (1), "I disagree" (2), "neither/nor" (3) to "I agree" (4), "I strongly agree" (5). Finally, quantitative data was also collected from the phpBB, VCS and UOC Virtual Campus databases and log files.

3.3.3 Procedure

Two in-class collaborative formal discussion assignments were scheduled during the Fall term of 2012. The first one was scheduled during the first 3 weeks of October 2012 and the second one from the last 2 weeks of December 2012 and first week of January 2013. The activities were individual and mandatory for all students and consisted of discussing on topics related to Computer Science project management. In the assignments, each student was required to post one contribution at least on the discussion topic in hand. Hence, participation in the discussions was mandatory to pass the course. On the other hand, participation in the experiment (i.e. submitting the final questionnaire) was optional. Finally, students could contribute as many times as needed by posting new contributions, replying to others as well as start extra discussion threads to provide new argumentations with regards to the discussion topics proposed.

The first assignment (control group) was supported by the phpBB forum only while the second one (experimental group) was supported by the phpBB equipped with the VCS. Hence, unlike the control group, the experimental group could follow the discussion by also watching the video scenes of the VCS prototype integrated in the phpBB. The aim was to evaluate the participation effects of the VCS by comparing the activity levels during the first discussion (control group) supported by the phpBB to the second discussion (experimental group) supported by the phpBB with the VCS tool. After the assignment, a questionnaire was sent to students who were asked with questions on the VCS system. Finally, the students were asked about their emotional state and usability issues when using the VCS.

3.3.4 Experimental results

Following the previous methodology, in this subsection we provide the experimental results of our empirical study on the activity, usability and emotional aspects of the VCS tool as well as on the VCS as a valuable educational resource and its impact in knowledge acquisition. These results are discussed in the next section for evaluation and validation purposes.

- *Activity levels*

In order to study the students' activity levels with the VCS, data was collected from both the experimental group and the control group. For the posts, words metrics, we computed the mean and its standard deviation. Finally, for the "visits" to the VCS (i.e. number of SLO scenes played) we collected information from the VCS log files. In order to compare the post visits (i.e., read) to the scene visits (i.e., watched) we computed the number of SLO created and played multiplied by the average of first scenes watched of each SLO played. Table 1 shows the results.

- *Usability*

To study on the usability of the VCS tool, we collected data from students' ratings and open

Table 1. Results on activity levels of the discussion in both the control and experimental groups. Note that the number of participants in both groups is higher than the sample of our study (n = 29) due to a higher number of students participated in the discussion activities but only 29 of them completed the experiment (by also submitting the final questionnaire)

Metric/Statistic	Experimental group phpBB forum (with VCS)	Control group phpBB forum (without VCS)
Number of students	40	47
Total of posts	145	120
Mean posts/student	M = 3.6	M = 2.6
SD posts/student	SD = 3.8	SD = 1.2
Total words	31330	19182
Mean words/student	M = 764.1	M = 411.5
SD words/student	SD = 756.7	SD = 233.7
Total words	31330	19182
Mean words/post	M = 216.1	M = 162.5
SD words/post	SD = 116.1	SD = 95.2
Total visits	2213 (360)	1909
Mean visits/student	M = 55.3 (9.0)	M = 40.6

comments on the user interface, functionality, efficiency and integration of the tool. After calculating the SUS score for each student (n=29), we got an average for 29 SUS scores of 66.81, thus very near the SUS mean.

- *Emotional aspects*

Regarding the students' emotions of the experimental group during the work with the VCS, the results from the 12 items of the CES scale describing four emotions of each student (n = 29) are as follows: Happiness (M = 1.13, SD = 1.02, Md = 1); Sadness (M = 0.24, SD = 0.51, Md = 0); Anxiety (M = 0.17, SD = 0.38, Md = 0) and Anger (M = 0.27, SD = 0.52, Md = 0).

- *Educational worthiness*

To study the level of worthiness of the VCS as an educational tool, we collected quantitative and qualitative data in section (iii) of the questionnaire from seventeen open questions addressed to students. The rating scales for the majority of the quantitative questions were based on the usual 0-10 point scale. The rating scale went from the lowest (0) to the highest (10) considering a "good" assessment from 5.0 to 10 and a "bad" assessment from 0 to 4.9, being the "good" assessment the expected scores for each question (n = 29; df = 1; p < 0.05 for the calculated X^2). We show next the most relevant questions asked to all students and the results obtained (note that we used the term "video-discussions" to refer the VCS player tool):

(1) *What did you like and what did not about the video-discussions?*

Results: M = 5.87, SD = 1.82, Md = 6 and X^2 (1) = 9.11, p < 0.01

(2) *Do you think the video-discussion has helped you follow the discussion in comparison to the text-based phpBB forum?*

Results: M = 5.21, SD = 2.66, Md = 5 and X^2 (1) = 5.451, p < 0.02

(3) *Let us know your opinion about the potential of the video-discussions to observe how people discuss and collaborate, and how knowledge is constructed and consolidated.*

Results: M = 5.62, SD = 2.01, Md = 5 and X^2 (1) = 10.823, p < 0.01

(4) *Express your opinion about the video-discussions in terms of efficiency and performance.*

Results: M = 6.83, SD = 1.54, Md = 7 and X^2 (1) = 16.046, p < 0.001

After calculating the 0-10 scale for all the four questions and participants (n = 29), we got a general mean score of 5.65 (SD = 2.09 and Md = 6) with X^2 (1) = 8.7, p < 0.01.

- *Knowledge acquisition*

To study the level of knowledge acquisition by using the VCS tool, all students were assessed on summarizing the discussion in both the experimental and the control groups. For the control group we considered a similar discussion of previous courses at UOC supported by the phpBB forum without the VCS (see [5] for details). To this end, Section (ii) of the questionnaire included 3 evaluative questions: 2 first questions to assess the discussion topics and the last question asked student to assess their knowledge acquisition by the discussion assignment. This part of each questionnaire was addressed by a lecturer who used the standard 10-point scale to score the students' responses. Table 2 shows the results.

4. Discussion

In this section an in-depth analysis and interpretation of the previous experimental results is provided in order to evaluate the activity, usability and emotional aspects of the VCS tool (H1, H2 and H3) as well as to validate the VCS as a valuable educational resource (H5) and its impact in knowledge acquisition (H4).

4.1 Activity level fostered by the VCS

In order to evaluate the students' activity levels with the VCS (H3) we analyze the results of Table 1. These results indicate that by using the VCS the participation quantitative behavior was increased since the number of posts and mean posts/student are significantly higher in the experimental group (27.7%) than in the control group. Similarly, the number of visits

Table 2. Results of the discussion evaluation

Evaluative questions	Experimental group phpBB forum with VCS (n = 40)	Control group phpBB forum without VCS (n = 31)
Question 1	M = 7.34 SD = 1.71 Md = 7	M = 6.93 SD = 1.15 Md = 7
Question 2	M = 6.77 SD = 0.89 Md = 7	M = 6.83 SD = 1.34 Md = 7
Question 3	M = 8.12 SD = 1.33 Md = 8	M = 7.12 SD = 1.14 Md = 7
Overall	**M = 7.14** **SD = 1.31** **Md = 7**	**M = 6.96** **SD = 1.21** **Md = 7**

(i.e. readings of text posts) and mean visits/student were higher in the experimental group (25.5%) than in the control group, pointing out that the VCS also motivated the students from the experimental group to follow closer and more frequently the discussion than the control group. This was confirmed by the data collected from the VCS activity logs (360 first scenes seen by the experimental group). Note the high SD statistic of posts/student (3.8) due to a single outlier, without which this statistic is 1.8, in line with the control group.

Participation qualitative behavior is measured in terms of the number of words per post and per student. The significantly higher mean statistics of words per student (46.2%) in the experimental group indicate that the users of the VCS were more participative and collaborative when communicating their ideas and opinions by either sending new posts or reply posts. Moreover, the longer contributions in the experimental group (mean of words per post is 24.8% higher than the control group) show a better communicative behavior in line with the high levels of participation and collaboration, resulting in higher levels of engagement and motivation in the discussion process. Note again the high SD statistic of words/student (756.7) due to the same outlier mentioned before, without which this statistic is 371.3, in line with the control group.

4.2 Usability of the VCS

To evaluate student's satisfaction with the VCS tool as regards efficient and user-friendly management (H1), we got an average for 29 SUS scores of 66.81, thus very near the SUS mean. In particular, for each of the 10 SUS items in the 5 point Likert scale, students using the VCS tool thought they will use this tool often (M = 3.10, SD = 1.17, Md = 3). Students did not find the tool unnecessarily complex (M = 2.20, SD = 0.67, Md = 2) nor it was found cumbersome (M = 2.31, SD = 0.89, Md = 2). In addition, students stated that they did not need the support of a technical person to be able to use the VCS (M = 1.68, SD = 0.76, Md = 2), they thought that most people would learn to use this system very quickly (M = 3.68, SD = 0.80, Md = 4), and they felt quite confident using the VCS (M = 3.62, SD = 0.90, Md = 4).

From the technical perspective, students found the VCS functionality well integrated in the phpBB forum (M = 3.55, SD = 0.82, Md = 4) and without too much inconsistency in the user interface (M = 2.34, SD = 0.81, Md = 2). Finally, students stated that the tool was easy to use (M = 3.13, SD = 0.95, Md = 3) and there was no need to learn many things to know how to use it (M = 1.82, SD = 0.71, Md = 2). In sum, the usability of the VCS was found in general satisfactory or very satisfactory in line with the general SUS score.

4.3 Emotional aspects

From the CES results obtained we evaluate here the students' emotions of the experimental group during the work with the VCS (H2), showing that students felt more often happiness than sadness, anxiety or anger when using the new VCS tool. The most noticeable result is found in Happiness highest value, while students felt the same level of Sadness, Anxiety and Anger emotions, which were all very low, almost inappreciable (Md = 0), being the Anxiety emotion the lowest (M = 0.17). These results demonstrate that students were curious with the video format of the discussion and that they did not experience these bad feelings when using the VCS.

Overall, these are very good results considering that students faced a modern learning resource that was new for them and they had to learn its functionality and how to use it for their benefit. Finally, this result is in line with the results presented above concerning usability.

4.4 The VCS as a valuable resource

In this sub-section, we validate the level of worthiness of the VCS as an educational tool (H5). From the four questions of the questionnaire based on the 0–10 point scale, the general mean score obtained of 5.65 (SD = 2.09 and Md = 6) with X^2 (1) = 8.7, $p <$ 0.01 is in line with the previous results on usability and emotions, both confirming the value of VCS as an educational resource. The analysis of the open responses to these four questions provided the following interpretation:

- Question 1, asking students to value the VCS system, in general indicated that the VCS allows for watching how knowledge was constructed step by step in a real situation instead of having to believe the knowledge construction process without real evidences. On the other hand, only a very few students complained on technical issues that made uneasy to follow the discussion with VCS while others found the video format of the VCS monotonous and preferred to read the text-based posts of the phpBB forums.

- Question 2, aimed to compare the video format to the text-based posts of the phpBB forum, resulted with fair scores though the lowest scores of all the questions. Many students indicated that the innovative format of the VCS engaged them into the discussion while fostering reflection and reasoning processes instead of simply scanning others' opinions. As a result, the new learning resource helped students understand the concepts more easily than traditional text-based forums. On the other hand, some students found the VCS excellent but as a complement of the standard forum rather than replace it. Other students mentioned not to see further advantages from the video format and even they found easier to read than watch the video-discussion, while others found the oral format faster and clearer to understand. Finally, most of students thought that the new video format has a lot of potential though they were used to reading posts rather than watching it, thus showing some steps of resistance to change and needing time and more experiences to get used to study this way.
- Question 3 that seeks the potential of the VCS system to observe how knowledge is built indicated that most of students found this resource very useful to learn and acquire knowledge by watching rather than reading long texts. They also mentioned that the video resource was very suitable for those who are accustomed to face-to-face learning by watching people rather than reading materials. In addition, they reported that by the new resource they could observe and build new knowledge based on others' opinions and replies on them, and as a result to form own and mature opinions on the discussion topic. On the other hand, a few students indicated that the content of the material should be refined for the purpose of observing how knowledge is constructed, such as changing the overall discussion from sequential to tree structure and shortening certain responses. Finally, some students reported that some video scenes were useful to observe the knowledge construction process while other scenes brought certain level of confusion due to the length or repetition of previous contributions, similarly to text-based posts.
- Question 4 related to the efficiency and performance of the VCS obtained quite good results and the highest score of all the questions. Almost all students indicated that the VCS was intuitive and easy to use, as well as very convincing from the efficiency and performance perspective. This result is in line with the results obtained on usability. A few students who were Linux users reported problems with installing the VCS plugins (i.e., MS Silverlight) in their computer systems. Also, some students mentioned they found the "robotic voice" of the animated avatars monotonous and bothering.

Finally, many students provided some hints to improve the VCS in general as they suggested using this type of learning resources in more courses and programs of the UOC. In overall, the above are good results considering this version of the VCS system at the time of the experience was far from being fully developed. In particular, the user interface needed to take several iterations of improvements before being completed.

4.5 Knowledge acquisition

In this sub-section we validate the level of knowledge acquisition by using the VCS tool (H4). From the results of Table 2, students from the experimental group scored higher than the control group though the difference is not significant. Both groups got good marks on average and showed a good level of knowledge acquisition. These results are in line with the results from the impact of the VCS tool in the students' activity levels (see Section 4.1), which was higher than in the other classroom but also in line with the quantity and quality of the participation reported in Section 4.4 where students indicated that the VCS did not foster the quantity and quality of the participation.

In summary, we cannot conclude that the current version of the VCS tool had an impact on the knowledge acquisition of the discussion. This conclusion is in line with previous experiments with the VCS [5, 18].

5. Conclusions and further directions of research

In this final section the results are summarized by focusing on the goals determined at the beginning of this study (from G1 through G6—see the research goals in Section 3.2). Then, based on these results, further research and technological directions of research are provided.

In general, the students of the engineering course liked the approach proposed and found the VCS tool interesting so as to have another option to follow the in-class discussion-based assignments. During the experience with the VCS tool, students indicated they could generate the storyboard from the phpBB forum without problems (G1) and it was effective to support the discussion for review and summary purposes of engineering topics (G5). Despite some technical problems, the majority of students reported to be able to generate the storyboard efficiently (G6) and create, use and playback it as many times as needed easily and with positive emotions (G4). In addition, the VCS was proved to become a worth engineering educational resource by assessing several aspects of the learning process (G2), such as knowledge building and participation. In particular, the gain in knowledge acquisition in technical aspects the engineering course by using the VCS could also be validated by comparing the gain of knowledge with previous experiments in the same course with the phpBB forum without the VCS, though the results obtained were not significant. Finally, the students' comments gave many hints for possible improvements of the tool (G3).

Current research aims at identifying the exact processes needed to create CC-LOs, whether the content itself requires creation, or rather CC-LOs may be formed by appropriately recognizing the pedagogic relationship between existing technical and conceptual components, and consolidating them into the LO approach and within the curricula of the engineering courses of the UOC. From this pedagogic perspective, ongoing work aims to develop clear guidelines for the creation and use of CC-LOs both within different engineering application domains (e.g., software and computer engineering) and by engineering educators on a wider scale.

Next iterations of our approach will provide a full featured version of the VCS prototype to support specific aspects of the engineering curricula, such as systems models and simulation. Innovative functionality will be incorporated, such as an editor tool that allow for building a reusable CC-LO by eliciting the knowledge acquired in previous live collaborative sessions. From this technology perspective, we plan to provide a new type of collaborative complex learning resource, which have an impact on the knowledge acquisition and in the learning process in general. For this purpose, these new resources will incorporate new forms of cognitive assessment and the embodiment of emotion awareness to empower the learning experience and improve the student motivation and engagement. Overall, these extensions with complex cognitive and emotional dimensions will eventually provide learners with balanced levels of challenge, interaction and empowerment during the collaborative learning experience.

Acknowledgements—This work has been supported by the Open University of Catalonia (Teaching innovation project: APL2012 PID002) and by the European Commission under the Collaborative Project ALICE "Adaptive Learning via Intuitive/Interactive, Collaborative and Emotional System", VII Framework Programme, Theme ICT-2009.4.2 (Technology-Enhanced Learning), Grant Agreement n. 257639.

References

1. P. Dillenbourg, Introduction; What do you mean by "Collaborative Learning"? In P. Dillenbourg (Ed.), *Collaborative learning. Cognitive and computational approaches,* Elsevier Science, 1999.
2. A. Goodsell, M. Maher, V. Tinto, B. Leigh Snith and J. MacGregor, Collaborative Learning: A Sourcebook for Higher Education. Pennsylvania State University: *National Center on Postsecondary Teaching, Learning, and Assessment,* 1992.
3. G. Stahl, Group Cognition: Computer Support for Building Collaborative Knowledge, *Acting with Technology Series*, MIT Press, Cambridge, MA, USA, 2006.
4. S. Caballé, D. Gañan, I. Dunwell, A. Pierri and T. Daradoumis, CC-LO: Embedding Interactivity, Challenge and Empowerment into Collaborative Learning Sessions. *Journal of Universal Computer Science*, **18**(1), 2012, pp. 25–43.
5. S. Caballé, Evaluation and Validation of the Virtualization of Live Collaborative Learning Sessions. *International Journal of Engineering Education*, **28**(6), 2012, 1274–1287.
6. A. D. Wiley, Connecting learning objects to instructional design theory: A definition, a metaphor and a taxonomy, *The instructional use of learning objects Bloomington*: Association for Educational Communications and Technology, Utah, USA, 2001
7. R. Farrell, S. D. Liburd and J. C. Thomas, Dynamic assembly of learning objects. *Proceedings of the 13th International World Wide Web Conference*, New York, USA, 2004, pp. 162–169.
8. A. Bandura, *Social learning theory*, General Learning Press, New York, 1977.
9. L. S. Vygotsky, *Mind in Society: The development of higher order psychological processes*, Harvard University Press, Cambridge and London, 1978.
10. J. Conesa, S. Caballé, D. Gañán and J. Prieto, Exploiting the Semantic Web to Represent Information from On-line Collaborative Learning. *International Journal of Computational Intelligence Systems*, **5**(4), 2012, pp. 653–667.
11. N. Capuano, S. Miranda and F. Orciuoli, IWT: A Semantic Web-based Educational System. *Proceedings of the IV Workshop of the AI*IA Working Group on Artificial Intelligence & E-Learning,* Reggio Emilia, Italy, 2009, pp. 11–16.
12. S. Caballé, T. Daradoumis, F. Xhafa and A. Juan, Providing Effective Feedback, Monitoring and Evaluation to On-line Collaborative Learning Discussions. *Computers in Human Behavior*, **27**(4), 2011, pp. 1372–1381.
13. B. Ertl, K. Ebner and K. Kikis-Papadakis, Evaluation of E-Learning, *International Journal of Knowledge Society Research*, **1**(3), 2010, pp. 33–43.
14. Bortz, J. and Döring, N. *Forschungsmethoden und Evaluation*, Springer, Heidelberg, 2006.
15. M. Alexander, F. A. Graybill and D. C. Boes, *Introduction to the Theory of Statistics.* McGraw-Hill, 1974.
16. J.Brooke, SUS: A "quick and dirty" usability scale. *Usability evaluation in industry.* London: Taylor & Francis, 1996.
17. R. H. Kay and S. Loverock, Assessing emotions related to learning new software: The computer emotion scale. *Computers in Human Behavior*. **24**, 2008, pp. 1605–1623.
18. J. E. Labra, P. Ordóñez de Pablos and J. M. Cueva Lovelle, WESONET: Applying Semantic Web Technologies and Collaborative Tagging to Multimedia Web Information Systems, *Computers in Human Behaviour*, **26**(2), 2010, pp. 205–209.

Santi Caballé received his Ph.D. Masters and Bachelors in Computer Science from the Open University of Catalonia (UOC) in Barcelona, Spain. He is an Associate Professor and Academic Director at the UOC, where he teaches and coordinates a variety of on-line courses of the Bachelor and Master in Computing Engineering and other post-graduate programs in the areas of Software Engineering, Collaborative Learning and Information Systems. He is also supervising several Master and PhD thesis at the UOC. He received a teaching accreditation as Tenure-track Lecturer issued by the Catalan Government and was awarded with teaching merits by the UOC. In addition, Dr. Caballé is an Associate Researcher at the Internet Interdisciplinary Institute and at the eLearn Center of the UOC and was formerly a visiting scholar at the International Computer Science Institute (Berkeley, CA, USA). He was awarded by the Catalan Government with both research merits and a research accreditation as Tenured Assistant Professor. His research interests focus mainly on e-Learning, CSCL, Software Engineering, and Distributed Computing. Dr. Caballé has leaded and participated in over 20 competitive research projects, including leading EU-FP7 and US-NSF multi-million funded projects, and has been involved in the organization of several international conferences and workshops. His publication record spans over 150 peer-reviewed research contributions, including 10 books and 35 journal papers, and has been invited to give keynote talks in international conferences and seminars. Finally, he has served as a guest editor and reviewer for many books and journals, and currently he serves as Editorial Board member of leading journals.

David Ganán is a computer science engineer specialized on databases design and software engineering. He works at the Open University of Catalonia since 1999 taking different roles: lecturer, coordinator, author and tutor, in some Computer Science subjects of different courses, especially he participated in the design and creation of the Microsoft .NET master area, where he is still currently collaborating. He also developed many academic projects inside the eLearning field. Apart from UOC activities he works as freelance independent professional for 3rd parties. He has collaborated with several important companies in the software development area like Microsoft, Bitmakers, Raona, Itequia or WorldSensing.

Màrius Gómez is a professional with 20 years of experience in the ICT sector. He is in charge of the new services transformation department for the Regional Government at the T-Systems company in Barcelona, Spain. He is also collaborating as a lecturer of the Bachelors in Computing Engineering at the Open University of Catalonia and he is currently pursuing his Doctorate degree by conducting research on Knowledge Management in the e-Government area (focus on Tourism and Education). Finally, he is the Vice Dean University Relations and Technological Transfer at COEINF. His professional specialties focus on e-Government Services and Large IT & Complex Systems.

Jordi Conesa is an Assistant Professor of Information Systems at Open University of Catalonia. He received his PhD in Software Engineering from the Technical University of Catalonia, after a research stay in Georgia State University of Atlanta (US). His research interest concerns the areas of conceptual modeling, ontologies, Semantic Web, knowledge-based systems and e-learning. His long-term goal is to develop methodologies and tools to use ontologies effectively in several application domains, such as conceptual modeling, software engineering and e-learning. He has authored more than 50 research papers, has participated in several research projects, including EU-FP7, CICYT and AVANZA funded projects, and has contributed in the organization of some international conferences, such as the ER 2008.

Àngels Rius is a Lecturer of Computer Science at Universitat Oberta de Catalunya since 2001. She had also been part-time Assistant Professor in the Universitat Politècnica de Catalunya for sixteen years. She received her PhD in Information and Knowledge Society, her B.S. degree in Computer Science and her M.S. degree in Software Engineering at the Universitat Politècnica de Catalunya. Her research interests concerns the areas of ontolologies, Semantic Web, Knowledge-Based Systems and e-Learning, especially focused on frameworks to formally representing educational settings in order to contribute to the automation of the main learning processes which usually occurs in Learning Management Systems.

Francesc Santanach has a Bachelor degree in Software Engineering from the Polytechnic University of Catalonia (UPC). He currently works in the Office of Learning Technologies of the Universitat Oberta de Catalunya (UOC). He is not only responsible for the design and technical architecture of the UOC Virtual Campus, but also for the interoperability and integration of e-learning solution and educational resources. He runs national and international projects in the field of education contents, eLearning tools and standards, such as SCORM and IMS QTI platforms, videoconferencing, audio and video blogs, 3D environments and integration and interoperability services based on IMS LTI and OKI OSIDs. He has also been a researcher in the e-learning field, author of learning materials and tutor for the UOC.

2.3. An Application Framework to Systematically Develop Complex Learning Resources Based on Collaborative Knowledge Engineering

Gañán, D., Caballé, S., Conesa, J., Xhafa, F. (2015). *An Application Framework to Systematically Develop Complex Learning Resources Based on Collaborative Knowledge Engineering*. International Journal of Applied Mathematics and Computer Science (AMCS). University of Zielona Góra Press. ISSN: 1641-876X. IF: 1.390, Q1: 45/250 (JCR-2013 SE). To be published in Vol. 25, No. 2.

This contribution proposes the provision of software infrastructure to support new types of learning methodologies and resources based on collaborative knowledge engineering by means of an innovative application framework called Virtualized Collaborative Sessions Framework (VCSF). The VCSF helps meet challenging collaborative knowledge engineering requirements in online learning, such as increasing group members' learning performance during the on-line collaborative learning process. In turn, the systematic application of the VCSF platform enriched with semantic knowledge engineering technologies enables e-learning developers to leverage successful collaborative learning experiences in a software reuse fashion while saving development time and effort. The framework is prototyped and successfully tested in real environments, thus showing the software reuse capability and the collaborative knowledge engineering benefits of the VCSF approach.

This paper will be published in the current year and allocated in Volume 25 Number 2 of the journal. The journal editor's acceptance letter is attached in section A.1 of Annex A.

Int. J. Appl. Math. Comput. Sci., , *Vol.* , *No.* , –
DOI:

AN APPLICATION FRAMEWORK TO SYSTEMATICALLY DEVELOP COMPLEX LEARNING RESOURCES BASED ON COLLABORATIVE KNOWLEDGE ENGINEERING

DAVID GAÑÁN *, SANTI CABALLÉ *, JORDI CONESA *, FATOS XHAFA **

* Open University of Catalonia, Department of Computer Science, Multimedia, and Telecommunication
Barcelona, Spain
{dganan, scaballe, jconesac}@uoc.edu

**Technical University of Catalonia, Department of Languages and Informatic Systems
Barcelona, Spain
fatos@lsi.upc.edu

This contribution proposes the provision of software infrastructure to support new types of learning methodologies and resources based on collaborative knowledge engineering by means of an innovative application framework called Virtualized Collaborative Sessions Framework (VCSF). The VCSF helps meet challenging collaborative knowledge engineering requirements in online learning, such as increasing group members' learning performance during the on-line collaborative learning process. In turn, the systematic application of the VCSF platform enriched with semantic knowledge engineering technologies enables e-learning developers to leverage successful collaborative learning experiences in a software reuse fashion while saving development time and effort. The framework is prototyped and successfully tested in real environments, thus showing the software reuse capability and the collaborative knowledge engineering benefits of the VCSF approach. The research reported in this paper was undertaken within the ALICE project funded under the European Seventh Framework Program (FP7).

Keywords: software infrastructure, application framework, collaborative knowledge engineering, on-line collaborative learning, discussion forums, virtualized, collaborative sessions, collaborative complex learning resources

1. Introduction

Computer-Supported Collaborative Learning (CSCL) is a mature research field in the educational domain dedicated to improving teaching and learning through the introduction of modern ICT (Dillenbourg, 1999b). Learning collaboratively is represented by a set of educational approaches, involving joint intellectual effort by learners, or learners and teachers together (Goodsell et al., 1992). Collaborative learning activities vary widely, though most of them are centered upon student's exploration or application of the course material, not simply the teacher's presentation or explication of it.

However, many researchers (Dillenbourg, 1999a; Goodsell et al., 1992; Stahl, 2006) argue that students must be meaningfully engaged in the CSCL resources for effective collaborative learning to occur. Such a lack of engagement is especially evident in on-line collaborative learning content, and can be attributed to the lack of (i) real interactivity (in many cases the only interaction available is to click on the *next* button to obtain the next message in a discussion forum); (ii) challenging collaborative tools, instead of tools which fail to stimulate learners, making the collaborative experience unattractive and discouraging progression; and (iii) empowerment, as learner expects to be in control of their own collaborative learning.

In order to overcome these limitations, in previous research, we reported on a new collaborative learning methodology called Collaborative Complex Learning Object (CC-LO) (Caballé *et al.*, 2012) through the development of a system prototype called Virtualized Collaborative Session (VCS) that enables the embedding and execution of the CC-LO approach (Gañán *et al.*, 2013). The VCS application creates CC-LOs from the virtualization and registration of live collaborative sessions, which can be augmented by alternative learning paths, cognitive and emotional features, additional content, etc., during an authoring phase (i.e. an expert managing the CC-LO). The registered CC-LOs are eventually packed and stored in the form of Collaborative Complex Learning Resource (CC-LR) (see Fig. 1) for further reuse, enriching live sessions of collaborative learning with balanced levels of interaction, challenge and empowerment (Caballé *et al.*, 2013).

However, current Learning Management Systems (LMS) do not support a straightforward integration of modern pedagogical models and methodologies nor the corresponding complex learning resources yielded (Abad, 2008), instead great development efforts must be made to integrate these resources into LMSs most of times in an ad hoc fashion, with very inefficient results in terms of productivity, quality and cost (Moscinska and Rutkowski, 2011; Christie and Jurado, 2009). Further, LMS developers have no opportunities to leverage computational experiences of on-line collaborative learning designed to meet modern and changing pedagogical requirements, hence the software reuse capacity in this field is rather low (Caballé and Xhafa, 2010).

In this paper, we propose the provision of software infrastructure to support new types of pedagogically augmented collaborative learning methodologies and resources by means of an innovative application framework (Schmidt, 1997) called Virtualized Collaborative Sessions Framework (VCSF). A first step towards this direction was proposed in Gañán *et al.* (2013). The VCSF supports the entire process of creation, management and execution of the mentioned SLO and CC-LR resources from any LMS and collaborative learning tool. As part of the process, the VCSF exploits the VCS application and leverages Web semantic technologies (Conesa *et al.*, 2012) to enable e-learning software developers to embed many types of successful collaborative learning experience into different LMSs in a software reuse and systematic fashion. For validation purposes, the paper presents successful experiences, both pedagogical and technical, evaluating our framework into different LMS and e-learning tools to support the virtualization process of live collaborative learning sessions. The ultimate aim is to show the software reuse capability from the systematical application of the VCSF approach as well as the resulting pedagogical benefits, such as increasing students engagement and learning performance.

The paper is structured as follows: Section 2 presents related concepts, theories and technologies applied and sets the research goals. The proposed application framework that supports the development of complex collaborative learning resources is defined and prototyped in section 3. Section 4 validates our application framework through experimentation in a real e-learning context. Finally, section 5 concludes the paper and outlines ongoing and future work.

2. Background and research aims

In this section, a brief overview of each of the technologies and paradigms related to this work is presented, namely (i) software infrastructure for collaborative learning, (ii) technology support for collaborative learning and (iii) semantic knowledge engineering technologies. This overview will serve as background for setting the main goals of this research, which are defined at the end of this section, becoming the very rationale of the software infrastructure approach for collaborative learning presented in this paper.

2.1. Software infrastructure for engineering collaborative learning applications. Generic platforms, frameworks and components are normally developed for the construction of complex software systems through the reuse technique (Gamma *et al.*, 1995; Fayad *et al.*, 1999; Schmidt, 1997; Caballé and Xhafa, 2010; Rius *et al.*, 2013). This approach has been successfully applied to different domains thus providing applications of increased quality, and reduced cost and development time (Czarnecki and Eisenecker, 2000; Gomaa, 2005).

In particular, application frameworks promote a standard structure for developing software applications and tools. Programmers find it much simpler to create automatic creation tools when using a standard framework, since this defines the underlying code structure of the application in advance. Developers usually use object-oriented programming techniques to implement frameworks such that the unique parts of an application can simply inherit from pre-existing classes in the framework (Fayad *et al.*, 1999). Application frameworks became popular with the rise of graphical user interfaces (GUIs) and Web applications, which alleviate the overhead associated with common activities performed in web development and creating GUI tools by providing libraries for database access, template frameworks and session management, and they often promote code reuse (Schmidt, 1997). The outcome of our work reported in this paper follows this application framework approach.

However, a revision of the latest research to provide framework support to the development of applications within the field of CSCL domain shows that the results are still scarce (see Caballé, 2008 and Caballé et al., 2007 for an extensive overview of related work). Main focus is still on leveraging the great research efforts and technological advances within the general Computer-Supported Cooperative Work (CSCW) domain (Penichet *et al.*, 2010; Fonseca *et al.*, 2009; Petropoulakis and Flood, 2007; Bao-Qing *et al.*, 2007;

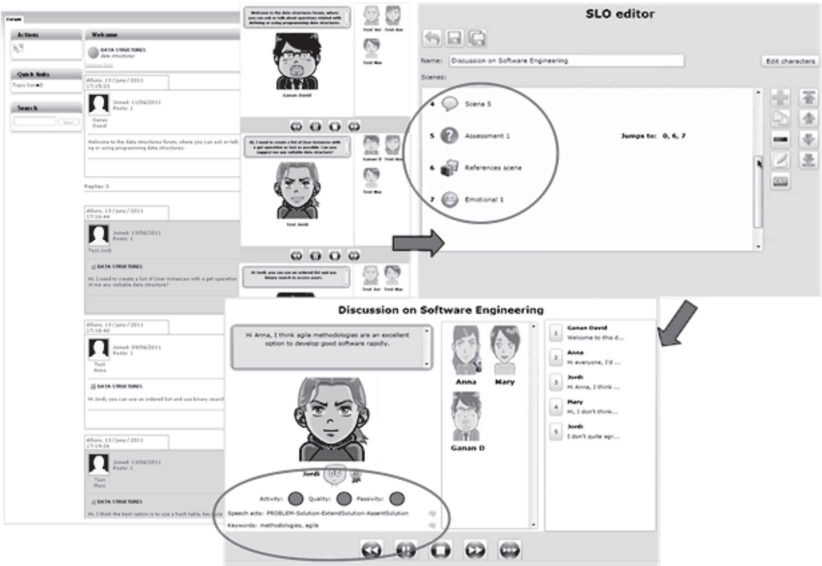


Fig. 1. The process of producing, managing and storing a CC-LR by the VCS system from a CC-LO/SLO (left part), incorporating different types of scenes and author information (right part), such as cognitive assessment and emotional awareness of the original participant and contributions.

Lukosch and Schümmer, 2006). These approaches provide exhaustive support for cooperative work, such as group and workflow management, group editing, document sharing and many types of both synchronous and asynchronous communication (Fonseca *et al*., 2009). However, many of them are not even prepared to support essential collaborative learning features, such as collaborative knowledge building and scaffolding as well as specific monitoring and assessment of the learning process (Dillenbourg, 1999a). Representative researchers (Stahl, 2006) argue whether intrinsic CSCL requirements should be considered from the very beginning of the development and not as an extension to experimented CSCW tools for work (Bentley *et al*., 1997).

2.2. Technological approach for enhancing collaborative learning applications. Technologists have made many attempts to provide better tools for content creation, management, and execution of learning resources to educators, but the transition from the role of content creator to moderator generates inherent resistance in the educator (Mosley, 2005). In particular, CSCL tools commonly focus on the provision of design aids to educators, which seek to ensure best-practice in pedagogy is facilitated, or required, by the software and its user interface (Abdullah and Abbas, 2006). This has the potential to address the common concern in technology-supported learning of technologists, rather than educators, taking a lead role (Zyda, 2005), by lowering the technological skills required to create and implement scenarios.

The research drive here is in creating CSCL tools which are a degree abstracted from low-level technical implementation. However the concept of a CSCL tool composable within different LMS, demands to realize it in practice. Such demand arises from the evolving nature of technology and its increasing ability to facilitate various learning styles and content items, and therefore transfer of pedagogic content between technologies requires some ability to adapt this content autonomously to meet the capability of the system.

2.3. Semantic knowledge engineering technologies for learning. There has been a great effort in the Semantic Web community in order to provide specifications, standards and ontologies to facilitate semantic processes in learning (Wilson, 2004; Inaba *et al*., 2000). The difficulties of the current standards and specifications for defining learning objects unambiguous specifications pose a serious problem in its adoption to semantic approaches (Rodrguez *et al*., 2009). Several ontologies have been created to define learning objects unambiguously. The more representative of them are Al-Khalifa and Davis (2006); Brase (2005); Dodero *et al*. (2005); Ullrich (2005); Zarraonandía *et al*. (2004).

Semantic approaches related to the definition and implementation of learning processes in the field of CSCL include Babič *et al*. (2008) who define an ontological framework to describe the common semantics needed for the implementation of collaborative learning environments. Rius *et al*. (2013) also propose the use of educational patterns in a Domain Specific Language fashion in order to specify and reuse patterns of processes that occur repeatedly in learning environments, providing a good alternative to model and reuse learning processes. Similarly, Dodero et al. (2010; 2012) use ontologies in a model driven approach in order to use a standard vocabulary to specify learning artifacts and mechanisms to automatically implement such artifacts in different LMS. In a higher level of abstraction, (Conesa *et al.*, 2012) propose a framework that supports bottom-up learning processes, such as support registration, management, and sharing methods. It also creates high-level elements, such as courseware and e-learning tools, with remarkable benefits of ubiquity and interoperability, in line with tutors needs and requirements. Indeed, with a well-defined ontology structure, collaborative learning can accumulate the knowledge representation of learning objects and their use, including participant background, instruction designs, learning activities and outcomes, etc (Babič *et al.*, 2008).

To sum up, current attempts fail in providing appropriate response to the two main objectives of our research: (i) provision of software infrastructure to support advanced types of pedagogically augmented collaborative learning resources, and (ii) enable LMS developers to systematically reuse successful collaborative learning sessions. To this end, next section presents a methodological approach to validate our VCSF approach aimed to yield more effective and quality pedagogically augmented CSCL applications while saving development time and effort.

3. Research methodology

In order to achieve the goals of this research, we present in this section our application framework for the creation of storyboard learning objects that are interactive, attractive and easy to use for the e-learning actors. The framework also promotes the reutilization of previous knowledge and the reusability of the created resources.

The application framework we proposed in this paper is called Virtualized Collaborative Session Framework (VCSF). The VCSF was originally meant for the virtualization of collaborative sources, such as forums and chats (Gañán *et al.*, 2013), but it has been extended with other capabilities, such as emotional awareness and cognitive assessment, in order to support the creation and management of CC-LR resources. Next we describe the VCSF in detail, from its architectural components to relevant guidelines and recommendations for LMS domain developers to extract the most of it (see Section 2 for a definition and rationale of the concepts mentioned in this section).

3.1. VCSF architecture and tools. The VCSF architecture (see Fig. 2) is made up of two layers, namely Conversion and VCS layers. It starts with the Conversion layer, which converts data from different data sources of collaborative sessions into a common ontology specification known as Collaborative Session Conceptual Schema (CS^2) (Conesa *et al.*, 2012). Then, the VCS layer creates an SLO from the CS^2 data and stores the SLO in a special repository for further use of the system tools and services. Next, these architectural components are explained in more detail.

3.1.1. Conversion layer. The Conversion layer of the VCSF defines a generic converter component that can be particularly implemented for specific data sources from forums and chats tools of different LMS. As shown in Fig. 2, the input collaborative session from those data sources is read by the converters components and represented using CS^2 common specification, which is based on Semantically-Interlinked Online Communities (SIOC) and Friend of a Friend (FOAF) ontologies. CS^2 can be stored or imported from files in Collaborative Session Markup Language (CSML) format, which is in turn based on the RDF representation for the SIOC ontology (see Conesa *et al.* (2012), for an exhaustive procedure view).

The conversion process done by each specific converter component can be viewed as a deterministic mapping between two data models (original data source schema and CS^2 data model) following a set of predefined mapping rules. Such rules may vary depending on the converter being developed. Although each converter would have its own specific implementation, a two steps sequential process is expected for any converter: (i) a reader component reading data from the data source, and (ii) a mapper component transforming this data into CS^2 model.

The CS^2 model includes entities and relations between them for describing collaborative sessions in a simple way (see Fig. 3). The main entity of the CS^2 model is the *CollaborativeSession*, which is included in *Site* and has a set of *UserAccounts* that participate on it. It also has a list of posts per *UserAccount*. Posts are interrelated in a threaded structure through the *Replies* relation.

3.1.2. VCS Layer. The VCS layer or component is the core of the VCSF architecture (see Fig. 2). This sub-section describes the VCS layer in detail including the tools and services required to create, edit, reproduce and store SLO and eventually produce CC-LR resources.

The CC-LR outcome allows representing collaborative learning objects with a storyboard structure (SLO) which model is depicted in Fig. 4. In this model each step of the collaboration is represented by a different scene. Scenes can in turn be composed by a list of

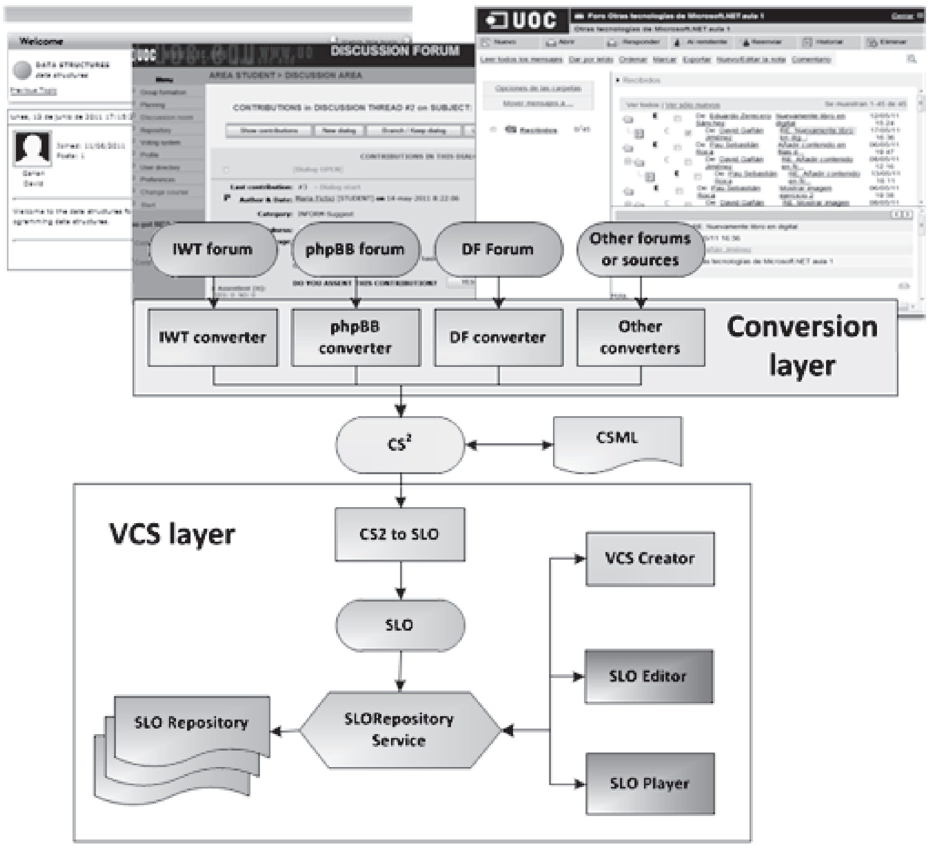


Fig. 2. VCSF general architecture, which is compatible with multiple forums.

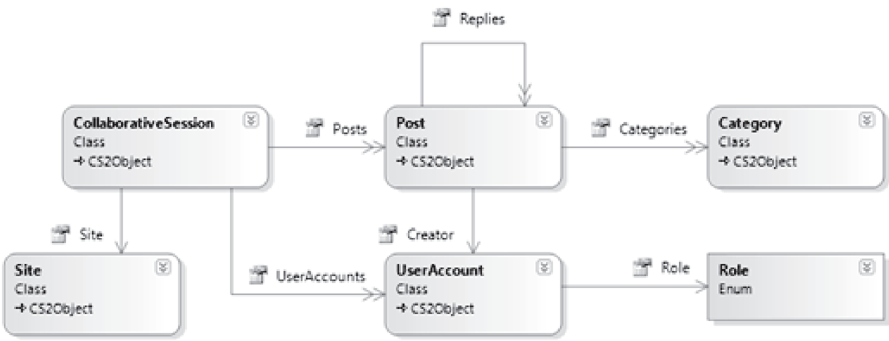


Fig. 3. CS^2 data model.

scene parts, of different types depending on the type of scene. Other kind of scenes can be added to the CC-LR model in straightforward fashion in order to add new functionalities. This is one of the extensibility aspects of the VCSF. On the other hand, a *DialogScenePart* is associated with a *Character*, which has a unique name, a face (avatar) and vocal timbre (for speech). An emotional state is also bind to a *DialogScenePart*.

The architecture of components of the VCS layer (shown in Fig. 2), has the following three types of components:

- *SLO Repository:* This is a core component of the system, which takes care of managing the storage of previously created SLO for reutilization.
- *Tools:* Represented by rectangles in the diagram, they enable the user to interact with the system, by creating, editing or playing SLOs.
- *Services:* Represented by the hexagonal shapes in the diagram, they offer different generic functionalities

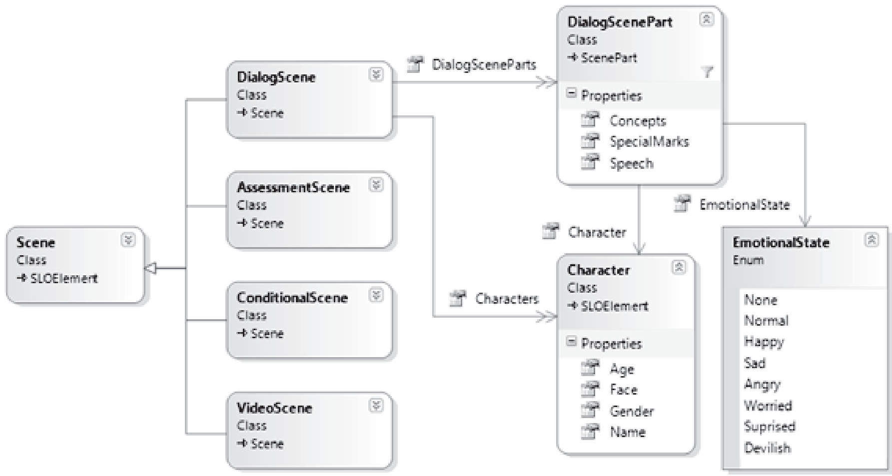


Fig. 4. SLO Model Classes.

to the system that are used within the tools and other components.

Finally, the VCS layer can be extended by adding new services and tools for meeting new requirements and functionalities. The main components of the VCS layer are explained next in more detail.

a) CS^2 to SLO

This component of the VCS layer translates a collaborative scenario represented in CS^2 data into SLO data. The translation consists of a simple and deterministic mapping between the two data models; further process of the results is done manually by the use of the SLO Editor tool (see VCS tools below).

b) SLO Repository

The SLOs created by the VCS system are stored in a common place or SLO Repository to be available for the different tools and services. In order to encapsulate SLOs storage and management functionalities, a SLO Repository service was created in the VCS layer. This service defines different operations to interact with the repository, like getting a list of available SLOs, get an SLO by id, creating a new SLO from a collaborative session, etc.

c) VCS tools

The VCSF provides user interaction through the VCS tools, enabling the user to create, edit and reproduce SLOs. The VCS layer provides by default the following tools:

- *SLO Player tool*

  This tool enables the user to reproduce available SLOs (see Fig. 1 for a screenshot) and its design is flexible enough to reproduce on-the-fly updates of the SLO model. The main element of this tool handles the storyboard defined in the SLO being played at a high level, being unaware of the kind of scenes that compose the storyboard. This is possible because each type of scene represented in a SLO must have a corresponding component to reproduce it. The SLO Player tool relies on services, such as the SLO Repository service or the Speech synthesizer service in order to both access the repository and make text-to-speech requests respectively.

- *SLO Editor tool*

  The main goal of the SLO Editor tool is to enable users to edit an existing SLO and store the changes. Editing a SLO involves creating, modifying or deleting SLO scenes. There are different types of scenes, such as Dialog, Assessment and Emotional scenes, each one needing a custom edition procedure. Similarly to the player tool, the editor tool has its own scene editor for each type of scene, and those scene editors are created by a factory entity depending on the current scene type. The editor tool also relies on services for some generic tasks, such as accessing a SLO list available in the repository, and recovering and updating a SLO.

- *VCS Creator tool*

  This is a helper tool to support the whole process of converting live collaborative sessions into SLOs. It connects to different data sources and shows a list of available sessions so that the user can select the session to convert. Then, the tool recovers the CS^2 data through the corresponding converter, and uses the CS^2 to SLO component in order to create a new SLO, which is eventually stored into the repository.

d) VCS services

The VCS services support the creation, edition and reproduction process of SLOs, such as the above described SLO Repository service. The rest of services are described next:

- *Speech service:* This service provides text-to-speech (TTS) capabilities to the framework. The service receives a text message and a set of features (language, gender, etc.) and returns a byte array containing the generated audio. For the TTS conversion the service relies on the Microsoft TTS system.

- *Multimedia repository service:* This service is for the storage in a repository of multimedia resources used in SLOs and enables interaction with this repository.

- *Conversion service:* Communication with the conversion layer is addressed by this service, to avoid coupling with many modules.

- *Activity log service:* The purpose of this service is to enable logging capabilities to the rest of the framework components.

- *Keywords and Classification services:* SLO messages (Dialog scenes) can be tagged and classified while editing the SLO (see Fig. 5). The keywords service provides access to a dictionary of predefined keywords for tagging, while classification service receives a message and suggests a possible tag or category (see Section 3.1.3).

- *Video generation service:* This service provides functionalities to convert an SLO into a video sequence.

3.1.3. VCSF extensions. Following the above mentioned extensibility of the VCSF framework, this sub-section presents two important pedagogically-based extensions integrated into the VCSF in order to support cognitive assessment (Mora *et al*., 2012) and emotional awareness capabilities (Feidakis *et al*., 2012). The integration of these capabilities is addressed from two time dimensions, namely deferred and immediate time (Caballé *et al*., 2013).

The deferred time approach analyzes data coming from the live collaborative session and considers some data about the participants and messages found in the original collaboration (i.e. the forum tool supporting the live discussion). This approach is performed during the conversion from CS^2 to SLO (CS^2 to SLO component). Note that the CS^2 must be previously extended to support optional fields related to deferred time data though depending on whether the original data source can provide this information, the corresponding converter will fill these optional fields accordingly.

On the other hand, immediate approach focuses on the student who is consuming the CC-LR and is addressed by creating specific types of interactive scenes that provide feedback.

a) Cognitive assessment

Cognitive assessment is essential in virtual collaborative learning scenarios because it provides many forms of feedback to students about their learning progress, thus getting them more engaged in the on-line learning process (see Mora *et al*. (2012)).

Following the time dimensional approach presented earlier, the VCSF supports deferred time assessment by processing the contents of collaborative sessions (e.g. post tags, number of posts, replies, etc.) and presenting CC-LR consumers some visual indicators (Fig. 1) showing the most important contributions and active participants in the collaboration.

The teacher can run an automatic post tagging system included in the SLO Editor, which automatically assigns a tag to each original post by processing the corresponding text following a machine learning approach (see Fig. 5 and also Caballé *et al*. (2009) for the complete procedure). The teacher or learning designer can also manually edit this tag to best express the posts original intentions.

Immediate time assessment is implemented in the VCSF as a set of specific scenes with test questions about the discussion topic and appropriate feedback from the test results. Assessment scenes are created and handled by the SLO Editor tool, which permits the teacher to edit the test questions and answers as well as define a set of feedback rules that change the flow of the SLO depending on the result obtained in the test (Fig. 6). Hence, whether the answer is right or wrong, the student may be redirected either to the next scene or to a previous scene respectively. In case of failing the same test repeatedly the students is redirected to a special scene with complementary material on the test topic, thus filling the knowledge gaps.

b) Emotional awareness

Emotional awareness is considered a relevant aspect of e-learning, providing feedback to user emotions while learning can help orientate students and increase their engagement (see Feidakis *et al*. (2012), also for a complete view of the emotional procedures of the VCSF described next).

Similarly to the cognitive assessment perspective, the VCSF approaches emotional awareness also from two time dimensions, namely deferred and immediate time. Emotional awareness in deferred time shows the emotional state of each participant while posting the corresponding message to the live collaborative session (see Fig. 1). This emotional state is calculated during

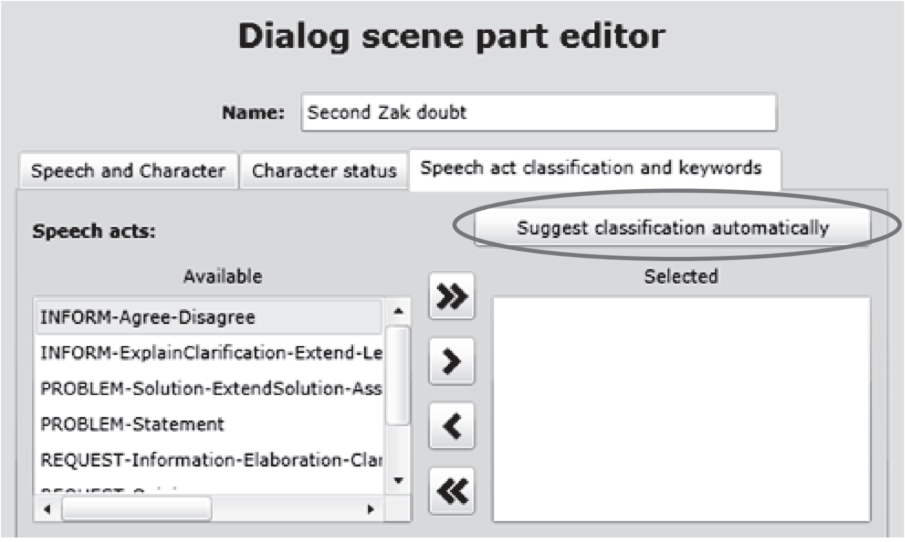


Fig. 5. Tags on speech acts either suggested by the system or selected manually.

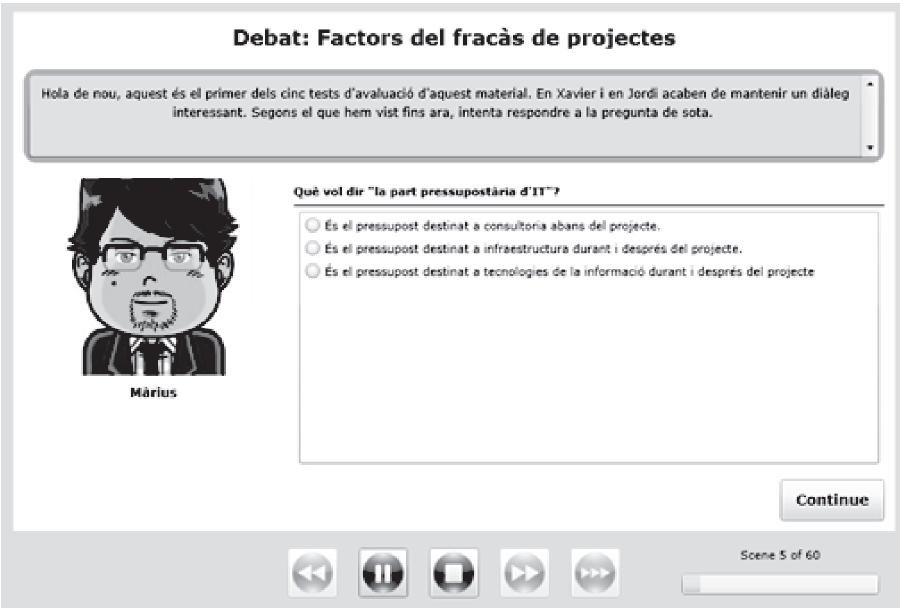


Fig. 6. Immediate assessment scene during the reproduction of an SLO.

the conversion from CS^2 to SLO in case of that the CS^2 contains emotional state information from the live collaborative session. The SLO editor tool also enables the teacher to set up the emotional state of the participants in each dialog in order to best transmit the original participants emotions.

On the other hand, emotional awareness in immediate time is implemented by a set of scene types that can be created and managed by the SLO Editor tool, which ask the student about her emotional state using non-verbal reporting mechanisms (i.e. icons, see Fig. 7a). Based on the students selection, certain empathetic response is shown in order to engage or motivate the student to move forward (see Fig. 7b).

3.2. VCSF proof of concept. The VCSF was successfully tested in a LMS system called IWT, with the purpose to greatly enhance and improve its underlying collaborative learning processes and experiences. In particular, the VCSF fully assisted in the generation of SLO from the mentioned LMS, namely IWT forum. This experience gave us the opportunity for an in-depth practice with the framework, in terms of flexibility, abstraction and potential reuse capabilities.

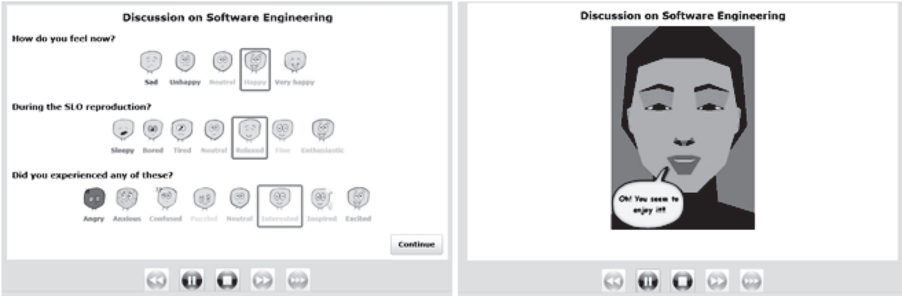


Fig. 7. Immediate emotional awareness: on the left (a) the student her emotional state; on the right (b) a virtual agent provides an empathetic response.

Following the architecture of the VCSF (see Section 3.1.1), the only component that had to be developed from the scratch during the integration process was the corresponding converter for the data sources of each web forum. The rest of components of the VCSF were integrated transparently into the web forums of the LMS.

The general strategy to build a converter for a new e-learning system (i.e. web forum data source) consists of the following 3-step process (see also Section 3.1):

1. Install and set-up the VCSF main components (services, tools, etc.), in a web server.
2. Develop a converter piece of software for the new data source of the targeted web forum.
3. Add the new converter into the VCSF framework.

From the above, the most interesting step for research purposes is the development of the converter piece of software. The implementation varies depending on the location and structure of the data in the data source, but the strategy is similar in all cases. For obtaining the list of available live collaborative sessions, the converter queries the data source (database, file system, etc.) and recover some basic information about the sessions, such as session id and title. Then, the converter uses this information to obtain the entities and attributes from the forum data source and matches them with the CS^2 model, thus realizing the conversion. Finally, once we have the CS^2 model, the VCSF uses it as an input to automatically generate the SLO through the CS^2 to SLO component.

Finally, we prototype the VCSF components in the IWT system and its supported web forums, which store information about collaborative sessions in a database using a custom structure. The main issue found in this experience was that the IWT and the VCSF system were installed in separated servers, and a direct access to the IWT database was not available from the VCSF server. The solution to this problem was to split the converter component in two parts communicated between them by the Internet. The one installed on the IWT server read data from database, converted it into CS^2 data model, and then sent it to the component installed on VCSF server, which in turn made it available to the VCSF system in order to convert it into an SLO.

From the point of view of the user this process is transparent, which is up to the VCSF to handle it. When the user requires a collaborative session of IWT web forums to convert into SLO, IWT opens a new web page calling the VCS Creator tool and passes on the corresponding session id. The VCS Creator then recovers the session data in CS^2 format by using the converter, converts the CS^2 data into SLO (by the CS^2 to SLO component) and eventually stores the SLO into the repository (SLO repository tool). Once the SLO is created, the VCS Creator automatically starts the SLO Player tool to show the SLO reproduction to the user.

4. Experimentation and validation

An empirical study (an in-class experimentation with real students) was conducted to evaluate the prototypes presented in the previous section. This study was performed on a proof of concept of a CC-LR coming from a SLO built and supported by the VCSF framework. Therefore, the results and interpretation of this study help validate the underlying VCSF framework used to develop the proofs of concept in different collaborative learning tools (see section 3.2).

In the next sub-sections, we first describe the set-up and procedure of the study and then show the experimental results along with an analytical data discussion on these results.

4.1. In-class experimentation. For the in-class experiment, a CC-LR resource was developed by the VCSF. Firstly, the data source of a live collaborative learning session was derived from a typical discussion forum used to support in-class discussions at the Open University of Catalonia (UOC). Then, we used the VCSF to generate an animated SLO from the forum tool showing how people discussed and collaborated, how discussion threads grew and how knowledge was constructed, refined

Fig. 8. Screenshot of a moment discussion supported by the IWT Web forum is virtualized as a video storyboard (SLO) created by the VCS tool (facial images have been faded and surnames have been removed for private reasons).

and consolidated (see Fig. 1). By the VCS tools this SLO was then stored for further reuse in the form of a CC-LR and augmented by the Editor with emotional and assessment information as explained in Section 3.3.

The ultimate goal was to evaluate the pedagogical benefits of the VCSF approach to build a CC-LR and analyze their effects in the learning process. The experimentation took place in the real context of learning of the UOC.

4.1.1. Experimentation set-up and procedure. The sample of the experiment consisted of 55 undergraduate students enrolled in the course Organization Management and Computer Science Projects in the Engineering Computing degree at the UOC. Despite all 55 students participated in this experience, only 29 out of them (52.7%) submitted the final questionnaire, the rest of students (26) dropped out the discussion and the course for personal reasons. It is worth mentioning that the 45% dropout ratio found is considered normal at the end of the academic term. The group was supervised by a tutor who was in charge of the course.

The experimentation procedure was as follows. A formal in-class learning assignment was scheduled during the first 2 weeks of January 2013. The activity was individual and mandatory for all students and consisted in filling a test with questions on Software projects management. Besides the usual didactical material of the course, students of the experimental group were required to use a new material to support specifically this activity in the form of a video-discussion (CC-LR) called Factors that lead a Computer Science project to failure which contained a discussion about project management (see Fig. 3). This material was enriched with emotional information, which made the material highly interactive. The students could watch this interactive CC-LR material embedded in the VCS system from their on-line classroom of the UOC.

After the assignment, students were required to fill out a questionnaire, which included: (i) test-based evaluation on the usability of the VCS system; (ii) test-based evaluation on the emotional state when using the VCS system and (iii) test-based evaluation of the CC-LR consumed. Quantitative and qualitative data were collected from the questionnaire containing quantitative and qualitative questions, the answer categories varied between rating scales, multiple choice or open answers. For qualitative data analysis, we summarized the open answers in the questionnaires. For the quantitative analysis we employed basic descriptive statistics, such as Mean (M), Standard Deviation (SD) and median (Md) to analyze the scores obtained in the questionnaire. We complemented this quantitative analysis by employing accepted statistical procedures (Alexander *et al.*, 1974), such as Chi-square (X^2), so as to compare the observed scores to the expected scores.

For the section (i) (usability of the VCS Player showing the CC-LR) we used the System Usability Scale (SUS) developed by Brooke (1996), which contains 10 items and a 5 point Likert scale to state the level of agreement or disagreement (it ranges from I strongly disagree (1), I disagree (2), neither/nor (3) to I agree (4), I strongly agree (5)). SUS is generally used after the respondent had an opportunity to use the system being evaluated.

To investigate the emotional state of the students using the new system (section ii of the questionnaire), we included the 12 items of the Computer Emotion Scale (CES) (Kay and Loverock, 2008). The CES scale is used to measure emotions related to learning new computer software. Research showed that the 12 items are describing four emotions:

- Happiness (When I used the tool, I felt satisfied/excited/curious.)
- Sadness (When I used the tool, I felt disheartened/dispirited.)
- Anxiety (When I used the tool, I felt anxious/insecure/helpless/nervous.)
- Anger (When I used the tool, I felt irritable/frustrated/angry)

The answer categories in this section are None of the time, Some of the time, Most of the time or All of the time.

4.1.2. Results and discussion. This section shows the results collected from the aforementioned experiment from which we evaluated the implicit students satisfaction with the VCSF approach as an educational resource, considering the level of worthiness of the CC-LR as well as the usability and emotional aspects on using the VCS tool.

a) Usability assessment

To evaluate students satisfaction with the tool as regards efficient and user-friendly management, we collected data from students ratings and open comments on the usability/functionality/integration of the tool. SUS scores have a range of 0 to 100 with an average score of 68, obtained from 500 studies. A Score above a 68 would be considered above average and anything below 68 is below average. A score above an 80.3 is considered an A (the top 10% of scores). Scoring at the mean score of 68 gets you a C and anything below a 51 is an F (putting you in the bottom 15%).

After calculating the SUS score for each student (n=29), we got an average for 29 SUS scores of 67.91, thus just on the SUS mean. In particular, students of the experimental group thought they will use the CC-LR (video-discussion) often (M = 3.83, SD = 1.10, Md = 4). Students did not find the tool unnecessarily complex (M = 2.21, SD = 0.90, Md = 2). In addition, students stated that they did not need the support of a technical person to be able to use the video-discussion (M = 1.41, SD = 0.57, Md = 1), they thought that most people would learn to use this system very quickly (M = 4.22, SD = 0.58, Md = 4), and they felt quite confident using the video-discussion (M = 3.90, SD = 1.01, Md = 4). Finally, students stated that the VCS functionality was well integrated (M = 3.48, SD = 0.78, Md = 4) whereas video-discussion was found easy to use (M = 3.24, SD = 1.02, Md = 3). In sum, the usability of the video-discussion enriched with complex aspects, such as emotional information, was found in general satisfactory or very satisfactory in line with the general SUS score.

b) Emotional assessment

Regarding the students emotions of the experimental group during the work with the CC-LR, the results from a 4-point rating scale (n=29) are as follows:

- Happiness (M=1.28, SD=0.71, Md=1). This result shows students were curious with the new type of emotional scenes incorporated in the video-discussion.
- Sadness (M=0.52, SD=0.58, Md=0); Anxiety (M=0.34, SD=0.68, Md=0); and Anger (M=0.24, SD=0.65, Md=0). These results are very good with Md=0, which means that students did not experienced these bad feelings.

In sum, students felt more often happiness than sadness, anxiety or anger when studying with the new learning material (CC-LR) extended with emotional aspects. The most noticeable result is found in Happiness highest value, while students felt the same level of Sadness, Anxiety and Anger emotions, which were very low, almost inappreciable (Md=0), being the Anger emotion the lowest (M=0.24). Overall, this is a good result considering that students faced a complex type of learning material that was new for them and they had to learn its functionality and how to use it for their benefit. Finally, this result is in line with the results presented above concerning usability.

c) The CC-LR as a valuable resource

In this section we evaluate the level of worthiness of the CC-LR enriched with emotional information supported by the VCS as an educational tool. To this end, we collected quantitative and qualitative data in section (iii) of the questionnaire from seventeen open questions addressed to students. The rating scales for the majority of the quantitative questions were based on the usual 0-10 point scale. The rating scale went from the lowest (0) to the highest (10) considering a good assessment from 5.0 to 10 and a bad assessment from 0 to 4.9, being the good assessment the expected scores for each question (n = 29; df = 1; p ¡ 0.05 for the calculated X^2).

To evaluate the CC-LR material, we show next the most relevant questions asked to all students and the results (note that we used the term video-discussions to refer the CC-LR material to be evaluated). Each of the following four questions required to assess the CC-LR from the questions view in the scale 0-10:

1. What do you think in general about the video-discussions?
2. Compare the video-discussions with traditional teaching material and tools (books, web pages, forums, blogs, etc) and indicate pros and cons of the video-discussions.
3. Let us know your opinion about the potential of the video-discussions to observe how people discuss and collaborate, and how knowledge is constructed.
4. Express your opinion about the video-discussions in terms of efficiency and performance.

After calculating the 0-10 scale for all the four questions and participants (n=29) we got a general mean score of 6.93 (SD=1.96 and Md=7) with with $X^2(1)$ = 16.04, p ¡ 0.001. This result is in line with the previous results on usability and emotions, both confirm the value of CC-LR as an educational resource, and in turn the value of the VCSF framework to develop pedagogically complex learning resources.

In particular, for Question 1, students valued the CC-LR enriched with cognitive and emotional aspects with a very good score (M=7.28, SD=1.53, Md=7) with $X^2(1)$ = 16.04, p ¡ 0.001, the highest score of all the questions. Most of students found the video discussions didactical and useful since they are based on opinions and experiences from other students, thus helping understand the topic of the discussion from people with similar background and perspectives. In the same line, students found interesting to know how other students collaborated in previous in-class discussions from past editions of the course. Moreover, some students indicated that the video-discussion allows watching how knowledge is constructed step by step in a real situation instead of having to believe the knowledge construction process without real evidences. Finally, most of students found specially useful and interesting the test questions added in certain points of the material so as to self-evaluate their own progress by the feedback provided. On the other hand, a few students felt some confusion of having different opinions from each character, thus having doubts on what character was right. Only a very few students complained on technical issues that made uneasy to study with this resource while others found the format of the video-discussion monotonous and preferred to study with traditional material (books and text-based learning units). Finally, students did not fully understand the purpose of the emotional scenes nor how this information could help their learning progress in the material.

Question 2, aimed to compare CC-LR with traditional teaching material and tools, achieved good average scores (M=6.93, SD=2.33, Md=7) with $X^2(1)$ = 10.822, p ¡ 0.01. Many students indicated that the innovative format of the video-discussion engaged them into the study and foster reflection and reasoning processes instead of memorizing the contents. As a result, the new learning resource helped students understand the concepts more easily than traditional teaching material. On the other hand, some students found the video-discussion excellent but as a complement of the official teaching material (traditional books and learning units) rather than replace it. In the same line, students indicated that the official material based on traditional formats provide fundamental concepts that cannot be replaced by this new type of resource. Other students mentioned not to see further advantages from traditional text-based discussion forums and even they found easier to read than watch the video-discussion, while others found the oral format faster and clearer to understand. Finally, most of students thought that this new type of material has a lot of potential though they were used to reading material rather than watching it, thus needing time and more experiences to get used to study this innovative way.

Question 3 that seeks the potential of the VCS tool and the embedded CC-LR material to observe how knowledge is built, got fair scores (M=6.62, SD=1.78, Md=7), though the lowest of all questions, with $X^2(1)$ = 8.75, p ¡ 0.01. On the one hand, most students found this resource very useful to learn and acquire knowledge by watching rather than reading long texts. They indicated that the resource was very suitable for those who are accustomed to face-to-face learning by watching people rather than reading materials. In addition, they mentioned that by the new resource they could observe and build new knowledge based on others opinions and replies on them, and as a result to form an own and mature opinion on the discussion topic. On the other hand, some students indicated that the content of the material should be refined for the purpose of observing how knowledge is constructed, such as changing the overall discussion from sequential to tree structure and shortening certain responses. Finally, some students reported that some scenes were useful to observe the knowledge construction process while other scenes brought certain level of confusion due to the length or repetition of previous contributions.

In line with the previous questions, Question 4 related to the efficiency and performance of CC-LR got also good results: M=6.90, SD=2.21, Md=7, and $X^2(1)$ = 10.82, p ¡ 0.01. Almost all students indicated that the video-discussion was intuitive and easy to use, as well as very convincing from the efficiency and performance perspective. This result is in line with the results obtained on usability. A few students who were Linux users reported problems with installing the VCS system in their computer systems. Also, some students mentioned they found the robotic voice of the animated characters monotonous and bothering. Finally, a very few students reported technical problems to interact with the emotional area of the video-discussion.

Finally, students provided some hints to improve the CC-LR in general and the emotional area of the VCS in particular. Moreover, they suggested using this type of learning resources in more courses and programs of the UOC. In overall, the above are good result considering the VCS system included in the VCSF framework is in beta version, far from being fully developed and the user interface needs to take several iterations of improvements before being completed.

5. Conclusions and further developments

This contribution proposes the provision of software infrastructure in the domain of CSCL to support the development of modern and pedagogically augmented collaborative learning resources. As a result, an innovative application framework called VCSF has been presented. Moreover, the systematic application of the VCSF provides e-Learning domain developers the opportunity to leverage successful collaborative learning experiences in a software reuse fashion. The ultimate aim is to yield more effective and prompt responses to meet the demanding and changing pedagogical requirements of current educational institutions by developing timely quality pedagogically-augmented CSCL applications and resources while saving great amounts of development time and effort.

The architectural vision of the VCSF in the form of a reusable software infrastructure has been presented and evaluated to help develop complex, flexible, and advanced types of collaborative learning resources. Each of the components and tools forming the VCSF architecture were first described in detail as well as relevant guidelines and experiences gained in systematically using this approach for the development of collaborative complex learning resources with complex pedagogical aspects of cognitive assessment and emotional awareness. Then, a proof of concept of the VCSF was provided and exhaustively evaluated in a real context of learning to validate the mentioned goals, in terms of technical and pedagogical benefits for both developers and educational institutions.

Despite encouraging, the validation results achieved are not conclusive due to the exploratory nature of the empirical students. More experiences are expected to come and validate the VCSF as a general application framework to support the development of demanding types of complex and advanced learning resources. We plan to run experiments al larger scale to collect more feedback of the VCSF from both technical and pedagogical aspects. Therefore, further directions of research will go to subsequent iterations of the VCSF development of technological and experimentation activities, aimed at the improvement and refining of VCSF components from feedback of previous iterations. This iterative approach will allow the integration of feedback gained through the VCSF components and tools experimentation in further prototype implementations of the framework and of feedback gained during implementation and experimentation in further requirements and design improvement.

From the technology perspective, we plan to leverage modern multimedia technologies by integrating them into the VCSF components and tools in order to enhance and improve further the collaborative learning experience from the software applications developed with our framework.

Acknowledgment

This work has been supported by both the European Commission under the Collaborative Project ALICE Adaptive Learning via Intuitive/Interactive, Collaborative and Emotional Systems, VII Framework Programme, Theme ICT-2009.4.2 (Technology-Enhanced Learning), Grant Agreement n. 257639, and the Ministerio de Educación y Ciencia and FEDER under project TIN2008-00444/TIN.

References

Abad, C. L. (2008). Learning through creating learning objects: Experiences with a class project in a distributed systems course, *Proceedings of the 13th Annual Conference on Innovation and Technology in Computer Science Education*, ITiCSE ’08, ACM, New York, NY, USA, pp. 255–259. *http://doi.acm.org/10.1145/1384271.1384340

Abdullah, S. and Abbas, M. (2006). The effects of inquiry-based computer simulation with cooperative learning on scientific thinking and conceptual understanding.

Al-Khalifa, H. S. and Davis, H. C. (2006). The evolution of metadata from standards to semantics in e-learning applications, *Proceedings of the Seventeenth Conference on Hypertext and Hypermedia*, HYPERTEXT ’06, ACM, New York, NY, USA, pp. 69–72. *http://doi.acm.org/10.1145/1149941.1149956

Alexander, M., Graybill, F. A. and Duane, C. (1974). *Introduction to the Theory of Statistics*, McGraw-Hill.

Babič, F., Wagner, J. and Paralic, J. (2008). The role of ontologies in collaborative systems, *Applied Machine In-*

telligence and Informatics, 2008. SAMI 2008. 6th International Symposium on, pp. 119–124.

Bao-Qing, G., Xiu-Fen, F. and Su-Xia, X. (2007). P2p distributed cooperative work model based on jxta platform, *in* M. Xu, Y. Zhan, J. Cao and Y. Liu (Eds), *Advanced Parallel Processing Technologies*, Vol. 4847 of *Lecture Notes in Computer Science*, Springer Berlin Heidelberg, pp. 658–665.

Bentley, R., Horstmann, T. and Trevor, J. (1997). The world wide web as enabling technology for cscw: The case of bscw, *Computer Supported Cooperative Work (CSCW)* **6**(2-3): 111–134.

Brase, J. (2005). *Usage of metadata*, PhD thesis, Fakultät für Elektrotechnik und Informatik der Universität Hannover, Hannover, Germany.

Brooke, J. (1996). SUS: A quick and dirty usability scale, *in* P. W. Jordan, B. Weerdmeester, A. Thomas and I. L. Mclelland (Eds), *Usability evaluation in industry*, Taylor and Francis, London.

Caballé, S., Jiménez, D. G., Dunwell, I., Pierri, A. and Daradoumis, T. (2012). Cc-lo: Embedding interactivity, challenge and empowerment into collaborative learning sessions, *J. UCS* **18**(1): 25–43.

Caballé, S., Lapedriza, À., Masip, D., Xhafa, F. and Abraham, A. (2009). Enabling automatic just-in-time evaluation of in-class discussions in on-line collaborative learning practices, *JDIM* **7**(5): 290–297.

Caballé, S., Mora, N., Feidakis, M., Gañán, D., Conesa, J., Daradoumis, T. and Prieto, J. (2013). Cc–lr: providing interactive, challenging and attractive collaborative complex learning resources, *Journal of Computer Assisted Learning* .

Caballé, S. and Xhafa, F. (2010). Clpl: Providing software infrastructure for the systematic and effective construction of complex collaborative learning systems, *Journal of Systems and Software* **83**(11): 2083–2097.

Christie, M. and Jurado, R. G. (2009). Barriers to innovation in online pedagogy, *European Journal of Engineering Education* **34**(3): 273–279.

Conesa, J., Caballé, S., Gañán, D. and Prieto, J. (2012). Exploiting the semantic web to represent information from on-line collaborative learning, *International Journal of Computational Intelligence Systems* **5**(4): 653–667.

Czarnecki, K. and Eisenecker, U. W. (2000). *Generative programming - methods, tools and applications*, Addison-Wesley.

Dillenbourg, P. (1999a). *Collaborative Learning: Cognitive and Computational Approaches. Advances in Learning and Instruction Series.*, Elsevier Science Ltd.

Dillenbourg, P. (1999b). What do you mean by collaborative learning?, *Collaborative-learning: Cognitive and computational approaches.* pp. 1–19.

Dodero, J. M., del Val, Á. M. and Torres, J. (2010). An extensible approach to visually editing adaptive learning activities and designs based on services, *Journal of Visual Languages & Computing* **21**(6): 332–346.

Dodero, J. M., Díaz, P., Aedo, I. and Cabezuelo, A. S. (2005). Integrating ontologies into the collaborative authoring of learning objects., *J. UCS* **11**(9): 1568–1578.

Dodero, J. M., Ruiz-Rube, I., Palomo-Duarte, M. and Cabot, J. (2012). Model-driven learning design, *Journal of Research and Practice in Information Technology* **44**(3): 267–288.

Fayad, M. E., Schmidt, D. C. and Johnson, R. E. (1999). *Building application frameworks: object-oriented foundations of framework design*, John Wiley & Sons, Inc.

Feidakis, M., Daradoumis, T., Caballé, S. and Conesa, J. (2012). Design of an emotion aware e–learning system, *International Journal of Knowledge and Learning* **8**(3): 219–238.

Fonseca, B., Paredes, H., Sousa, J. P., Martins, F. M. and Carrapatoso, E. (2009). Saga reloaded: Towards a generic platform for developing cooperative applications, *Computer Supported Cooperative Work in Design, 2009. CSCWD 2009. 13th International Conference on*, IEEE, pp. 331–337.

Gañán, D., Caballé, S. and Conesa, J. (2013). Towards software infrastructure for the systematic virtualization of collaborative learning sessions, *Intelligent Networking and Collaborative Systems (INCoS), 2013 5th International Conference on*, IEEE, pp. 422–429.

Gamma, E., Helm, R., Johnson, R. and Vlissides, J. (1995). Design patterns: Elements of reusable software architecture, *Reading: Addison-Wesley* .

Gomaa, H. (2005). *Designing software product lines with UML: From Use Cases to Pattern Based Software Architectures*, Reading, Massachusetts: Addison-Wesley.

Goodsell, A. S. et al. (1992). Collaborative learning: A sourcebook for higher education.

Inaba, A., Supnithi, T., Ikeda, M., Mizoguchi, R. and Toyoda, J. (2000). An overview of” learning goal ontology, *Proceedings of the Workshop Analysis and Modelling of Collaborative Learning Interactions at the European Conference on Artificial Intelligence ECAI-2000. Berlin, Germany*.

Kay, R. H. and Loverock, S. (2008). Assessing emotions related to learning new software: The computer emotion scale, *Computers in Human Behavior* **24**(4): 1605 – 1623. ¡ce:title¿Including the Special Issue: Integration of Human Factors in Networked Computing¡/ce:title¿.

Lukosch, S. and Schümmer, T. (2006). Groupware development support with technology patterns, *International Journal of Human-Computer Studies. Special issue on Theoretical and empirical advances in groupware research* **64**(7): 599–610.

Mora, N., Caballe, S., Daradoumis, T. and Ganan, D. (2012). Towards a multi-fold assessment approach to enrich the virtualization of collaborative learning, *Complex, Intelligent and Software Intensive Systems (CISIS), 2012 Sixth International Conference on*, pp. 935–940.

Moscinska, K. and Rutkowski, J. (2011). Barriers to introduction of e-learning: A case study, *Global Engineering Education Conference (EDUCON), 2011 IEEE*, pp. 460–465.

Mosley, P. (2005). A taxonomy for learning object technology, *J. Comput. Sci. Coll.* **20**(3): 204–216.
*http://dl.acm.org/citation.cfm?id=1040196.1040223

Penichet, V. M. R., Lozano, M. D., Gallud, J. A. and Tesoriero, R. (2010). Requirement-based approach for groupware environments design, *J. Syst. Softw.* **83**(8): 1478–1488.
*http://dx.doi.org/10.1016/j.jss.2010.03.029

Petropoulakis, L. and Flood, F. (2007). Design and development of a general purpose collaborative environment, *Int. J. Comput. Appl. Technol.* **29**(1): 2–10.
*http://dx.doi.org/10.1504/IJCAT.2007.014055

Rius, A., Conesa, J., Garca-Barriocanal, E. and Siclia, M.-A. (2013). Specifying patterns of educational settings by means of ontologies, *Journal of Universal Computer Science* **19**(3): 353–382.

Rodrguez, M., Conesa, J. and Sicilia, M. (2009). Clarifying the semantics of relationships between learning objects, *in* F. Sartori, M. Sicilia and N. Manouselis (Eds), *Metadata and Semantic Research*, Vol. 46 of *Communications in Computer and Information Science*, Springer Berlin Heidelberg, pp. 35–47.

Schmidt, D. C. (1997). Applying design patterns and frameworks to develop object-oriented communication software, *in Handbook of Programming Languages*, MacMillan Computer Publishing.

Stahl, G. (2006). *Group Cognition: Computer Support for Building Collaborative Knowledge (Acting with Technology)*, Cambridge, MA: The MIT Press.

Ullrich, C. (2005). The learning-resource-type is dead, long live the learning-resource-type, *Learning Objects and Learning Designs* **1**(1): 7–15.

Wilson, R. (2004). The role of ontologies in teaching and learning, *TechWatch Reports* .

Zarraonandía, T., Dodero, J., Díaz, P. and Sarasa, A. (2004). Domain ontologies integration into the learning objects annotation process, *Proceedings of the Workshop on Applications of Semantic Web Technologies for e-Learning, 34*, Vol. 39.

Zyda, M. (2005). From visual simulation to virtual reality to games, *Computer* **38**(9): 25–32.

David Gañán. David Gañán Jiménez is a computer science engineer specialized on databases design and software engineering. He works at UOC (Universitat Oberta de Catalunya) since 1999 teaching and developing many academic projects inside the eLearning field, particularly he actively participated in the Alice European project for the construction of an adaptative elearning system. Apart from the research activities he works as freelance independent professional for 3rd parties, developing all kinds of projects and applications, both desktop, web or mobile ones, primarily using Microsoft .NET technologies.

Santi Caballé Santi Caballé has a PhD, Masters and Bachelors in Computer Science from the Open University of Catalonia (Barcelona, Spain). Since 2003 he has been an Assistant Professor and in 2006 he became Associate Professor at the Open University of Catalonia in the area of Software Engineering and Web-applications for Collaborative Work. He has been involved in the organization of several international conferences, conference tracks and workshops, and has published over 130 research contributions as books, book chapters, international journal and conference papers. He has also acted as editor for books and special issues of leading international journals. His research focuses on Distributed Technologies, e-Learning and Collaborative and Mobile Learning, and Software Engineering.

Jordi Conesa Jordi Conesa is an Assistant Professor of Information Systems at Open University of Catalonia. He received his PhD in Software Engineering from the Technical University of Catalonia, after a research stay in Georgia State University of Atlanta (US). His research interest concerns the areas of conceptual modeling, ontologies, Semantic Web, knowledge-based systems and e-learning. His long-term goal is to develop methodologies and tools to use ontologies effectively in several application domains, such as conceptual modeling, software engineering and e-learning. He has authored more than 50 research papers, has participated in several research projects, including EU-FP7, CICYT and AVANZA funded projects, and has contributed in the organization of some international conferences, such as the ER 2008.

Fatos Xhafa Fatos Xhafa holds a PhD in Computer Science from the Department of Languages and Informatics Systems (LSI) of the Technical University of Catalonia (UPC), Barcelona, Spain. He was a Visiting Professor at the Department of Computer Science and Information Systems, Birkbeck, University of London, UK (2009/2010) and a Research Associate at College of Information Science and Technology, Drexel University, Philadelphia, USA (2004/2005). Dr. Xhafa is Habilitated Full Professor by the Spanish Ministry of Education and Science. Dr. Xhafa has widely published in peer reviewed international journals, conferences/workshops, book chapters and edited books and proceedings in the field. Dr. Xhafa has an extensive editorial and reviewing service. Dr. Xhafa is actively participating in the organization of several international conferences. His research interests include parallel and distributed algorithms, combinatorial optimization, approximation and meta-heuristics, networking and distributed computing, Grid and P2P computing.

Received:

3. Conclusions and future directions of research

This thesis proposes the provision of software infrastructure in the domain of CSCL to support the development of modern and pedagogically augmented collaborative learning resources. As a result, an innovative application framework called VCSF has been developed. The systematic application of the VCSF provides e-Learning domain developers the opportunity to leverage successful collaborative learning experiences in a software reuse fashion. The ultimate aim is to yield more effective and prompt responses to meet the demanding and changing pedagogical requirements of current educational institutions by developing timely quality pedagogically-augmented CSCL applications and resources while saving great amounts of development time and effort [1][11].

The architectural vision of the VCSF in the form of a reusable software infrastructure was built and evaluated in this thesis to help develop complex, flexible, and advanced types of collaborative learning resources. Furthermore, the VCSF architecture approach can be taken as a guideline to systematically develop collaborative complex learning resources with advanced pedagogical aspects of cognitive assessment and emotional awareness. By means of a proof of concept, the VCSF has been exhaustively evaluated in a real context of learning to validate the goals mentioned on section 1.3, in terms of technical and pedagogical benefits for both developers and educational institutions [1][9].

In particular, we show next how the main thesis objectives (see Section 1.3) were fulfilled by the scientific results achieved, which were reported in the many thesis' contributions. In later sections, the main thesis outcomes, in terms of technology and evaluation and validation, will be presented.

3.1. Thesis achievements

The main goal of this thesis is the **provision of a software infrastructure to create and support advanced types of pedagogically augmented CC-LRs coming from CC-LOs, thus increasing interaction, challenge and empowerment during the learning process**. This goal is fully discussed in [1][8][11][22] (see also figure 3), and validated as an application framework used in different learning scenarios and courses [1][5][6][9][10][13]. As a result, the framework can save development time and effort whilst providing tools for the development of collaborative learning resources with complex pedagogical aspects of cognitive assessment and emotional awareness.

The above main goal comprises the following research objectives and justifications:

- **Provision of flexible mechanisms to facilitate the addition of further functionalities into the framework for extending CC-LRs.** Such mechanisms are discussed and thoroughly tested in [1] and [4]. In fact, some works are based on specific extensions of the presented framework. For instance the work explained in [10][13] show the ability of the system to include cognitive assessment functionalities, while the work in [5][6] present the extension of the framework in order to support emotional awareness capabilities.

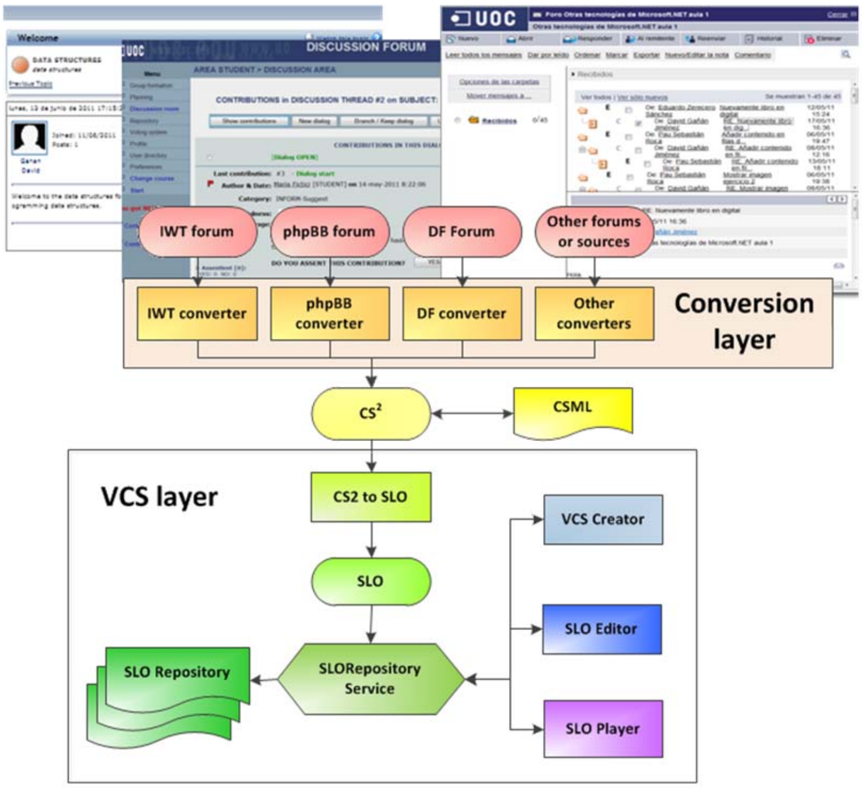


Figure 3 - VCSF general architecture, which is compatible with multiple forums.

- **Enable LMSs to systematically reuse collaborative learning sessions by means of CC-LOs**. The reusability of CC-LOs is guaranteed by their intrinsic definition as explained in [19][20][23][25], and the use of the SLO Repository (see figure 3) that stores CC-LO as SLO elements for further reuse [3]. In addition, the ease of integration of the framework in different learning systems is enabled by the definition of an abstraction layer between the LMS and the VCS layer called 'Conversion layer'. Such layer converts the collaborative session in the LMS into a common specification named CS^2 (Collaborative Session Conceptual Schema), which is the input for the VCS Layer [7][14][17][18][24]. The VCSF framework has been successfully integrated with multiple LMS, including the Virtual Campus and the phpBB Web Forums at UOC [1][2], the IWT system (Intelligent Web Teacher) at an Italian network of schools [84], and the Moodle system at the Universities of Aegean (UoA) [5][6] and Cadiz (UCA) [10][13].
- **Leverage multimedia technologies to enhance and improve the collaborative learning experience.** Multimedia and networking technologies are found an important support for education [76][77], providing online and interactive learning resources, which can be accessed from anywhere and anytime through the Internet [78]. Multimedia technologies also make the presentation of learning materials easier to be adapted to different learning goals. From a pedagogical perspective, this flexibility becomes essential for delivering personalized learning materials to students with different learning styles or needs [79] as well as for allowing students to learn more effectively and increase their motivation and engagement as some studies confirm [80]. The VCSF framework has been designed for the intensive use of multimedia technologies, such as animations, videos, images, or text-to-speech because of the importance of such kind of technologies have in education as discussed in [8][9][22].

- **Provision of authoring tools to simplify the task of creating and modifying CC-LRs, especially for teachers and learning managers without tecnological skills.** Among all the components and tools provided by the framework and explained in [1], there are some of them specific to help in the process of CC-LR creation. First, the VCS Creator enables teachers to select a forum in any of the available collaborative datasources, and convert it into a new CC-LO automatically. Then, the resulting CC-LO is playable directly without any effort from the teacher [3][11]. As this learning resource may contain useless and wrong content from the original source of knowledge (i.e. discussion forum), an SLO Editor is necessary to enable teachers to manage scenes in the CC-LO by, for example, changing the sequence of the scenes, removing useless content or reordering concepts. Finally, the SLO Editor enables learning managers to insert new kinds of scenes which enrich the learning object with additional functionalities, such as cognitive assessment [10][13] and emotional awareness [5][6]. These extensions convert the CC-LOs into a new kind of complex learning resource called CC-LR [8][9][4].
- **Promote the use of eLearning standards in order to enhance interoperability and portability of learning systems and applications.** The interoperability between the VCS framework and eLearning systems in order to obtain and convert available collaborative sessions into CC-LOs is based on the use of standards. The CS^2 was defined based on the SIOC (Semantically-Interlinked Online Communities) and FOAF (Friend of a Friend) standard ontologies [2][17][18], in order to enable the share of information between the collaborative session source and the VCS framework. The CS^2 specification is extensively discussed in [7].

3.2. Main thesis outcomes

The research work of this thesis was partially performed within the Seventh Framework European Programme project called 'Adaptive Learning via Intuitive/Interactive, Collaborative and Emotional systems' (ALICE)[2], where the candidate participated. This project was run between 2010 and 2012 and was devoted to providing on-line collaborative learning with authentic interactivity, challenging tools and user empowerment, with the ultimate aim to influence learner motivation and engagement (see the project deliverables co-participated by the candidate [23][24][25]). As a result, a new type of LO called Collaborative Complex Learning Object (CC-LO) was created and managed by the VCSF system, with the purpose to register live collaborative sessions and produce an animated storyboard such that learners can observe how people discuss and collaborate, and how knowledge is constructed [3][7][11][19][20].

In particular, the development of the VCSF prototype was investigated from an inductive methodological perspective considering the CC-LO as an input to collect the relevant requirements so as to build our general framework to create many types of CC-LO [11]. The notion and nature of the CC-LO was first validated by running extensive tests on a proof of concept of the VCS system that embeds a CC-LO [3]. These validation activities were carried out following the same methodological procedures in several international sites with different

[2] ALICE Project web site: http://www.aliceproject.eu

perspectives and expectations towards the research presented in this thesis. This includes the evaluation of the VCSF in the real context of learning of the Open University of Catalonia [2][9].

The VCSF components and tools (see next section for a more detailed description) allowed for the creation, management and reproduction of a new type of learning resource called Collaborative Complex Learning Resource (CC-LR) as an extension of the CC-LO approach, which turned out to have an important impact in the knowledge acquisition and the learning performance [4]. In particular, the VCSF Editor tool incorporated into CC-LR new forms of cognitive assessment to empower the learning experience and improve the student motivation and engagement [13][16][19]. In addition, the embodiment of emotion awareness provides the system with the ability to capture engineering students' affective state during the use of the learning resource [5][6][11]. Students could eventually consume these complex features and the whole learning resources by using the VCSF Player tool. Finally, intensive experimentation and validation activities of the VCSF were conducted in real on-line courses in order to create, manage and integrate attractive and challenging CC-LRs to support the collaborative learning activities, in particular in-class discussions [1][3][4][5][6].

Overall, the VCSF components and tools allowed for creating CC-LRs with complex cognitive and emotional dimensions, which provided learners with balanced levels of challenge, interaction and empowerment during the collaborative learning experience [1][4].

3.2.1. Technological outcomes

Here, the most relevant technological outcomes of the thesis are described in more detail (see also figures 2 and 3 in Section 1 for graphical representations). In particular, (i) the VCSF framework, (ii) the VCS tools and services and (iii) the VCSF products are presented.

a) VCSF Framework

The VCSF architecture (see figure 3) is made up of two layers, namely Conversion and VCS layers, which both leverages a new ontological specification called Collaborative Session Conceptual Schema (CS^2) also developed within this thesis work The VCSF architecture includes the Conversion layer, which converts data from different data sources of collaborative sessions into a CS^2 [7]. Then, the VCS layer creates an SLO from the CS^2 data and stores the SLO in a special repository for further use of the system tools and services. Next, these architectural components and the CS^2 common ontology specification are explained in more detail.

- **Conversion layer**

The Conversion layer of the VCSF defines a generic converter component that can be particularly implemented for specific data sources from forums and chats tools of different LMS. The input of each converter component is collaborative data from a specific data source, and the output is a representation of such data using a common specification named CS^2. The CS^2 model defines entities and relations between them for describing collaborative sessions in a simple way. Each converter will map data from the corresponding data source into CS^2 entities. During the VCSF prototype implementation, converters for different data sources were developed, including those for IWT forums [46] and phpBB Forums at UOC [2].

- **CS^2 Ontology**

The CS^2 ontology it's aimed to provide the VCS Layer with a unique and common representation of collaborative data, independent from its origin. It is based on the Semantically-Interlinked Online Communities (SIOC) and Friend of a Friend (FOAF) ontologies. CS^2 can be stored or imported from files in Collaborative Session Markup Language (CSML) format, which is in turn based on the RDF representation for the SIOC ontology (see [7][17][18], for an exhaustive procedure view). The CSML data representation is an outstanding outcome of this thesis work as it is expected to become standard in the future for the representation of data from live collaborative sessions (see [7] for an extensive review).

- **VCS layer**

The VCS layer is the core of the VCSF architecture (see figure 3). This layer includes all the components, services and tools that enable the creation, edition and reproduction of CC-LOs and CC-LRs in SLO format [1].

b) VCSF tools

All the above-mentioned VCSF artifact, services and tools are described briefly below. See [1] and figure 2 for further explanation of each component.

- **VCS Creator tool**

The VCS Creator tool allows teachers to select a collaborative source form a list of available live discussion experiences, and to create a CC-LO from it. The creation is a two-step process: first, the data from the collaborative source is retrieved as CS^2 by using the corresponding converter component; second the 'CS^2 to SLO' component of the VCS Layer creates the corresponding CC-LO for the obtained CS^2, which is stored into the SLO repository for further use.

- **VCS Editor and player tools**

An editor tool was developed in order to augment the CC-LO and convert them into CC-LR with author-generated information (see figure 2). For instance, e-assessment scenes can be added to the VCS, such as tests (with optional jumps to storyboard scenes) as well as supporting videos, to be connected with scene parts according to the dialogue timeline. As a result, tutors are provided with edition capabilities of the SLOs, such as cutting scenes, modifying involved characters, selecting emotional states, dialogues and connected concepts.

In order to be able to reproduce SLOs, a player tool was also developed. This tool uses different types of graphical interfaces to reproduce each type of scene defined into the SLOs, and enables the users to navigate between scenes, and start, pause or stop reproduction.

- **VCS Services**

The VCS tools rely on a set of services that provide some common functionality:

- SLO Repository Service: gives access to the SLOs in the repository.
- Speech Service: provides text-to-speech functionalities.
- Conversion Service: is the service in charge of the conversion process between data sources and the SLO format.
- Activity log service: gathers activity information and logs it for evaluation purposes.

- **VCSF Extensibility**

The VCSF architecture was designed to be extensible enough to enable the addition of new functionalities either on the CC-LR objects and the available tools. Two important pedagogically-based extensions were successfully integrated into the VCSF in order to support cognitive assessment [16] and emotional awareness capabilities [15]. The integration of these capabilities is addressed from two time dimensions, namely deferred and immediate time [13].

The deferred time approach, on the one hand, analyzes data coming from the live collaborative session and considers information about the participants and contributions found in the original collaboration (i.e. the forum tool supporting the live discussion). On the other hand, immediate approach focuses on the student who is consuming the CC-LR and is addressed by creating specific types of interactive scenes that provide feedback. Next, both extensions are explained in more detail (see figure 4).

Figure 4 - An SLO generated from a live discussion is edited by the VCS-SLO Editor to create a CC-LR, which contains different types of scenes and author information. Two different areas are provided in the SLO Player: the video-discussion area is shown on the left (a) while the emotional area is shown on the right (b).

- **Cognitive assessment**

Cognitive assessment is essential in virtual collaborative learning scenarios because it provides many forms of feedback to students about their learning progress, thus getting them more engaged in the on-line learning process (see [16]).

The VCSF supports deferred time assessment by processing the contents of collaborative sessions (e.g. post tags, number of posts, replies, etc.) and presenting CC-LR consumers some visual indicators, such as the most important contributions and active participants in the collaboration. The teacher can run an automatic post tagging system included in the SLO Editor, which automatically assigns a tag to each original post by processing the corresponding text following a machine learning approach (see [81] for the complete procedure). The teacher or learning designer can also manually edit this tag to best express the post's original intentions.

Immediate time assessment (see figure 5) is implemented in the VCSF as a set of specific scenes with test questions about the discussion topic and appropriate feedback from the test results. Assessment scenes are created and handled by the SLO Editor tool, which permits the teacher to edit the test questions and answers as well as define a set of feedback rules that change the flow of the SLO depending on the result obtained in the test. Hence, whether the answer is right or wrong, the student may be redirected either to the next scene or to a previous scene respectively. In case of failing the same test repeatedly the students may be redirected to a special scene with complementary material on the test topic, thus filling the knowledge gaps.

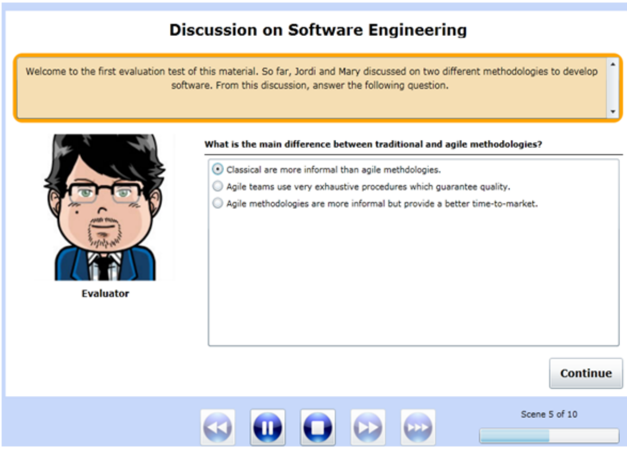
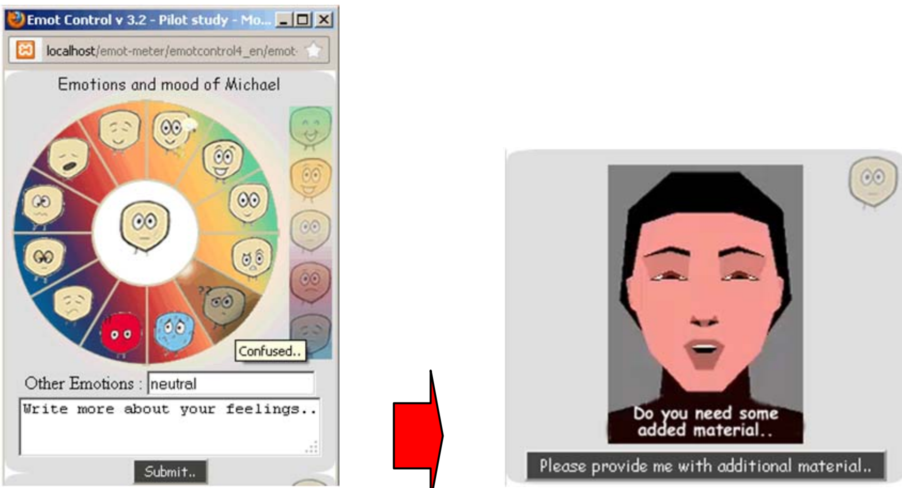


Figure 5 - Immediate cognitive assessment with an evaluation test shown with automatic feedback.

- **Emotional awareness extension**

Emotional awareness (see figure 6) is considered a relevant aspect of e-learning, providing feedback to user emotions while learning can help orientate students and increase their engagement (see [15], also for a complete view of the emotional procedures of the VCSF described next).



(a) Emotion report **(b) Affective feedback**

Figure 6 - Immediate emotional awareness; on the left (a) the learner is asked about the emotional state, from which, on the right (b), an agent provides an empathetic response.

Similarly to the cognitive assessment perspective, the VCSF approaches emotional awareness also from two time dimensions, namely deferred and immediate time.

On the one hand, emotional awareness in deferred time shows the emotional state of each original participant while posting the corresponding message to the live collaborative session. This emotional state is calculated during the conversion from CS^2 to SLO in case of that the CS^2

data contains emotional state information from the live collaborative session. The SLO editor tool also enables the teacher to set up the emotional state of the participants in each dialog in order to best transmit the original participants emotions.

On the other hand, emotional awareness in immediate time is implemented by a set of scene types that can be created and managed by the SLO Editor tool, which ask the current student who consumes the CC-LR about her emotional state using non-verbal reporting mechanisms (i.e. icons). Based on the student's selection of emotions, certain predefined empathetic and affective response is shown in order to engage or motivate the student to move forward.

c) VCSF products

Here, the main VCSF products are presented briefly as new paradigms for e-learning participated in the context of this thesis work.

- **CC-LO (Collaborative Complex Learning Object)**

A CC-LO is a representation of collaborative data in the form of scenes and transition between them. The scenes can be of different types and contain more or less information depending on the collaborative source (see full description in [3]).

- **SLO format (Storyboard Learning Object)**

CC-LOs and CC-LR are stored in a file repository using the SLO format, which as its name indicates, stores the content using a storyboard structure. The SLO repository enables the availability and reusability of the stored SLOs (see full description in [3]).

- **CC-LR (Collaborative Complex Learning Resource)**

The VCS edition tools enable teachers to modify the CC-LOs structure and to extend it with complex functionalities (e.g., cognitive assessment and emotion awareness explained above) converting them into CC-LRs (which can be saved back into repository in SLO format) (see full description in [4])

3.2.2. Evaluation and validation

Three empirical studies were conducted to evaluate the VCSF Framework: (i) subjective user assessment, (ii) in-class experimentation with real students, and (iii) technical testing for developers. All these studies were performed on a proof of concept of a CC-LR coming from a SLO built and supported by the VCSF framework. Therefore, the results and interpretation of these studies help validate the underlying VCSF framework used to develop the proofs of concept in different collaborative learning tools [1], [9].

a) Subjective user assessment

The design of this study consisted of two user assessments of the VCSF framework used to develop a CC-LR embedded in the VCS platform with the aim to evaluate the proof of concept. The first user assessment was at Coventry University Serious Games Institute in United Kingdom (Site A), and the second at the company Modelli Matematici e Applicazioni in Italy (Site B). In both sites, the object of the experiment was only the CC-LR play, thus comments and results are only relating to this aspect.

The test group at Site A was formed by three members: a researcher with knowledge about the CC-LR approach but not directly involved in the VCSF (Expert), a doctoral student working in a technical discipline but unfamiliar with the VCSF approach (Technician) and a doctoral student unfamiliar with the VCSF approach and working in a non-technical discipline (Novice). At Site B the test group was composed by two members: an analyst programmer working in e-learning projects (Expert) and a computer science student (Novice).

Table 1 shows basic statistics of the quantitative marks on the 5 point Likert scale with the following range values: I strongly disagree (1), I disagree (2), neither/nor (3) I agree (4) and I strongly agree (5). The indicators of interest considered were:

1. Create, edit, manage, store and playback the generated storyboard.
2. The VCS prototype allows users to observe how knowledge is constructed.
3. The cognitive information provided in the CC-LR becomes an enjoyable and complete collaborative learning experience.

	Testers	Questions / indicators of interest			
		#1	#2	#3	Total
SiteA	# Expert	5	5	4	4.7
	# Tech	4	4	4	4.0
	# Novice	2	4	3	3.0
SiteB	# Expert	3	4	1	2.7
	# Novice	4	2	3	3.0
	Total M(SD)	3.6(1.1)	3.8(1.0)	3.0(1.2)	**3.4(0.8)**

Table 1 – Subjective user assessment quantitative results with mean (M) and standard deviation (SD) statistics.

In summary, all the indicators scored over the average 0-5 (see Table 1). In particular, indicators #1 and #2 were well scored by all testers who acknowledged that the new learning material (CC-LR) was engaging and entertaining though the sense of empowerment may depend on individual learners. In general, users acknowledged the system was more engaging and entertaining that the static web forums used as a source of learning content and they commented on the robustness of the interface. The lowest scores were caused by some technical or usability concerns found by Novice users, although they describe the overall experience as enjoyable. In site B the Expert user rated the third indicator very low because he found the assessment scenes potentially problematic if abused or not designed in line with the course objectives. This was considered a pedagogical rather than a technical issue.

b) In-class experimentation

The ultimate goal of this test was to evaluate the pedagogical benefits of the VCSF approach to build a CC-LR and analyze their effects in the learning process. The experimentation took place in the real context of learning of the UOC. For the execution of the test, a new CC-LO was created using the VCSF framework from an existing live collaborative forum at UOC, and then converted it into a CC-LR with the VCS editor by including emotional and assessment information. Then the students had to use the CC-LR as a new material to support an activity consisting on filling a test with questions on software projects management. After the experiment, students were asked to fill out a questionnaire, which included:

- Test-based evaluation on the usability of the VCS system
- Test-based evaluation on the emotional state when using the VCS system.
- Test-based evaluation of the CC-LR consumed.

- **Usability assessment**

To evaluate student's satisfaction with the tool as regards efficient and user-friendly management, we collected data from students' ratings and open comments on the usability/functionality/integration of the tool. We used the System Usability Scale (SUS) developed by Brooke [85], which contains 10 items and a 5 point Likert scale to state the level of agreement or disagreement (it ranges from "I strongly disagree" (1), "I disagree" (2), "neither/nor" (3) to "I agree" (4), "I strongly agree" (5)). SUS is generally used after the respondent had an opportunity to use the system being evaluated. SUS scores have a range of 0 to 100 with an average score of 68, obtained from 500 studies. A Score above 68 would be considered above average and anything below 68 is below average. A score above 80.3 is considered an A (the top 10% of scores). Scoring the mean (68) awards a C and anything below 51 is an F (putting one at the bottom 15%).

The SUS score for each student (n=24) obtained an average of 69.27, thus above the SUS mean. See figure 7 and also [1] for the results on each SUS item, which show that the usability of the video-discussion enriched with complex aspects was judged satisfactory or very satisfactory in line with the general SUS score.

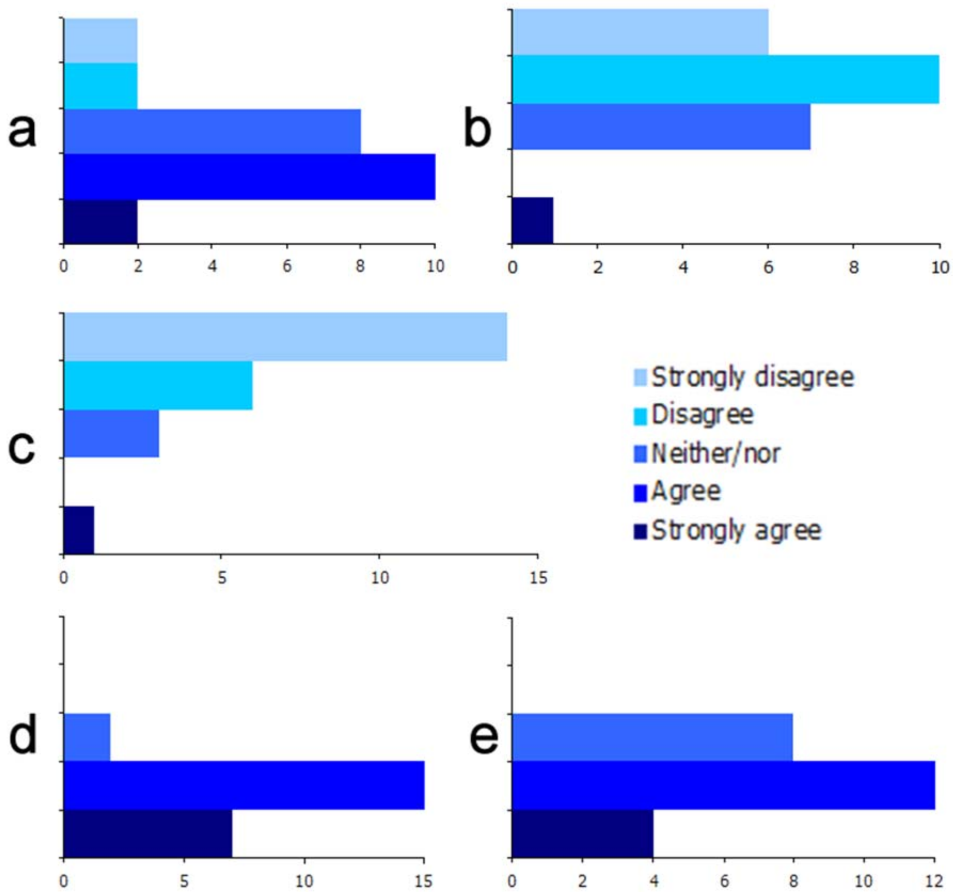


Figure 7 - Results on the SUS items a) "I think I will use the video-discussion often", b) "I think the video-discussion was unnecessarily complex", c) "I think that I would need the support of a technical person to be able to use the video-discussion", d) "I would imagine that most people would learn to use the video-discussion very quickly" and e) "I felt very confident using the video-discussion".

- **Emotional assessment**

To investigate the emotional state of the students using the new system, the 12 items of the Computer Emotion Scale (CES) [86] were included. The CES scale is used to measure emotions related to learning new computer software. Research showed that the 12 items are describing four emotions:

- Happiness (“When I used the tool, I felt satisfied/excited/curious.”)
- Sadness (“When I used the tool, I felt disheartened/dispirited.”)
- Anxiety (“When I used the tool, I felt anxious/insecure/helpless/nervous.”)
- Anger (“When I used the tool, I felt irritable/frustrated/angry”)

The answer categories in this section are “None of the time”, “Some of the time”, “Most of the time” or “All of the time”. The obtained results from a 4-point rating scale (n=24) for each emotion are shown in figures 8 and 9, and described in [1].

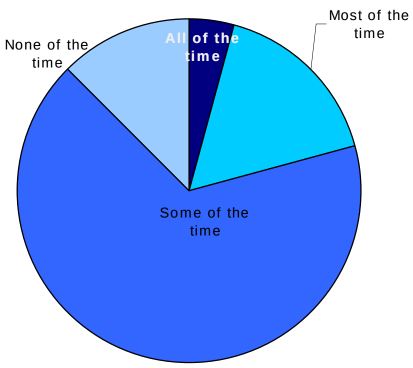


Figure 8 - Results on the Happiness emotion

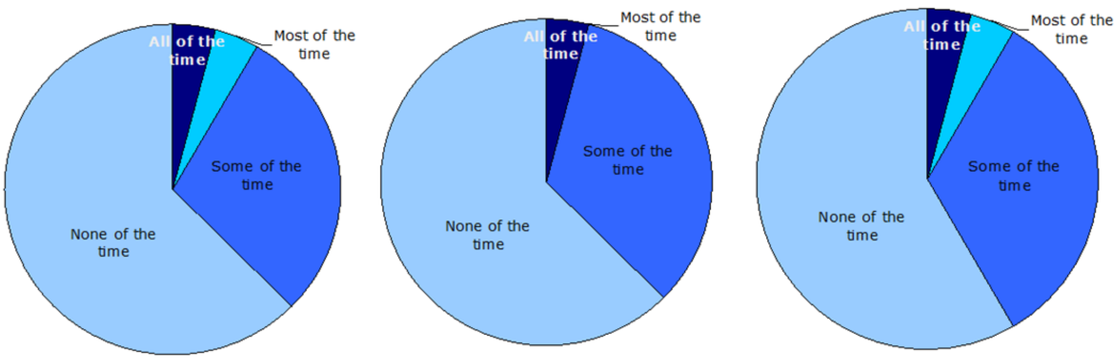


Figure 9 - Results on Sadness on the left (a), Anxiety in the middle (b), and Anger emotion on the right (c).

In sum, students felt more often happiness than sadness, anxiety or anger when studying with the new learning material (CC-LR). The most noticeable result regards Happiness, attributing the highest value to it, while the values of Sadness, Anxiety and Anger emotions were very low, almost inappreciable (Md=0).

- **CC-LR as a valuable resource**

In this section we evaluate the level of worthiness of the CC-LR enriched with complex information and supported by the VCS as an educational tool. To this end, we collected quantitative and qualitative data of the questionnaire that included seven open questions addressed to students. The rating scales for the majority of the quantitative questions were based on the usual 0-10 point scale. The rating scale went from the lowest (0) to the highest (10) considering a "good" assessment from 5.0 to 10 and a "bad" assessment from 0 to 4.9, being the "good" assessment the expected scores for each question ($n = 24$, $df = 1$ and $p < 0.05$ for the calculated Chi-square ($\chi^{2)}$).

To evaluate the video-discussion (CC-LR) material, the following questions were asked to all students (each question required to assess the CC-LR from the question's view in the scale 0-10):

1. What did you like and what you did not like from the video-discussions.
2. Compare the video-discussions with traditional teaching material and tools (books, web pages, forums, blogs, etc) and indicate pros and cons of the video-discussions.
3. Do you think the video-discussions have helped you acquire more knowledge about the discussion topics in comparison to the text-based forums?
4. Express your opinion about the video-discussions in terms of efficiency and performance.
5. Let us know your opinion about the potential of video-discussions to observe how people discuss and collaborate, and how knowledge is constructed.
6. Do you think that both performance indicators on each character and test questions integrated in the video-discussion allowed you to understand the contents of the video and acquire more knowledge?
7. Indicate whether the consideration of both characters' emotional states and your own emotional state in the video-discussion has had any impact on your learning experience?

After calculating the 0-10 scale for all the seven questions and participants ($n=24$) we obtained a general mean score of 6.28 ($SD=1.31$ and $Md=6.5$) and χ^2 $(1) = 4.46$, $p < 0.05$. These results are in line with the previous usability and emotion assessment results, both confirming the value of CC-LR as an educational resource. See [1] for the description of the results for each of the seven questions.

c) Technical testing

The aim of this scenario was to test the whole building process of a CC-LR by means of the VCSF framework. This experimentation, therefore, focused on testing the technical and functional aspects of the VCSF components and tools to generate and manage CC-LR. To this end, the test was conducted at the UOC site from the developers and lecturers viewpoint. The results of this study provide relevant feedback of how the VCSF supports developers in order to create complex learning resources with the frameworks components and services. Additionally, combined feedback is provided by the lecturer as a user of the VCSF tools to manage the CC-LR generated by the developer. Therefore, in this phase of the experiments we were primarily interested in the functionality of the VCSF.

The experimentation procedure was divided into four steps or work sessions (see [1] for more detail):

- <u>Work session 1</u>: The developer collects requirements for the integration of VCSF with UOC phpBB forums and IWT forums, and prepares the later development. The lecturer chooses two representative collaborative sessions (one from each data source) in order to convert them into SLO later.

- Work session 2: The developer creates a converter for each data source in order to enable the conversion from those into a CS^2 model so the VCSF can convert them into SLO.
- Work session 3: The lecturer creates the selected collaborative sessions into SLO using the VCS Creator tool and the converters created by the developer on work session 2.
- Work session 4: The lecturer work on the newly created SLO to produce a teaching material in the form of CC-LR with the SLO Editor.

The results of the experiment were evaluated taking into account two main aspects: (i) the time required to run the tasks, and (ii) the experience with VCSF as a valuable resource.

- **Time to run the experience**

The time invested in the whole experiment was quite high for the developer (22 hours), and slightly higher time than expected for the lecturer (3 hours and 20 minutes). As for the developer, the high time spent was in line with the high learning curve needed to exploit the VCSF potential efficiently, as pointed out by the developer. The developer also mentioned that after learning how to use the framework the development time would surely decrease in next developments. As for the lecturer, most of the time was spent in preparing the dialog scenes of the CC-LR, and creating the tests (assessment scenes). The lecturer was also asked to estimate the time required to create more CC-LRs. The answer was that time would increase linearly.

- **VCSF as a valuable resource**

The lecturer found IWT a very complete and useful suite of tools and functionalities for helping teachers and students in e-learning activities. In particular, the lecturer reported that he liked the ability of editing and personalizing each SLO in order to meet the specific requirements of the course. The developer said the system architecture is well designed, and mentioned it enables the integration of different data sources with the system.

When asked for problems found with the system, the lecturer found the VCSF tools not very intuitive (especially the SLO Editor) and, for this reason, is hard to use them the first time. However, he added that considering the resulting CC-LR is a real learning material if we compare it to the workload to create a regular learning module or activity, the effort to create a CC-LR with the SLO Editor might be reasonable. The developer complained about the lack of interoperability of the services and tools of the framework because they are too tight to Microsoft technologies.

Recommendations were in line with the comments provided in the previous questions. The lecturer asked that the SLO Editor should be improved in order to facilitate much more the work and suggested to add functionalities to enable mass modifications. The developer keep insisting on the interoperable issues, such as tools could be implemented using a more portable technology like html5.

In summary, the lecturer recognized that VCSF is a great platform, with a lot of useful functionalities, although he pointed out that the learning curve to exploit its potential efficiently is rather high. The developer thought that the integration itself is easy if you have clearly in mind the data source model and CS^2, and then you define a mapping between them. He remarked the need for a migration to more portable technologies.

3.3. Future directions of research

Further directions of research will go to subsequent iterations of refinement and improvement of the VCSF framework and components from the feedback gained during implementation and experimentation in previous iterations.

From the technology perspective, the next steps in the VCSF development will focus on improving the usability of the framework tools in order to reduce the effort to create and manage CC-LRs with the Editor tool and provide new interesting features, such as massive edition operations, import and export capabilities, enhance categorization of messages, etc.

In addition, the VCS Player tool can be also improved taking into account the feedback obtained during the tests; apart from enhancing the user experience in general, the aim is to include more multimedia resources, improve interactivity, navigation and other aspects like the text-to-speech quality.

The creation of new types of scenes to enrich the navigability and increase the types of available resources will be also an improvement for the platform. In particular, the creation of new scenes or modification of the existing ones for the integration of student's affective monitoring in order to better guide them into the learning process.

Another technical goal for future versions of the platform will include the migration of existing tools and components to more portable technologies in order to make them more interoperable with other e-learning platforms. The increase of the use of standards will also help to this purpose. In the same line, the creation of more conversion tools for other collaborative sources will ensure the compatibility of the VCSF with more data sources.

From pedagogic perspective, ongoing work aims to develop clear guidelines for the creation and use of CC-LOs both within different engineering application domains (e.g., software and computer engineering) and by engineering educators on a wider scale, and the promotion of the framework and the reusability of the generated CC-LRs. A first step towards this direction has been to make the complete VCSF source code accessible at the web-based hosting service GitHub (https://github.com/dganan/VCSF), as an opportunity to share it with other institutions and researchers.

The VSCF framework is expected to be of great help both for software developers of the e-learning domain and for educators. The ultimate aim is to yield more effective and quality pedagogically-augmented CSCL applications and resources while saving great amounts of development time and effort.

Bibliographical references

Thesis' main contributions

[1] **Gañán, D.**, Caballé, S., Conesa, J., Xhafa, F. (2015). *An Application Framework to Systematically Develop Complex Learning Resources Based on Collaborative Knowledge Engineering.* International Journal of Applied Mathematics and Computer Science (AMCS). To be published in Vol. 25, No. 2. University of Zielona Góra Press. ISSN: 1641-876X. IF: 1.390, Q1: 45/250 (JCR-2013 SE).

[2] Caballé, S., **Gañán, D.**, Gómez-Cazorla, M., Conesa. J., Rius, A., Santanach, F. (2014). *Experiences with Engineering Education at the Open University of Catalonia by the Virtualization of Live Collaborative Learning*. International Journal of Engineering Education (IJEE), Vol. 30, No. 3, pp. 663–674. TEMPUS Publication. ISSN: 0949-149X. IF: 0.360, Q4: 74/87 (JCR-2013 SE).

[3] Caballé, S., **Gañan, D.**, Dunwell, I., Pierri, A., Daradoumis, T. (2012). *CC-LO: Embedding Interactivity, Challenge and Empowerment into Collaborative Learning Sessions.* Journal of Universal Computer Science (J.UCS), Vol. 18, No. 4, pp. 25-43. Verlag der Technischen Universität Graz. DOI: 10.3217/jucs-017-01-0025. ISSN: 0948-695X. IF: 0.762, Q3: 54/100 (JCR-2012 SE).

Other candidate's collaborations in ISI-JCR and SCOPUS indexed journals

[4] Caballé, S., Mora, N., Feidakis, M., **Gañán, D.**, Conesa, J., Daradoumis, T., Prieto, J. (2014). *CC-LR: Providing Interactive, Challenging and Attractive Collaborative Complex Learning Resources*. Journal of Computer Assisted Learning (JCAL), Vol. 30, No. 1, pp. 51–67. Wiley. DOI: 10.1111/jcal.12021. ISSN: 0266-4909. IF: 1.023, Q2: 61/219, Category: EDUCATION & EDUCATIONAL RESEARCH (JCR-2013 SSE).

[5] Feidakis, M., Caballé, S., Daradoumis T., **Gañán, D.**, Conesa, J. (2014). *Providing emotion awareness and affective feedback to virtualized collaborative learning scenarios*. International Journal of Continuing Engineering Education and Life-Long Learning (IJCEELL), Vol. 24, No. 2, pp. 141-167. Inderscience. ISSN: 1560-4624. Indexed in: Scopus (Elsevier), Compendex (Elsevier), Inspec, Scirus.

[6] Feidakis, M., Daradoumis, T., Caballé, S., Conesa, J., **Gañán, D.** (2013). *A Dual-Modal System that Evaluates User's Emotions in Virtual Learning Environments and Responds Affectively*. Journal of Universal Computer Science (J.UCS), Vol. 19, No. 11, pp. 1638-1660. Verlag der Technischen Universität Graz. ISSN: 0948-695X. IF: 0.401, Q4: 89/102, Category: COMPUTER SCIENCE, THEORY & METHODS (JCR-2013 SE).

[7] Conesa, J., Caballé, S., **Gañán, D.**, Prieto, J. (2012). *Exploiting the Semantic Web to Represent Information from On-line Collaborative Learning*. International Journal of Computational Intelligence Systems (IJCIS), Vol. 5, No. 4, pp. 653-667. Atlantis Press. DOI: 10.1080/18756891.2012.718111. ISSN: 1875-6883. IF: 0.451, Q4: 108/121, Category: COMPUTER SCIENCE, ARTIFICIAL INTELLIGENCE (JCR-2013 SE).

Other candidate's publications

[8] **Gañán, D.**, Caballé, S., Conesa, J., Barolli, L., Kulla, E., Spaho, E. (2014). *A Systematic Review of Multimedia Resources to Support Teaching and Learning in Virtual Environments.* The 8th International Conference on Complex, Intelligent and Software Intensive Systems (CISIS 2014), Birmingham, UK, July 2-4, 2014. In proceedings of the 8th International Conference on Complex, Intelligent and Software Intensive Systems. IEEE Computer Society, pp. 38-43. IEEE Computer Society. ISBN: 978-0-7695-5094-7/13.

[9] **Gañán, D.**, Caballé, S., Conesa, J., Barolli, L., Oda, T. (2014). *Evaluation of Using Software Infrastructure and Multimedia Technologies for the Creation of Complex Learning Resources.* Fourth International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional Approaches (ALICE 2014), Salerno, Italy. September 10-12, 2014. In proceedings of the Sixth IEEE International Conference on Intelligent Networking and Collaborative Systems. IEEE Computer Society, pp. 457-462. IEEE Computer Society. ISBN: 978-1-4799-6387-4/14.

[10] Mora, N., Caballé, S., Daradoumis, Th., **Gañán, D.**, Barolli, L. (2014). *Providing Cognitive and Social Networking Assessment to Virtualized Collaborative Learning in Engineering Courses*. Fourth International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional Approaches (ALICE 2014), Salerno, Italy. September 10-12, 2014. In proceedings of the Sixth IEEE International Conference on Intelligent Networking and Collaborative Systems, pp. 463-468. IEEE Computer Society. ISBN: 978-1-4799-6387-4/14.

[11] **Gañán, D.**, Caballé, S., Conesa, J. (2013). *Towards Software Infrastructure for the Systematic Virtualization of Collaborative Learning Sessions*. Fifth IEEE International Conference on Intelligent Networking and Collaborative Systems (INCOS 2013), Xi'an, China. September 9-11, 2013. In proceedings of the Fifth IEEE International Conference on Intelligent Networking and Collaborative Systems, pp. 422-429. IEEE Computer Society. ISBN: 978-0-7695-4988-0/13.

[12] **Gañán, D.**, Guerrero-Roldán, A.E., Prieto-Blazquez J., Conesa, J. (2014). *A domain-specific language for Virtual Classrooms*. International Journal of Metadata, Semantics and Ontologies (IJMSO). Accepted. In press. Indexed in SCOPUS (Elsevier), Compendex (Elsevier), Academic OneFile and ACM Digital Library.

Candidate's collaborations in other publications

[13] Caballé, S., Mora, N., Daradoumis. Th., **Gañan, D.**, Dunwell, I., Pierri, A. (2013). *Prototyping a Cognitive Assessment System to Enrich the Virtualization of Collaborative Learning*. Third International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional Approaches (ALICE 2013). Taichung, Taiwan. July 3-5, 2013. In proceedings of the Seventh International Conference on Complex, Intelligent, and Software Intensive Systems, pp. 373-378. IEEE Computer Society. ISBN: 978-0-7695-4992-7/13.

[14] Conesa, J., Caballé, S., **Gañán, D.**, Prieto, J. (2012). *Towards the Representation of Emotional Information from On-line Collaborative Learning Sessions*. Second International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional Approaches (ALICE 2012). Palermo, Italy. July 4-6, 2012. In proceedings of the 2012 Sixth International Conference on Complex, Intelligent, and Software Intensive Systems, pp. 923-928. IEEE Computer Society. ISBN: 978-0-7695-4687-2/12.

[15] Feidakis, M., Daradoumis, Th., Caballé, S., **Gañán, D.** (2012). *Responding affectively in online learning situations*. XIV International Symposium on Computers in Education (SIIE 2012), Andorra, October 29-31, 2012. In proceedings of the SIIE 2012: Actas del XIV Simposio Internacional de Informática Educativa, pp. 271-276. La Salle Open University. ISBN: 978-84-939814-6-4.

[16] Mora, N., Caballé, S., Daradoumis, Th., **Gañán, D.** (2012). *Towards a Multifold Assessment Approach to Enrich the Virtualization of Collaborative Learning*. Second International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional Approaches (ALICE 2012). Palermo, Italy. July 4-6, 2012. In proceedings of the 2012 Sixth International Conference on Complex, Intelligent, and Software Intensive Systems, pp. 935-940. IEEE Computer Society. ISBN: 978-0-7695-4687-2/12.

[17] Conesa, J., Caballé, S., **Gañán, D.**, Prieto, J. (2011). *Towards an Ontology to Model and Represent Collaborative Learning Data*. 4th World Summit on the Knowledge Society (WSKS 2011), Mykonos, Greece, 21-23 September 2011. In proceedings of the 4th World Summit on the Knowledge Society, pp. 351–356. Communications in Computer and Information Science (CCIS), Vol. 278. Springer. ISBN: 978-3-642-35878-4.

[18] Conesa, J., Caballé, S., **Gañán, D.**, Prieto, J. (2011). *A Framework for Dealing with Knowledge About On-line Collaborative Learning Sessions*. International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional Approaches (ALICE 2011). Fukuoka, Japan. December 1, 2011. In proceedings of the Third IEEE International Conference on Intelligent Networking and Collaborative Systems, pp. 795-800. IEEE Computer Society. ISBN: 978-0-7695-4579-0/11.

[19] Caballé, S., Mora, N., Dunwell I., **Gañan, D.** (2011). *CC-LO: a New Type of Learning Object for the Virtualization of Live Collaborative Sessions*. International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional Approaches (ALICE 2011). Fukuoka, Japan. December 1, 2011. In proceedings of the Third IEEE International Conference on Intelligent Networking and Collaborative Systems, pp. 818-823. IEEE Computer Society. ISBN: 978-0-7695-4579-0/11.

[20] Caballé, S., Dunwell, I., Pierri, A., Zurolo, F., **Gañán, D.**, Daradoumis, Th. and Mora, N. (2011). *Towards Collaborative Complex Learning Objects by the Virtualization of Collaborative Sessions*. 4th World Summit on the Knowledge Society (WSKS 2011), Mykonos, Greece, 21-23 September 2011. In proceedings of the 4th World Summit on the Knowledge Society, pp. 344–350. Communications in Computer and Information Science (CCIS), Vol. 278. Springer. ISBN: 978-3-642-35878-4.

Other candidate's scientific papers and reports

[21] **Gañán, D.** (2013). *State Of The Art In The Use Of Multimedia Resources To Support Teaching and Learning In Virtual Environments* (Master's thesis awarded with honors).

[22] **David Gañán**, Santi Caballé, Jordi Conesa. *Recursos multimedia para aprendizaje on-line* (in Spanish). MOSAIC Tecnologías y comunicación multimedia (On-line journal). http://mosaic.uoc.edu/2013/11/11/recursos-multimedia-para-aprendizaje-on-line/ November 2013.

[23] Santi Caballé, **David Gañán**, Néstor Mora, Michalis Feidakis. *Deliverable D3.3.2: Prototype Components for Creation and Execution of Collaborative Complex Learning Objects*. 35 pp. ALICE (Adaptive Learning Via Intuitive/Interactive, Collaborative And Emotional Systems) project, co-funded by the European Commission within the 7th Framework Programme (2007-2013), n. 257639, March 2012.

[24] Jordi Conesa, Santi Caballé, **David Gañán**. *Deliverable D3.1.2: Methodologies and Techniques for Knowledge Modeling and Representation*. 77 pp. ALICE (Adaptive Learning Via Intuitive/Interactive, Collaborative And Emotional Systems) project, co-funded by the European Commission within the 7th Framework Programme (2007-2013), n. 257639, October 2011.

[25] Santi Caballé, **David Gañán**, Néstor Mora. *Deliverable D3.3.1: Prototype Components for Creation and Execution of Collaborative Complex Learning Objects*. 18 pp. ALICE (Adaptive Learning Via Intuitive/Interactive, Collaborative And Emotional Systems) project, co-funded by the European Commission within the 7th Framework Programme (2007-2013), n. 257639, June 2011.

[26] Gavidia, Á. R.; Caralt, J. C. & **Jimenez, D. G.** (2010), *A DSL Tool to Assist Specifications of Educational Settings*., in Hamid R. Arabnia; Andy Marsh & Ashu M. G. Solo, ed., 'SWWS' , CSREA Press, , pp. 112-118 .

[27] Jordi Conesa, Àngels Rius, **David Gañán**, and Diego Gómez. (2008). *LECO: an internal virtual tool to aid collaboration in the context of a virtual university*. In Proceedings of the Seventh IASTED International Conference on Web-based Education (WBE '08). ACTA Press, Anaheim, CA, USA, 247-252.

[28] Ernest Teniente, Carles Farré, Toni Urpí, Carlos Beltrán, and **David Gañán**. (2004). *SVT: schema validation tool for Microsoft SQL-server*. In Proceedings of the Thirtieth international conference on Very large data bases - Volume 30 (VLDB '04), Mario A. Nascimento, M. Tamer Özsu, Donald Kossmann, Renée J. Miller, José A. Blakeley, and K. Bernhard Schiefer (Eds.), Vol. 30. VLDB Endowment 1349-1352.

Other references

[29] Dillenbourg, P. (1999). *Introduction; What do you mean by "Collaborative Learning"?* P. Dillenbourg (Ed.), Collaborative learning. Cognitive and Computational Approaches, 1-19. Oxford: Elsevier Science.

[30] Goodsell, A., Maher, M., Tinto, V., Leigh Snith, B. and MacGregor, J. (1992). *Collaborative Learning: A Sourcebook for Higher Education.* Pennsylvania State University: National Center on Postsecondary Teaching, Learning, and Assessment.

[31] Dillenbourg, P. (1999). *Collaborative Learning. Cognitive and Computational Approaches*. Elsevier Science Ltd, 1-19. ISBN: 0-08-043073-2.

[32] Stahl, G. (2006). *Group Cognition: Computer Support for Building Collaborative Knowledge.* Acting with Technology Series, Cambridge, MA: MIT Press. ISBN: 978-0262195393.

[33] Abad, C.L. (2008). *Learning through creating learning objects: experiences with a class project in a distributed systems course.* 13th annual conference on Innovation and technology in computer science education. Madrid, Spain, ACM: 255-259.

[34] Moscinska, K. and Rutkowski, J. (2011). *Barriers to introduction of e-learning: A case study*, Global Engineering Education Conference (EDUCON), 2011 IEEE, pp. 460–465.

[35] Christie, M. and Jurado, R. G. (2009). *Barriers to innovation in online pedagogy,* European Journal of Engineering Education 34(3): 273–279.

[36] Caballé, S. and Xhafa, F. (2010). *Clpl: Providing software infrastructure for the systematic and effective construction of complex collaborative learning systems,* Journal of Systems and Software 83(11): 2083–2097.

[37] Koschmann, T. (1996). *Paradigm shifts and instructional technology.* In T. Koschmann (Ed.), CSCL: Theory and Practice of an Emerging Paradigm, Mahwah, 1-23. ISBN-0-8058-1346-2. New Jersey: Lawrence Erlbaum Associates.

[38] Strijbos, J-W., Martens, R., Prins, F., & Jochems, W. (2006). *Content analysis: What are they talking about?* Computers & Education. 46(1), 29-48, Elsevier Ltd.

[39] Stahl, G. (2006). *Group Cognition: Computer Support for Building Collaborative Knowledge.* Acting with Technology Series, Cambridge, MA: MIT Press. ISBN: 978-0262195393.

[40] Roseman, M. and Greenberg, S. (1996). *Building Real Time Groupware with GroupKit, A Groupware Toolkit*. March. ACM Transactions on Computer Human Interaction, 3(1), 66-106, New York, NY: ACM PressTeam.

[41] Wiley, A. D. (2001). *Connecting learning objects to instructional design theory: A definition, a metaphor and a taxonomy.* In D. A. Wiley (Ed.), The instructional use of learning objects Bloomington: Association for Educational Communications and technology.

[42] Fuentes, L. M., Arteaga, J. M. and lvarez Rodriguez, F.: *A Methodology for Design Collaborative Learning Objects*. 8th IEEE International Conference on Advanced Learning Technologies, 2008.

[43] Baloian, N., Galdames, P., Collazos, C., & Guerrero, L., *A model for a Collaborative Recommender System for Multimedia Learning Material.* Proceedings of the 10th International Workshop on Groupware. Berlin: Springer, 2004.

[44] Mosley, P. (2005). *A taxonomy for learning object technology,* J. Comput. Sci. Coll. 20(3): 204–216. *http://dl.acm.org/citation.cfm?id=1040196.1040223

[45] Singh, R.G., M. Bernard, Gardler, R.: *Creating shareable learning objects from existing digital course content.* 31st International Symposium on Computer Architecture. Munich, Germany, ACM: 8, 2004.

[46] Capuano, N., Miranda, S., Orciuoli, F. (2009). *IWT: A Semantic Web-based Educational System.* In: IV Workshop of the AI*IA Working Group on Artificial Intelligence & E-Learning. Reggio Emilia (Italia) AI*IA, pp. 11-16.

[47] Al-Ajlan, A. and H. Zedan (2007). *E-learning (MOODLE) based on service oriented architecture.* Proceeding of the European Association of Distance Teaching Universities 20th Conference, pp. 62-70.

[48] Dagger, D., O'Connor, A., Lawless, S., Walsh, E., Wade, V. (2007). *Service Oriented eLearning Platforms: From Monolithic Systems to Flexible Services*, IEEE Internet Computing Special Issue on Distance Learning.

[49] Gamma, E., Helm, R., Johnson, R. and Vlissides, J. (1995). *Design patterns: Elements of reusable software architecture,* Reading: Addison-Wesley.

[50] Fayad, M. E., Schmidt, D. C. and Johnson, R. E. (1999). *Building application frameworks: object-oriented foundations of framework design*, John Wiley & Sons, Inc.

[51] Rius, A., Conesa, J., Garca-Barriocanal, E. and Siclia, M.-A. (2013). *Specifying patterns of educational settings by means of ontologies*, Journal of Universal Computer Science 19(3): 353–382.

[52] Schmidt, D. C. (1997). *Applying design patterns and frameworks to develop object-oriented communication software,* in Handbook of Programming Languages, MacMillan Computer Publishing.

[53] Gomaa, H. (2005). *Designing Software Product Lines with UML: From Use Cases to Pattern Based Software Architectures.* Reading, Massachusetts: Addison-Wesley.

[54] Czarnecki, K. and Eisenecker, UW (2000). *Generative Programming: Methods, Techniques, and Applications.* Addison-Wesley.

[55] Caballe, S., *"Combining Generic Programming and Service-Oriented Architectures for the Effective and Timely Development of Complex e-Learning Systems,"* Complex, Intelligent and Software Intensive Systems, 2008. CISIS 2008. International Conference on, pp.94,100, 4-7 March 2008. doi: 10.1109/CISIS.2008.99.

[56] Caballe, S., *"On the Advantages of Using Web & Grid Services for the Development of Collaborative Learning Management Systems"* Complex, Intelligent and Software

Intensive Systems, 2007. CISIS 2007. First International Conference on, pp.263,270, 10-12 April 2007. doi: 10.1109/CISIS.2007.42.

[57] Penichet, V. M. R., Lozano, M. D., Gallud, J. A. and Tesoriero, R. (2010). *Requirement-based approach for groupware environments design*, J. Syst. Softw. 83(8): 1478–1488. http://dx.doi.org/10.1016/j.jss.2010.03.029.

[58] Fonseca, B., Paredes, H., Sousa, J. P., Martins, F. M. and Carrapatoso, E. (2009). *Saga reloaded: Towards a generic platform for developing cooperative applications*, Computer Supported Cooperative Work in Design, 2009. CSCWD 2009. 13th International Conference on, IEEE, pp. 331–337.

[59] Petropoulakis, L. and Flood, F. (2007). *Design and development of a general purpose collaborative environment*, Int. J. Comput. Appl. Technol. 29(1): 2–10. *http://dx.doi.org/10.1504/IJCAT.2007.014055.

[60] Bao-Qing, G., Xiu-Fen, F. and Su-Xia, X. (2007). *P2p distributed cooperative work model based on jxta platform*, in M. Xu, Y. Zhan, J. Cao and Y. Liu (Eds), Advanced Parallel Processing Technologies, Vol. 4847 of Lecture Notes in Computer Science, Springer Berlin Heidelberg, pp. 658–665.

[61] Lukosch, S. and Schümmer, T. (2006). *Groupware development support with technology patterns,* International Journal of Human-Computer Studies. Special issue on Theoretical and empirical advances in groupware research 64(7): 599–610.

[62] Bentley, R., Horstmann, T. and Trevor, J. (1997). *The world wide web as enabling technology for cscw: The case of bscw*, Computer Supported Cooperative Work (CSCW) 6(2-3): 111–134.

[63] Abdullah, S. and Abbas, M. (2006). *The effects of inquiry-based computer simulation with cooperative learning on scientific thinking and conceptual understanding.*

[64] Zyda, M. (2005). *From visual simulation to virtual reality to games,* Computer 38(9): 25–32.

[65] Wilson, R. (2004). *The role of ontologies in teaching and learning,* TechWatch Reports.

[66] Inaba, A., Supnithi, T., Ikeda, M., Mizoguchi, R. and Toyoda, J. (2000). *An overview of learning goal ontology*, Proceedings of the Workshop Analysis and Modelling of Collaborative Learning Interactions at the European Conference on Artificial Intelligence ECAI-2000. Berlin, Germany.

[67] Rodríguez, M., Conesa, J. and Sicilia, M. (2009). *Clarifying the semantics of relationships between learning objects*, in F. Sartori, M. Sicilia and N. Manouselis (Eds), Metadata and Semantic Research, Vol. 46 of Communications in Computer and Information Science, Springer Berlin Heidelberg, pp. 35–47.

[68] Al-Khalifa, H. S. and Davis, H. C. (2006). *The evolution of metadata from standards to semantics in e-learning applications*, Proceedings of the Seventeenth Conference on

Hypertext and Hypermedia, HYPERTEXT ’06, ACM, New York, NY, USA, pp. 69–72. *http://doi.acm.org/10.1145/1149941.1149956

[69] Brase, J. (2005). *Usage of metadata,* PhD thesis, Fakultat fur Elektrotechnik und Informatik der Universitat Hannover, Hannover, Germany.

[70] Dodero, J. M., Díaz, P., Aedo, I. and Cabezuelo, A. S. (2005). *Integrating ontologies into the collaborative authoring of learning objects.*, J. UCS 11(9): 1568–1578.

[71] Ullrich, C. (2005). *The learning-resource-type is dead, long live the learning-resource-type*, Learning Objects and Learning Designs 1(1): 7–15.

[72] Zarraonandía, T., Dodero, J., Díaz, P. and Sarasa, A. (2004). *Domain ontologies integration into the learning objects annotation process*, Proceedings of the Workshop on Applications of Semantic Web Technologies for e-Learning, 34, Vol. 39.

[73] Babic, F., Wagner, J. and Paralic, J. (2008). *The role of ontologies in collaborative systems,* Applied Machine Intelligence and Informatics, 2008. SAMI 2008. 6th International Symposium on, pp. 119–124.

[74] Dodero, J.M., del Val, A .M. and Torres, J. (2010). *An extensible approach to visually editing adaptive learning activities and designs based on services*, Journal of Visual Languages & Computing 21(6): 332–346.

[75] Dodero, J. M., Ruiz-Rube, I., Palomo-Duarte, M. and Cabot, J. (2012). *Model-driven learning design,* Journal of Research and Practice in Information Technology 44(3): 267–288.

[76] Richard Mayer. *Multimedia Learning.* Cambridge University Press, 2001.

[77] Evans, C., & Gibbons, N. J. (2007). *The interactivity effect in multimedia learning*. 49 (4), 1147-1160.

[78] Lau, R. W., Yen, N. Y., Li, F., & Wah, B. “Recent development in multimedia e-learning technologies.” World Wide Web, vol. 17, no. 2, pp. 189-198, 2014

[79] Felder, R., Silverman, L.: *Learning and teaching styles in engineering education.* J. Eng. Educ. 78(7), 674–681 (1988)

[80] Liaw, S.: *Investigating students’ perceived satisfaction, behavioral intention, and effectiveness of elearning: a case study of the blackboard system*. Comput. Educ. 51(2), 864–873 (2008)

[81] Caballé, S., Lapedriza, À., Masip, D., Xhafa, F. and Abraham, A. (2009). *Enabling automatic just-in-time evaluation of in-class discussions in on-line collaborative learning practices*, JDIM 7(5): 290–297.

[82] S. Caballé, T. Daradoumis, F. Xhafa and J. Conesa, *Enhancing Knowledge Management in Online Collaborative Learning*, International Journal of Software Engineering and Knowledge egineering 20(4) (2010) 485-497.

[83] Caballé, S., Daradoumis, A., Xhafa, F., Juan, A. (2011). *"Providing Effective Feedback, Monitoring and Evaluation to On-line Collaborative Learning Discussions"*. Computers in Human Behavior. 27, 4, pp. 1372-1381. ISSN.0747-5632.

[84] Santi Caballé, Gudrun Wesiak, Anna Pierri. *Deliverable D8.1.2: Final Experimentation and Evaluation Results*. 280 pp. ALICE (Adaptive Learning Via Intuitive/Interactive, Collaborative And Emotional Systems) project, co-funded by the European Commission within the 7th Framework Programme (2007-2013), n. 257639, June 2012.

[85] Brooke, J. (1996). *SUS: A 'quick and dirty' usability scale.* In P. W. Jordan, B. Thomas, B. A. Weerdmeester, A. L. McClelland (Eds.), Usability evaluation in industry (pp. 189–194). London: Taylor and Francis.

[86] Kay, R. H., & Loverock, S. (2008). *Assessing emotions related to learning new software: The computer emotion scale.* Computers in Human Behavior, 24, 1605–1623.

Appendix A Acceptance letters

This appendix includes the acceptance letter of the publication *An Application Framework to Systematically Develop Complex Learning Resources Based on Collaborative Knowledge Engineering* [1], which was accepted in press but not published yet when this document was created.

A.1 Acceptance letter AMCS

Dear Author: David Gañán,

I am pleased to inform you that your paper

Title: AN APPLICATION FRAMEWORK TO SYSTEMATICALLY DEVELOP
Author(s): David Gañán, Santi Caballé, Jordi Conesa, Fatos Xhafa,

has been accepted for publication in the International Journal of Applied Mathematics and Computer Science (AMCS).

You will be informed about the issue number in due course.

Now you need to
1. Upload the source files of your paper through the paper information page:
https://www.amcs.uz.zgora.pl/paper.php?paper=z8BRaXWen52bab47fa8bf9NTVEaGh1
Please follow our instructions for authors to prepare the final version of your paper properly.
Note that you are requested to use our special LaTeX style to do so.
2. Submit the license to publish, which is needed to proceed with the publication.

All necessary files can be found on our website in the 'Guide' section at
https://www.amcs.uz.zgora.pl/?action=guide
(If you have used any of those before, make sure you update to the currently binding versions.)

We will appreciate if you provide the above as soon as possible, but not later than within TWO MONTHS.

Yours sincerely,

Józef Korbicz
Professor, Editor-in-Chief

--
International Journal of Applied Mathematics & Computer Science
https://www.amcs.uz.zgora.pl
PRESENT YOUR RESEARCH WITH US!

Appendix B Programme committees

This appendix includes 10 memberships to program committees of international conferences and workshops in the scope of the thesis work that the candidate has joined over the last 3 years. This implied for the candidate to perform relevant research tasks, such as paper reviewer.

B.1 Technical Committee of CISIS 2015

Ninth International Conference on Complex, Intelligent, and Software Intensive Systems

Url: http://voyager.ce.fit.ac.jp/conf/cisis/2015/committee.html#e-learning

Track 4: E-Learning and Groupware Systems

PC Members:

Thanasis Daradoumis, University of Aegean, GR

Jordi Conesa, Open University of Catalonia, ES

Michael Feidakis, University of Aegean, GR

Nestor Mora, Open University of Catalonia, ES

Jorge Moneo, Open University of Catalonia, ES

David Ganan, Open University of Catalonia, ES

Luis Casillas, University of Guadalajara, MX

Kaoru Sugita, Fukuoka Institute of Technology, JP

Yoshiaki Kasahara, Kyushu University, JP

Shunsuke Mihara, Lockon Inc., JP

Shunsuke Oshima, Kumamoto National College of Technology, JP

Yuuichi Teranishi, NICT, JP

Kazunori Ueda, Kochi University of Technology, JP

B.2 Technical Committee of ALICE 2015

Fifth International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional approaches.

Url: http://www.aliceproject.eu/index.php?option=com_content&view=article&id=92:alice-2015&catid=1:ultime&Itemid=48

PROGRAM COMMITTEE

Jordi Conesa, Open University of Catalonia, Spain

Thanasis Daradoumis, University of the Aegean, Greece

Michalis Feidakis, University of the Aegean, Greece

David Gañán, Open University of Catalonia, Spain

Jorge Miguel, Open University of Catalonia, Spain

Néstor Mora, Open University of Catalonia, Spain

Anna Pierri, University of Salerno, Italy

Jose Mangione, University of Salerno, Italy

B.3 Technical Committee of CISIS 2014

Eight International Conference on Complex, Intelligent, and Software Intensive Systems

Url: http://voyager.ce.fit.ac.jp/conf/cisis/2014/committee.html#colesone

Track 17: Collaborative Learning using Social Networks

PC Members:

Alex Mackman, CM Group, UK

John Devaney, CM Group, UK

Steve Cox, CM Group, UK

Graham Papworth, CM Group, UK

Darren Dancey, Manchester Metropolitan University, UK

Thanasis Daradoumis, University of Aegean, GR

Jordi Conesa, Open University of Catalonia, ES

Michael Feidakis, University of Aegean, GR

Roxana Bassi, Open University of Catalonia, ES

Nestor Mora, Open University of Catalonia, ES

Jorge Moneo, Open University of Catalonia, ES

David Gañán, Open University of Catalonia, ES

Nicola Capuano, University of Salerno, IT

Jose Mangione, University of Salerno, IT

Anna Pierri, University of Salerno, IT

Luis Casillas, University of Guadalajara, MX

B.4 Technical Committee of INCoS 2014

Sixth International Conference on Intelligent Networking and Collaborative Systems.

Url: http://voyager.ce.fit.ac.jp/conf/incos/2014/committees.html

Track 9: Software engineering, semantics and ontologies for intelligent networking and collaborative systems

PROGRAM COMMITTEE

Nestor Mora, Open University of Catalonia, Spain

Jorge Moneo, Open University of Catalonia, Spain

David Ganan, Open University of Catalonia, Spain

Robert Clariso, Open University of Catalonia, Spain

Jordi Casas, Open University of Catalonia, Spain

Macario Polo, University of Castile-La Mancha, Spain

David Baneres, Open University of Catalonia, Spain

Elena Planas, Open University of Catalonia, Spain

Antoni Perez, Open University of Catalonia, Spain

Xiaodong Liu, Edinburgh Napier University, UK

Ricardo Martin, University of Valladolid, Spain

Elena Rodriguez, Open University of Catalonia, Spain

Isabel Guitart, Open University of Catalonia, Spain

B.5 Technical Committee of ALICE 2014

Fourth International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional approaches

Url: http://www.aliceproject.eu/index.php?option=com_content&view=article&id=91:alice-2014&catid=1:ultime&Itemid=48

PROGRAM COMMITTEE

Jordi Conesa, Open University of Catalonia, Spain

Luis Casillas, University of Guadalajara, Mexico

Thanasis Daradoumis, University of the Aegean, Greece

Stavros Demetriadis, Aristotle University of Thessaloniki, Greece

Ian Dunwell, Serious Games Institute, UK

Michalis Feidakis, University of the Aegean, Greece

Angelo Gaeta, University of Salerno, Italy

David Gañán, Open University of Catalonia, Spain

Giuseppina Rita Mangione, University of Salerno, Italy

Jorge Miguel, Open University of Catalonia, Spain

Néstor Mora, Open University of Catalonia, Spain

Anna Pierri, University of Salerno, Italy

Roberto Pirrone, University of Palermo, Italy

Pier Giuseppe Rossi, University of Macerata, Italy

B.6 Technical Committee of INCoS 2013

Fifth International Conference on Intelligent Networking and Collaborative Systems.

Url: http://voyager.ce.fit.ac.jp/conf/incos/2013/committees.html

Track 9: Software engineering, semantics and ontologies for intelligent networking and collaborative systems

PROGRAM COMMITTEE

Robert Clarisó, Open University of Catalonia, Spain

Antoni Perez Navarro, Open University of Catalonia, Spain

Jong Woo Kim, University of Massacusetts Boston, USA

Elena Planas, Open University of Catalonia, Spain

Macario Polo, University of Castile-La Mancha, Spain

Francisco José García Peñalvo, University of Salamanca, Spain

Xiaodong Liu, Edinburgh Napier University, UK

Laia Descamps, I.C.A. Informática y Comunicaciones Avanzadas, Spain

Joan Casas, Open University of Catalonia, Spain

David Gañan, Open University of Catalonia, Spain

Elena Rodriguez, Universitat Oberta de Catalunya, Spain

Thuy-Linh Nguyen, Australian Catholic University, Australia

David Bañeres, Universitat Oberta de Catalunya, Spain

Antoni Perez Navarro, Universitat Oberta de Catalunya, Spain

B.7 Technical Committee of ALICE 2013

Third International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional approaches

Url: http://www.aliceproject.eu/index.php?option=com_content&view=article&id=88:alice-2013-call-for-papers&catid=1:ultime&Itemid=48

PROGRAM COMMITTEE

Thanasis Daradoumis, Open University of Catalonia, Spain

Vincenzo Loia, University of Salerno, Italy

Saverio Salerno, University of Salerno, Italy

Sara de Freitas, Coventry University, UK

Eric Lin, Hamastar Technology Co. Ltd.,Taiwan

Chang-Shing Lee, National University of Tainan,Taiwan

Tzung-Pei Hong, National University of Kaohsiung,Taiwan

Jordi Conesa, Open University of Catalonia, Spain

Josep Prieto, Open University of Catalonia, Spain

David Gañán, Open University of Catalonia, Spain

Néstor Mora, Open University of Catalonia, Spain

Michalis Feidakis,University of Aegean, Greece

Sergio Miranda, University of Salerno, Italy

Anna Pierri, Centre for Research in Pure and Applied Mathematics, Italy

Giuseppina Rita Mangione, MOMA S.p.A., Italy

Margit Höfler, University of Graz, Austria

Luis Casillas, University of Guadalajara, Mexico

Maria Kordaki, University of the Aegean, Greece.

B.8 Technical Committee of INCoS 2012

Fourth International Conference on Intelligent Networking and Collaborative Systems.

Url: http://voyager.ce.fit.ac.jp/conf/incos/2012/committees.html

Semantics and ontologies for networking and collaborative systems

PROGRAM COMMITTEE

Sinuhe Arroyo, Playence, Austria

David Bañeres, Universitat Oberta de Catalunya, Spain

Joan Casas, Universitat Oberta de Catalunya, Spain

Robert Clarisó, Open University of Catalonia, Spain

Laia Descamps, I.C.A. Informática y Comunicaciones Avanzadas, Spain

David Gañan, Universitat Oberta de Catalunya, Spain

Antoni Perez Navarro, Universitat Oberta de Catalunya, Spain

Josep Prieto, Universitat Oberta de Catalunya, Spain

Angels Rius, Universitat Oberta de Catalunya, Spain

Elena Rodriguez, Universitat Oberta de Catalunya, Spain

Antonio Villegas, Technical University of Catalonia, Spain

Jong Woo Kim, University of Massacusetts Boston, USA

B.9 Technical Committee of ALICE 2012

Second International Workshop on Adaptive Learning via Interactive, Collaborative and Emotional approaches

Url: http://www.aliceproject.eu/index.php?option=com_content&view=article&id=75:alice-2012-second-international-workshop&catid=1:ultime&Itemid=48

PROGRAM COMMITTEE

Thanasis Daradoumis, Open University of Catalonia, Spain

Jordi Conesa, Open University of Catalonia, Spain

Josep Prieto, Open University of Catalonia, Spain

David Gañán, Open University of Catalonia, Spain

Néstor Mora, Open University of Catalonia, Spain

Anna Pierri, Centre for Research in Pure and Applied Mathematics, Italy

Jose Mangione, Modelli Matematici e Applicazioni SpA, Italy

Marcello Rosciano, Modelli Matematici e Applicazioni SpA, Italy

Gerardo Iovane, University of Salerno, Italy

Sergio Miranda, University of Salerno, Italy

Sara de Freitas, Coventry University, UK

Ian Dunwell, Coventry University, UK

Panagiotis Petridis, Coventry University, UK

Christian Gütl, Graz University of Technology, Austria

Mohammad Smadi, Graz University of Technology, Austria

Margit Höfler, Graz University of Technology, Austria

Gudrun Wesiak, Graz University of Technology, Austria

Nick Scerbakov, Graz University of Technology, Austria

Martin Ebner, Graz University of Technology, Austria

Michalis Feidakis, University of Aegean, Greece

Luis Casillas, University of Guadalajara, Mexico

Maria Kordaki, University of the Aegean, Greece

B.10 Scientific Committee of the JISE 2012

Journal of Information Science and Engineering Special Issue on Discovering knowledge through highly interactive information based systems

Url: http://grial.usal.es/grial/node/177

RESEARCH GROUP IN INTERACTION & ELEARNING (GRIAL)
Universidad de Salamanca. Instituto Universitario de Ciencias de la Educación
Paseo de Canalejas, 169. 37008 Salamanca (España)
Tel. (+34) 923 29 45 00 Ext. 3433 – Fax (+34) 29 45 14
grial@usal.es - http://grial.usal.es

Research GRoup in InterAction and eLearning

Salamanca, 6 March 2012

TO WHOM IT MAY CONCERN:

This is to confirm that D. David Gañán has participated in the Scientific Committee of the Journal of Information Science and Engineering - JISE (ISSN 1016-2364) Special Issue on Discovering knowledge through highly interactive information based systems. Also, he has been reviewer of several researching papers submitted to the above mention Special Issue.

Fran

Fdo. Francisco José García Peñalvo
GRIAL research group head
University of Salamanca
Discovering knowledge through highly interactive
information based systems Special Issue Guest Editor

B.11 Scientific Committee of the IJCIS 2012

International Journal of Computational Intelligence Systems Special Issue on Discovering knowledge through highly interactive information based systems

International Journal of International Journal of Computational Intelligence Systems

Acknowledge letter from the editor

Madrid, Spain, January 11th, 2012

Dear David Gañán,

This letter is to certificate that you have acted as a reviewer for the Special Issue on "Knowledge Society: Computational intelligence applications and tools" in the International Journal of Computational Intelligence Systems.

Paper reviewed: *Embedded Feature Selection for Multi-label Classification of Music Emotions*

Best wishes,

Ricardo Colomo Palacios
Guest Editor of the International Journal of Computational Intelligence Systems