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 on 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].

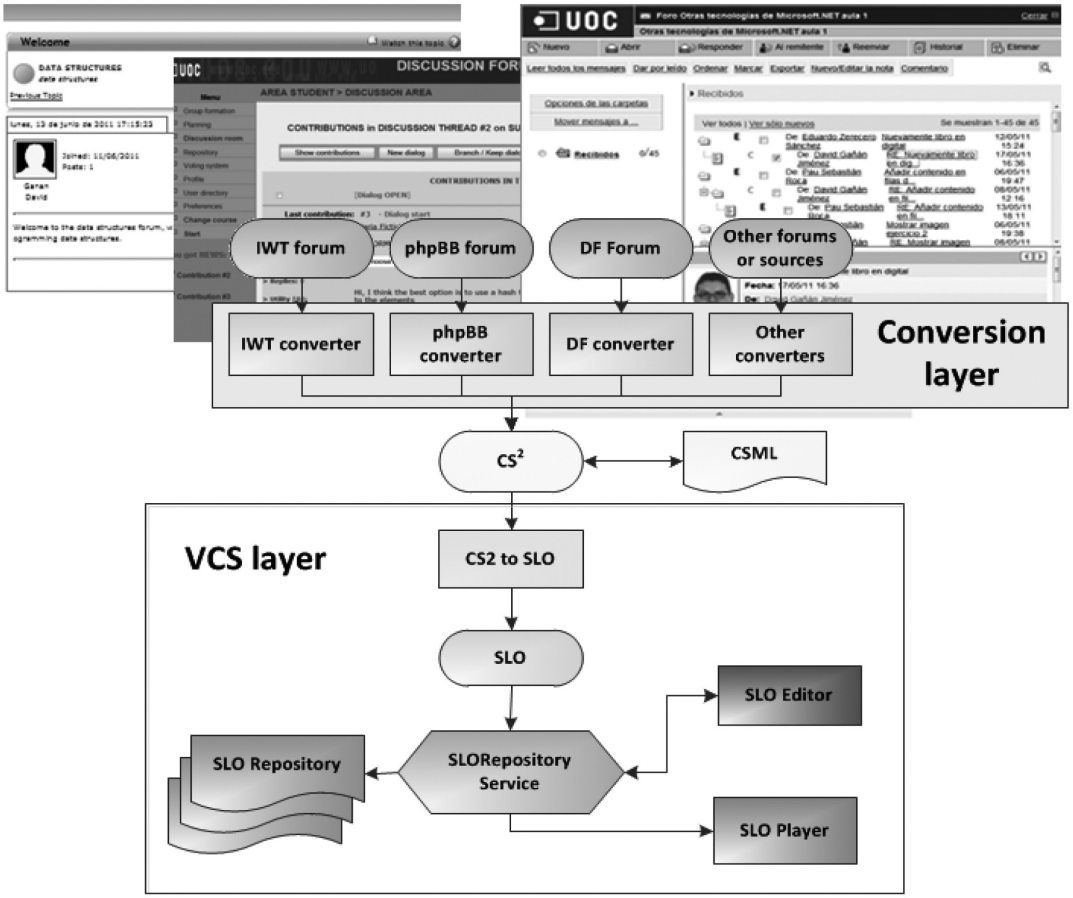

Fig. 1. Architecture of the VCS system.

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

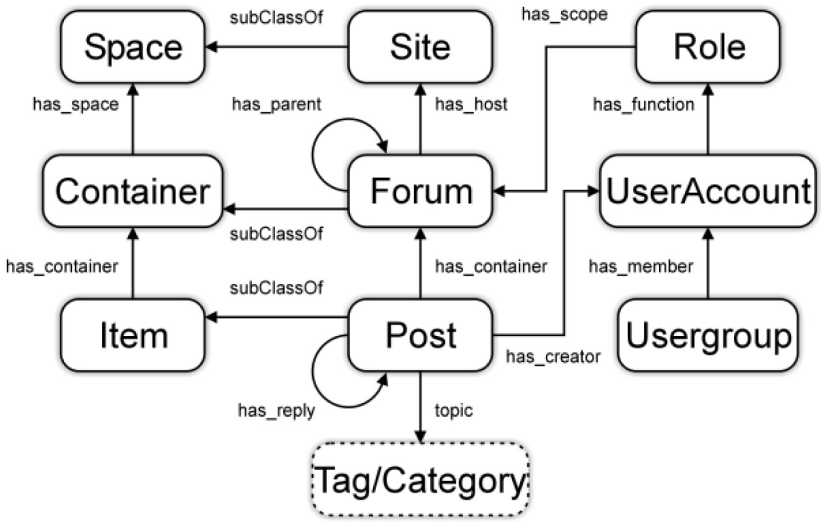

Fig. 2. SIOC core ontology classes.

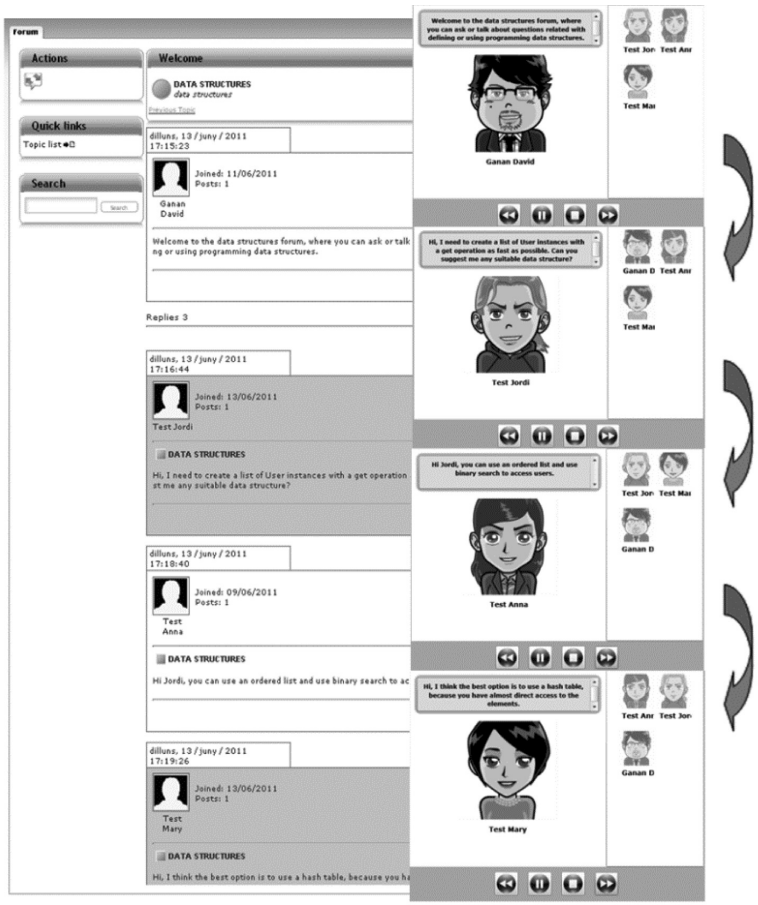

Fig. 3. Sequence of screenshots of the VCS embedding a CC-LO/SLO with a discussion

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

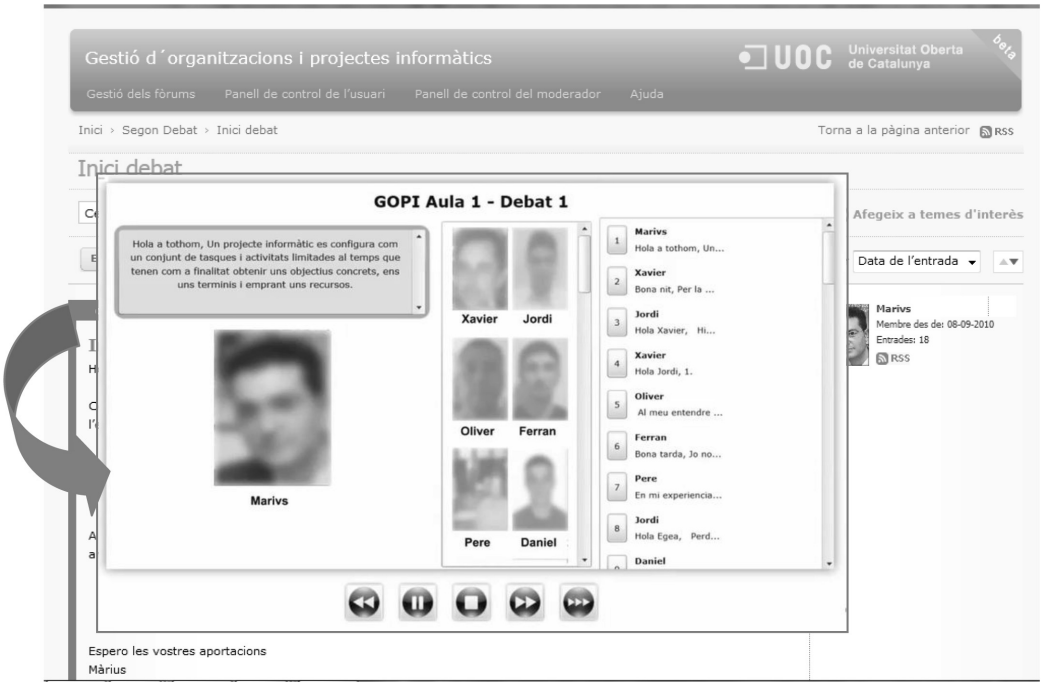

Fig. 4. Screenshot of the virtualization of the discussion supported by the UOC's phpBB web forum into a storyboard (SLO) created by the VCS tool (facial images have been faded and surnames have been removed for private reasons).

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.