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Evaluation and Validation of the Virtualization of Live Collaborative Learning Sessions*

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On-line collaborative learning is a mature research field that benefits from collaborative activities, which can increase learning efficacy. However, collaborative learning approaches are still not beneficial in every e-learning experience because they require people's presence and collaboration is frequently difficult to achieve. It is remarkable that collaborative learning resources still suffer from endemic problems, such as the lack of authentic interactivity, user empowerment, social identity and challenge, thus having a negative effect in learner motivation and engagement. To overcome these and other limitations and deficiencies, in previous research, a new type of learning object named Collaborative Complex Learning Object (CC-LO) was proposed to support the virtualization of collaborative learning with the aim to leverage the knowledge elicited during live sessions. During the CC-LO execution, the collaborative sessions are animated so learners can observe how avatars discuss and collaborate, how discussion threads grow and how knowledge is been constructed, refined and consolidated. The system produced from this research was naively tested to validate the notion and nature of the CC-LO. In this paper we proceed with an exhaustive empirical study of the system in a real context of learning in order to validate the impact of CC-LOs on complex dimensions of the collaborative learning process. The research reported in this paper is currently undertaken within a FP7 European project called 'Adaptive Learning via Intuitive/Interactive, Collaborative and Emotional systems' (ALICE).

Keywords: on-line; collaborative learning; collaborative complex learning object; virtualized collaborative sessions

1. Introduction

On-line collaborative learning is a mature research field in the educational domain dedicated to improve teaching and learning with the help of modern ICT [1, 2]. Collaborative learning is represented by a set of educational approaches involving joint intellectual effort by learners, or learners and teachers together. Collaborative learning activities vary widely, but most of them are centered in students' exploration or application of the course material, not simply the teacher's presentation or explication of it [3]. However, many researchers argue that students must be meaningfully engaged in the learning resources for effective learning to occur [4–8]. This lack of engagement is especially evident in collaborative learning activities and can be attributed to the lack of (also see [7, 9, 10]): (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; (iii) empowerment, as learners expect to be in control of their own collaborative learning experiences; and (iv) learning achieved through social interaction and collaboration, with learners feeling isolated from their peers.

To overcome these stated limitations of current collaborative learning systems, in previous research, we focused on a new type of Learning Object called Collaborative Complex Learning Object (CC-LO) embedded into a Virtualized Collaborative Sessions (VCS) system [11]. A VCS system allows for the virtualization and registration of live collaborative sessions (i.e., CC-LOs), which are augmented by alternative learning paths, additional content, etc., during an authoring phase (i.e. an expert managing the learning object). The VCS can be interactive and animated (by movies or comic strips) and learners can observe in the CC-LOs how knowledge is constructed, refined and consolidated. CC-LOs include also assessment, collaboration and communication features to enrich the learning experience provided by the VCS. The registered CC-LOs are 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 a FP7 European project called ALICE[1] currently undertaken, in this paper we report on a research methodology to evaluate and validate in a real context of learning the impact of CC-LOs in complex dimensions of the collaborative learning process.

To this end, Section 2 firstly outlines the research conducted so far to identify the notion and devel-

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

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opment of the concept of CC-LO and sets the aims of the research reported in this paper. Section 3 presents a methodological approach to evaluate and validate the definition of the notion and nature of a CC-LO by the development of a prototype of a VCS system that enables the embedding of CC-LOs. Section 4 and 5 provide respectively the evaluation and validation of the impact of virtualizing the collaborative sessions by means of CC-LOs in real learning processes. Section 6 concludes the paper by highlighting the key results achieved and outlining ongoing and future work.

2. Aims and background

In [11] a new issue and concept, called 'collaborative complex learning object' (CC-LO), was presented and discussed. The notion CC-LO was set off from the known concept of 'learning object' (LO) [12]) 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 [13] learning objects 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 [14] and [15]. 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. 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 [11] 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. CSML model is the set of object oriented elements needed to store and work with collaborative session data expressed in CSML way. The CSML specifies ontology named Collaborative Session Conceptual Schema (CS^2) that allows for modeling and representing knowledge about Web-based collaborative sessions [16]. The CSML is based on SIOC specification (see Fig. 2) so it contains some of the elements defined in this and other related specifications like FOAF (Friend of a friend)[2] or Dublin Core[3].

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), 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 [11]).

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 become an attractive learning resource to increase the learners' engagement in the collaborative activities.

The system produced from this research was naively tested to validate the notion and nature of the CC-LO [11]. In this paper we proceed with experimenting with the system in a real context of learning in order to validate the impact of the virtualization of live sessions of collaborative learning in complex dimensions of the collaborative learning process, such as participatory behavior, assessment, knowledge acquisition and motivation, as well as technical aspects of the VCS tool (e.g., usability and worthiness as an educational tool).

[2] http://www.foaf-project.org/
[3] http://dublincore.org/

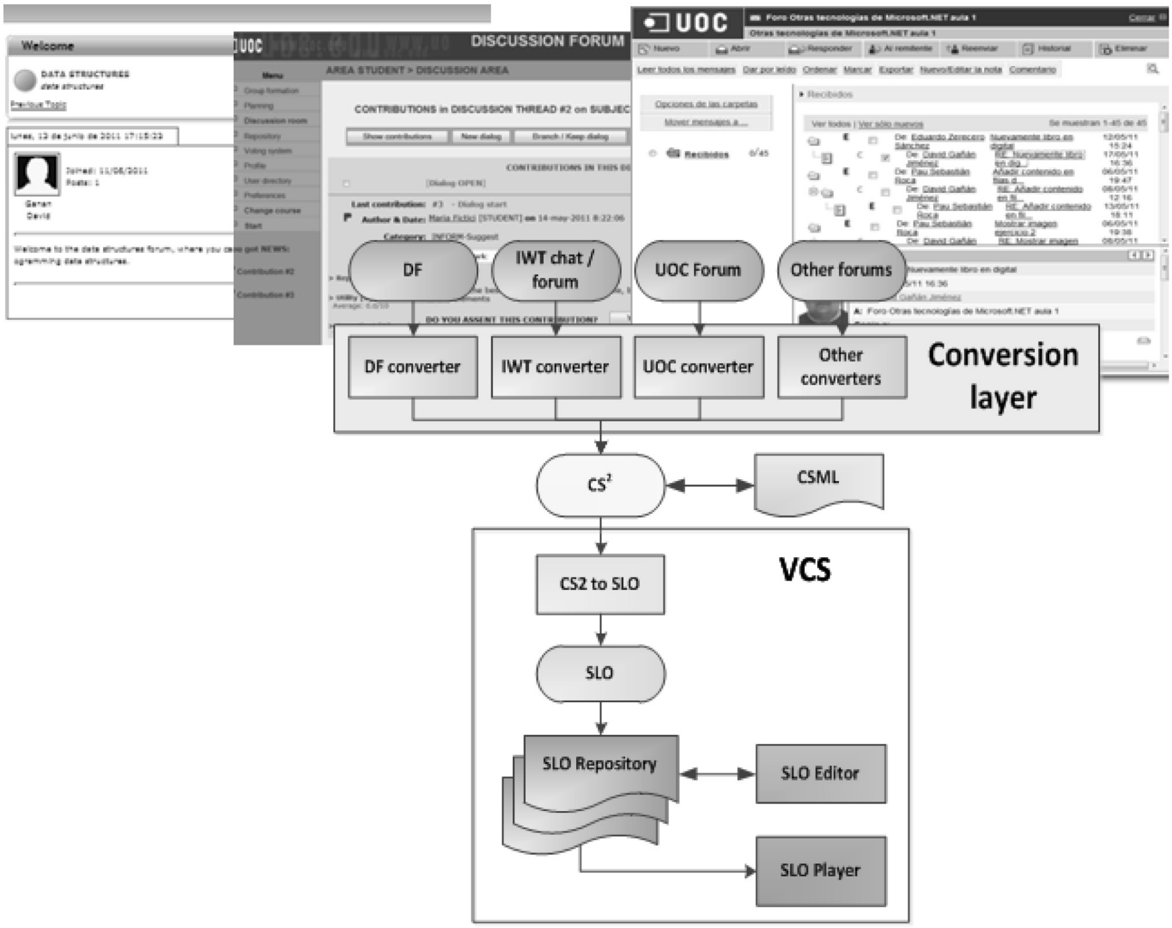

Fig. 1. Architecture of the VCS system.

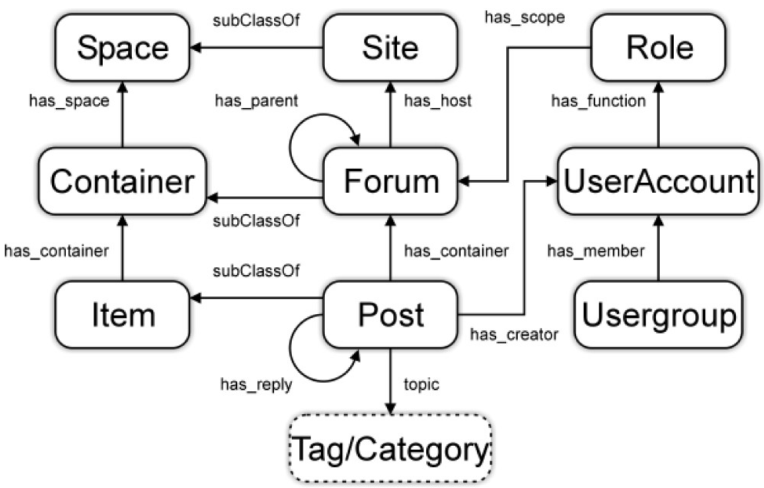

Fig. 2. SIOC Core Ontology Classes.

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, the empirical study includes details on the goals and hypotheses, the method (including number and type of participants, apparatus and stimuli, and procedure), and the evaluation and

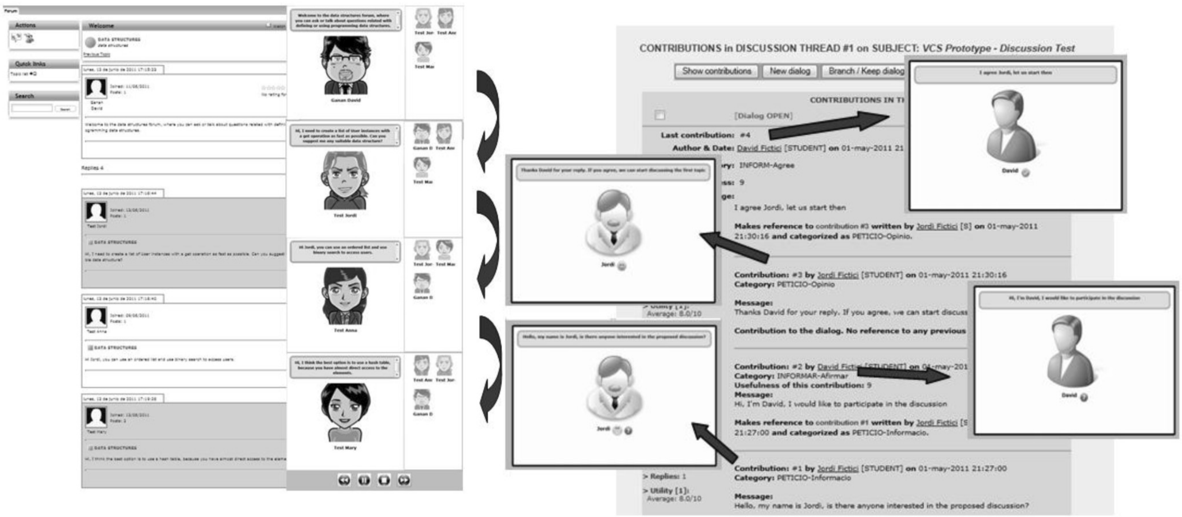

Fig. 3. Samples of two SLOs from the VCS prototype with discussions evolving over time after the virtualization of live collaborative sessions performed in different web forums.

Table 1. Reporting an empirical study (adapted from [18])

Step	Description/Questions to be considered
1. Research Goals and hypotheses	What is the learning purpose/are the learning goals of the planned study? Which hypotheses can be derived from the goals?
2. Method	
2.1. Participants	Selection/Description of the participants: • How many learners and teachers are necessary/available? • More detailed description • Are there any constraints? • Selection criteria • Are the participants informed about the goal of the study?
2.2. Apparatus and Stimuli	How is the learning problem investigated in detail? What is measured? How is the learning outcome measured/quantified?
2.3. Procedure	Description of the procedure of the planned study: • Short summary of the main design, assignment of the subjects to the groups, . . . • The course of events during the study
3. Evaluation Results	What about the usability/functionality of the learning tool? What did the students like/not like regarding the learning tool? Were the students aware of the functions of the learning tool? What can be improved regarding the learning tool?
4. Validation Results	Results from the pedagogical and psychological perspective • Were the students motivated regarding the experiment? • Did the learning tool support their learning process?
5. Conclusion	What are the most important results with respect to the predefined goals?

validation results [17]. The standard structure presented is based on the APA guidelines to report empirical results (see [18] and Table 1). Evaluation and validation results are reported in Sections 4 and 5.

The experimentation study was localized to better address the local circumstances pertaining to each user group. Implementation parameters were determined, such as the necessary adjustments to the agenda and needs of the course curricula, technical and organizational preparations, additional technological tools development, selection of the best technical configuration for the specific purposes, etc.

This methodology takes as input the user scenario described in Section 2 and in [11] and performs the definition, integration and experimentation tasks of the resulting software components.

To pursue these goals, groups of users (in general, students and teachers/lecturers) were organized in the pilot course, which is an educational environment with full e-learning quotes, and in which the extended computational capabilities of the VCS system enabled the exploitation by teachers and students of existing advanced educational technologies (such as discussion forums).

The deployed VCS system and the implicated scenario of use were exposed, through demonstration activities, to numbers of real users in real setting of learning, with the aim to validate the findings of the pilot with feedback from, and observations of, random (and not anymore deliberately selected) users in an educational context. In the validation course, an experiment with numerous users performing authentic technology-enhanced learning tasks was performed.

A key issue of the experiments is the organization and the management of the user-centered activities in the participating pilot courses. The precise ways of implementation as well as the necessary parameters were determined. The timetable of the proposed activities was designed in order to be discussed with the teachers involved.

3.1 Research goals and hypotheses

The goal of the requirement scenario is to virtualize live sessions of collaborative learning to produce storyboard learning objects embedded in an attractive learning resource (VCS) to be experienced and played by 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).

Despite, at the stage of this reporting, the VCS was fully functional and the development goals were achieved, it is still far from offering the actual potential to be provided at the end of the project ALICE. The expected and most distinctive features as for providing a reusable CC-LO as a result of recording live collaborative learning sessions and virtualizing and augmenting them with author information are still not available.

Current version of the VCS allows for virtualizing live collaborative sessions at the same time they occur and no augmentation no management of the virtualization process is possible. Hence the virtualization process keeps providing a live collaborative session in a different format.

Therefore, the goals and hypotheses formulated for this scenario are related to the current stage of the VCS prototype. In particular, the usability and functionality of the VCS tool to play and observe the current text-based discussion in a multimedia attractive format. To this end, an experiment was run to pilot this scenario 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 discussion forum called Intelligent Web Teacher (IWT) [19]. Next, the goals and hypotheses are formulated.

Goals:

G1: To build a system that is able to build a Virtualized Collaborative Session (VCS) from a threaded discussion (coming from a forum).
G2: To employ the VCS in online courses in order to enhance some aspects of 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 storyboard through a user friendly interface.
G5: To build (automatically) a draft storyboard from a collaborative activity effectively.
G6: To build (automatically) a draft storyboard from a collaborative activity efficiently.

Hypotheses:

H1: The VCS prototype allows non-expert users to build and use a Storyboard Learning Object (i.e., in a friendly way and efficiently).
H2: Use of VCS contributes to significantly improve students' motivation.
H3: Use of VCS contributes to support lecturers' task.
H4: Use of VCS contributes to significantly increase students' activity levels, both in individual and collaborative activities.
H5: Use of VCS contributes to significantly improve students' understanding of key concepts and students' results.
H6: VCS are considered as a worthy educational resource by both lecturers and students.

3.2 Method

Following the reporting study presented in Table 1, information about the participants, the apparatus used for experimentation and the procedure of the experiment are provided in this subsection.

3.2.1 Participants

The real context of this experience is the virtual learning environment of the Open University of Catalonia (UOC)[4]. Given the added value of asynchronous discussion groups, the UOC have incorporated on-line discussions as one of the pillars of its

[4] The Open University of Catalonia (UOC) is located in Barcelona, Spain. The UOC offers distance education through the Internet since 1994. Currently, about 60,000 students and 3500 lecturers and tutors participate in some of the 3000 on-line official courses available from 43 official degrees and other PhD and postgraduate programs. The UOC is found at http://www.uoc.edu

pedagogical model. To this end, great efforts are being made to develop adequate on-line tools to support the essential aspects of the discussion process, which include students' monitoring and evaluation as well as engagement in the collaboration.

In order to evaluate the prototype of the VCS and analyze its effects in the discussion process, the sample of the experiment consisted of 81 graduated students enrolled in the course Organization Management and Computer Science Projects from the Computer Science degree at the UOC were involved in this experience. Students were equally distributed into two classrooms and participated in the experience at the same time.

From 81 students who started and participated in the experiment, 69 out of them (85.1%) finished the experience, the rest of students (12) dropped out the discussion and the course for several personal reasons. It is worth mentioning here that the 14.9% dropout ratio found is considered rather low in the first third of the academic term when the experience was run. Eventually this higher number of participants (i.e. 69) allowed for obtaining more empirical data from the experience.

The students were supervised by two tutors. Each of the tutors was assigned to each classroom as the official lecturer teaching the whole course.

3.2.2 Apparatus and stimuli

Students from each classroom were required to use standard text-based discussion forums to support the same formal collaborative assignment with the same rules during the same time. In addition, in one of the classrooms (experimental group) the standard forum IWT was equipped with the multimedia-based VCS tool (see Fig. 4). The other classroom (control group) also used a standard discussion forum though the VCS was not available.

After the in-class discussion assignment, the students were required to fill in a questionnaire, which included the following 7 sections: (i) identification data (names and username); (ii) open questions about the knowledge acquired during the discussion; (iii) test-based evaluation of the supporting forum tool (either with or without the VCS), which included a motivation test; (iv) test-based evaluation of the VCS (only in the classroom where the VCS was available); (v) test-based evaluation on the usability of the system (either the VCS or the standard forum without the VCS); (vi) test-based evaluation on the emotional state (the IWT forum with the VCS and the standard forum without the VCS); (vii) a test-based evaluation of the questionnaire.

Fig. 4. Screenshot of a moment of the formal discussion virtualized as a video storyboard by the VCS tool (facial images have been faded and surnames have been removed for private reasons) A video demo is found at: http://clpl.uoc.edu/ALICEWP3.mov.

Therefore, the questionnaire for the group with the VCS equipped had all mentioned sections while the other group (without the VCS) had all but Section (iv). All sections had a final field to express suggestions and further comments about aspects not represented in the questions.

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). Then we compare these statistics between the control en the experimental group.

Section (iii) of the questionnaire included a subsection with a motivation test which dealt with the amount of motivation the students felt when they were working with the VCS. In this sub-section we used the following answer categories: 'absolutely unmotivated' (1), 'unmotivated' (2), 'motivated' (3), 'very motivated' (4).

For the Section (v) (usability of the forum tools with the VCS and without it) we used the System Usability Scale (SUS) developed by [9] 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.

Finally, to investigate what emotional state of the students was when they used the forum tool both equipped with the VCS and without, Section (vi) of the questionnaire concerned about the 'emotional state' of students when using the new system, which included 12 items of the Computer Emotion Scale (CES) [20]. 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 forums supporting the discussions in each classroom. 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 IWT, VCS and UOC Virtual Campus databases and log files.

3.2.3 Procedure

The in-class collaborative formal assignment in both groups lasted three weeks during the first third of the Fall term of 2011 and consisted of discussing the same issue: 'Factors that lead a Computer Science project to failure'. In this assignment, each student was required to post one contribution at least on the issue in hand. Hence, participation in the discussion was mandatory to pass the course.

During the discussion, any student could contribute as many times as needed in the discussion forum by posting new contribution, replying to others as well as start extra discussion threads to provide new argumentations with regards to the issue addressed. Both classrooms used the IWT text-based forum to participate in the discussion. In one classroom, participants could follow the discussion also by the VCS prototype in a video format. The aim was to evaluate the effects of the VCS system in the participation by comparing the activity levels of the discussion between the two groups.

After the assignment, two different questionnaires were sent to students, each to each classroom. Students of the classroom equipped with the VCS tool were asked about questions more focused on this tool. Students from the other classroom were asked about the standard discussion tool used. All students were asked about the results of the discussion in order to identify the knowledge acquired on the topic at hand as well as their emotional state and usability issues when using the tools.

4. Evaluation results and interpretation

Following the methodology described in Section 3, in this section we focus on the activity, usability and emotional aspects of the VCS tool (H1 and H4). The results of these aspects are shown and evaluated by the analysis and interpretation of the results. We also include an evaluation of the questionnaire. On the other hand, the analyses of the tool's overall impact on student's learning process are reported in Section 5 (Validation Results).

4.1 Activity level fostered by the VCS

In order to evaluate the students' activity levels with the VCS (H4), data was collected and analyzed by

Table 2. Results on activity levels of the discussion in both control and experimental groups

Metric/ Statistic	Experimental group Standard forum (VCS)	Control group Standard forum
Number of students	41	35
Total of posts	156	119
Mean posts/student	M = 3.7	M = 3.4
SD posts/student	SD = 2.0	SD = 1.9
Total words	26669	26591
Mean words/student	M = 634.9	M = 759.7
SD Mean words/student	SD = 406.8	SD = 563.1
Total words	26669	26591
Mean words/post	M = 170.9	M = 223.3
SD Mean words/post	SD = 116.1	SD = 111.9
Total visits	1927 (363)	2149
Mean visits/student	M = 47 (8.8)	M = 53.7
SD visits/student	SD = 8.3 (2.4)	SD = 6.7

comparing the participation behavior of the experimental group and the control group (Table 2).

For the posts, words and visits metrics, we computed the mean and its standard deviation. Since no extreme outliers were found, the mean in combination with the standard deviation produced a precise measure. Also for the visits to the forum posts we used the same statistics. 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 (33) multiplied by the average of first scenes watched of each SLO played (11).

Analyzing the results of Table 2, they indicate that by using the VCS the participation quantitative behavior was increased since the number of posts and mean posts/students is higher in the experimental group. On the other hand, the number of views (i.e., readings) of text posts was higher in the forum than in the forum equipped with VCS, pointing out that some of the students found in the storyboard an alternative to the reading of text posts, which was also confirmed by the data collected from the VCS activity logs (363 first scenes seen).

Participation qualitative behavior is measured in terms of the number of words per post and per student. The lower mean statistics of both words per post and per student in the experimental group indicates that the users of the VCS were more effective and dynamic when communicating their ideas and opinions by either sending new posts or reply posts. As a result, the contributions became more structured and specific whereas the control group promoted larger monolithic one-sided points of view.

4.2 Usability of the VCS

To evaluate student's satisfaction with the tool regarding an efficient and user-friendly management (H1), we collected students' ratings and open comments on the usability/functionality/integration of the tool.

To investigate the overall usability of the VCS tool, we used the SUS (see [9] and Section 3.2.2) included in Section (v) of the questionnaire. As mentioned previously, the answers were given on 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).

SUS scores have a range of 0 to 100 with an average score of 68, obtained from 500 studies [9]. A SUS 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, we got an average for 38 SUS scores of 63.02 thus nearby the SUS mean, which is a very good score considering the VCS tool is new and still far from being fully developed. Next, we present the most relevant results of the SUS score by providing several statistics: Mean (M), Standard Deviation (SD) and Median (Md).

Students found the tool particularly easy to use (M = 3.47, SD = 1.00, Md = 3) (Fig. 5-A). Students did not find the VCS unnecessarily complex (M = 2.2, SD = 0.97, Md = 2) (Fig. 5-B). In addition, students stated that they did not need the support of a technical person to be able to use the VCS (M = 1.89, SD = 0.88, Md = 2) (Fig. 5-C) and they thought that most people would learn to use this system very quickly (M = 3.58, SD = 1.00, Md = 4) (Fig. 5-D).

Some students (about 20%) complained about the VCS being slow to start playing the storyboard as well as the text-to-voice engine sometimes did not

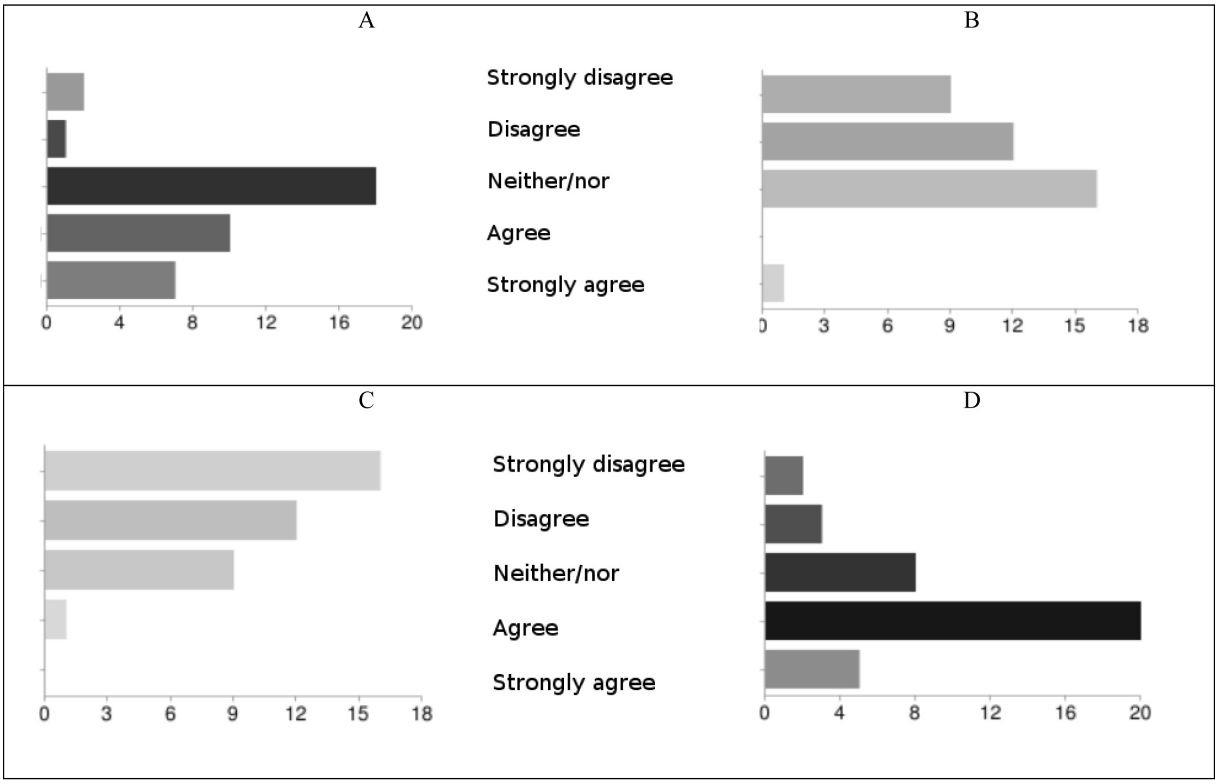

Fig. 5. Results on the SUS items: (A) 'I thought the system was easy to use'; (B) 'I found the VCS unnecessarily complex'; (C) 'I think that I would need the support of a technical person to be able to use the VCS'; (D) 'I would imagine that most people would learn to use the VCS system very quickly'.

reproduce the original contribution perfectly, especially if syntax mistakes were found. As a result, some students preferred to read the forum text messages rather than observe them. On the other hand, students found useful to be able to listen to the discussion while performing other tasks at the same time (e.g., update the agenda, etc.), without being focused only on reading the forum messages. Also they found useful and engaging the possibility to get new ideas and take notes in real time from listening to the discussion in a similar way to a face-to-face discussion.

In accordance with these results, students indicated in a balanced way they would and would not use the VCS system frequently (M = 2.97, SD = 1.16, Md = 3) in line with the overall SUS score of 63.02 and in Fig. 6-A.

Finally, students stated that the VCS functionality was well integrated (M = 3.25, SD = 1.01, Md = 3) and the tool itself was adequately integrated in the UOC virtual campus (Fig. 6-B). In particular despite some initial technical problems to gain access, they appreciated to be able to accede to the IWT forum equipped with the VCS directly from the UOC classroom with no reauthentication nor further navigation to the targeted web space.

4.3 Emotional aspects

Regarding the students' emotions we used the aforementioned CES scale [20] to measure four general emotions of the students during their work with the VCS tool (H1). The results from a 4-point rating scale (n = 38) were (see also Fig. 7): Happiness: M = 0.95, SD = 0.89, Md = 1; Sadness: M = 0.24, SD = 0.49, Md = 0; Anxiety: M = 0.21, SD = 0.47, Md = 0; Anger: M = 0.24, SD = 0.49, Md = 0.

Despite the Happiness emotion is rather low the students felt more often Happiness than Sadness, Anxiety or Anger when learning the new VCS tool. In addition, students felt the same level of Sadness, Anxiety and Anger emotions, which were very low, almost inappreciable, being Anxiety emotion the lowest. These results are in line with the results presented above concerning the evaluation of usability of the VCS tool about the SUS mean (see Section 4.2). As already discussed above, no remarkable degree of Anger, Anxiety and Sadness emotions were reported by the students though the level of satisfaction (i.e., Happiness emotion) was not high due chiefly to some technical problems when uploading the storyboard.

Finally, a very few cases of frustration (i.e., Anger

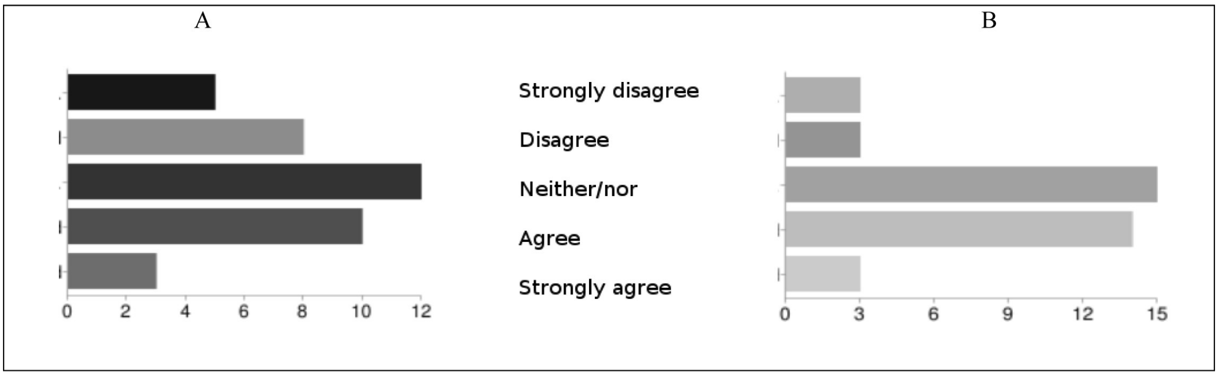

Fig. 6. Results on the SUS item (A) 'I think that I would like to use this system frequently' and (B) 'I found the various functions in the VCS were well integrated'.

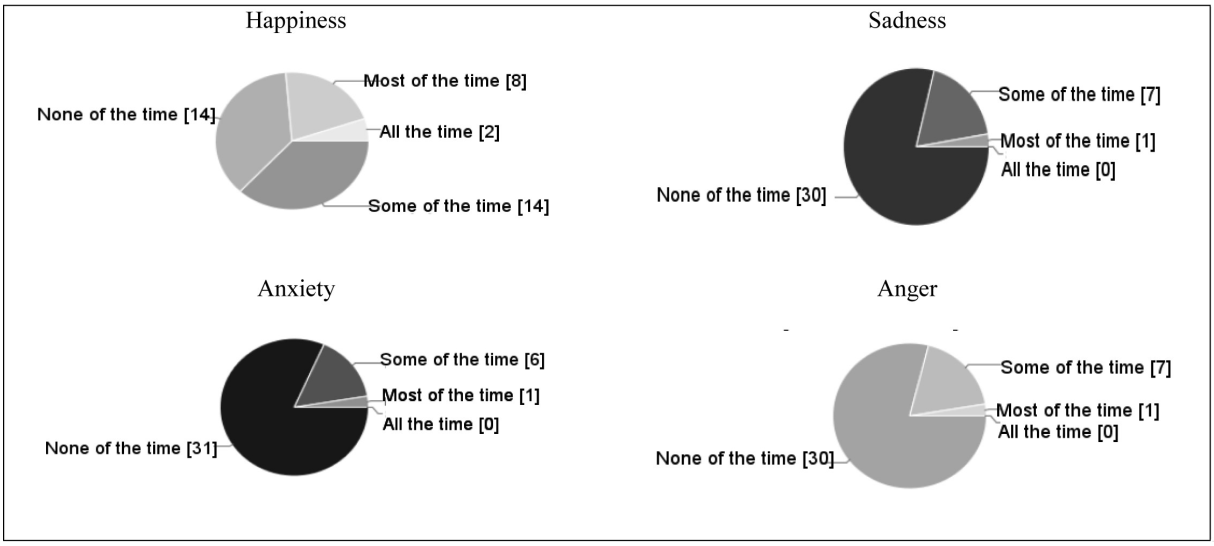

Fig. 7. Results of the CES scale on the four general emotions.

emotion) were reported by Linux users who could not install the Microsoft Silverlight plug-in to enable the VCS player.

In overall, this is a good result considering the system is far from being fully developed and the user interface needs to take several iterations of improvements before being completed.

4.4 Evaluation of the questionnaire

The questionnaire was designed not to be very intrusive in the students' responses by avoiding exceeding the length and/or time employed to fill it. Evaluation results of the suitability of the questionnaire design confirmed the expectations resulting in most of students filling and submitting the questionnaire in less than 30 minutes (Fig. 8-A) and 76% of them found it appropriate to evaluate the experience (Fig. 8-B).

5. Validation results and interpretation

Following the research methodology presented in Section 3, we focus in this section on validation that includes the following validation criteria and metric.

Validation criteria:

C1: Level of fulfillment of the VCS features.
C2: Potential increase in students' motivation caused by the use of VCS.
C3: Level of satisfaction of the lecturers with the inclusion of VCS in their courses.
C4: Potential increase in students' activity levels due to the incorporation of the VCS.
C5: Potential increase in students' understanding of concepts and students' results.
C6: Level of satisfaction of students with the inclusion of the VCS in their courses.

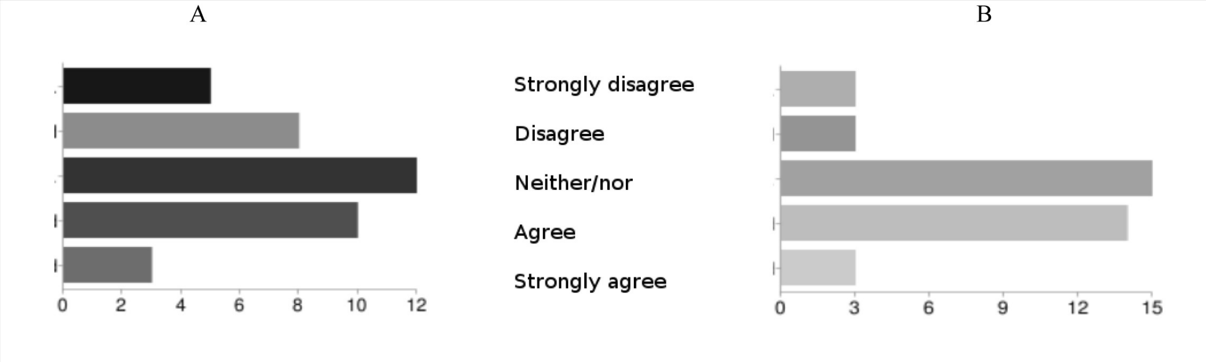

Fig. 8. Time employed to fill out the questionnaire (A) and appropriateness to evaluate the experience with the questionnaire (B).

Validation metrics:

M1: Number of students using the VCS.
M2: Number of visits of the VCS.
M3: Number of visits of the standard forum.
M4: Number of messages submitted by students related to the VCS topics.
M5: Number of messages submitted by students when no VCS is used.
M6: Number of words written by students when the VCS is used.
M7: Number of words written by students when no VCS is used.
M8: Number of students and lecturers that consider that the VCS is worthy.

The purpose of this validation methodology is to validate the improvement of motivation (H2), worthiness as an educational tool and teaching supporting tool of the VCS (H3 and H6) as well as the acquisition of collaborative knowledge (H5).

5.1 The VCS as a valuable resource

The purpose of this section is to evaluate the level of worthiness of the VCS as an educational tool (H6). To this end, we collected quantitative and qualitative data in order to know the user satisfaction with the tool. Both quantitative and qualitative data were collected in Section (iv) of the questionnaire from six open questions addressed to students. Finally, the lecturer in charge of the classroom also participated by providing his views of the VCS as a supporting tool for teaching (H3).

In the questionnaire, the rating scales for the majority of the quantitative questions we used a 0–10 point scale, so that students could assess the value of the VCS tool by a scale they felt very familiar with from their experience in the UOC courses. The scale went from the worst mark (0) to the best mark (10) considering a 'good' assessment marks from 5 to 10 and a 'bad' assessment marks under 5 points.

The following questions related to evaluate the VCS were asked to the students:

1. What did you like and what you did not like from the VCS tool (please assess the VCS from this view in the scale 0–10).
2. Do you think the VCS tool has fostered your active participation in the discussion in comparison to the text-based IWT forum? (please assess the VCS from this view in the scale 0–10)
3. Do you think the VCS tool has helped you follow the discussion in comparison to the text-based IWT forum? (please assess the VCS from this view in the scale 0–10)
4. Do you think the VCS tool has helped you acquire more knowledge about the discussion topics in comparison to the text-based IWT forum? (please assess the VCS from this view in the scale 0–10)
5. Express your opinion about the storyboard generation by the VCS tool in terms of efficiency and performance (please assess the VCS from this view in the scale 0–10)
6. Let us know your opinion about the potential of the VCS tool to observe how people discuss and collaborate, and how knowledge is constructed (please assess the VCS from this view in the scale 0–10).

About 10% of assessment marks were not provided in the questionnaire due to missing values or because the student could not use the VCS (lack of computer speakers, technical problems, etc) and followed the discussion by the usual text messages. We computed a by default value for these questions by the average mark of the rest of responses to the related question where the student's value is missing.

After calculating the 0–10 scale for each student we got a Mean of 4.98 (SD = 1.78, Md = 5). This result is good considering the VCS tool is still far from offering the full distinctive features. This lack influenced a great deal the responses of those questions related to cognitive benefits that are still not well-supported by the tool.

Students in general liked the VCS tool (Question 1: M = 6.07, SD = 1.63, Md = 5). They indicated to find this resource more attractive and pleasant to follow the discussion rather than the usual reading of the text-based messages in a forum. Also students felt the system was more 'communicative', meaning they were more engaged in the discussion. On the other hand, while some students appreciated the benefits to navigate among sentences and messages as well as direct access to a certain message (e.g., new message) others found more agile to follow the discussion by the text forum. Students found problematic to understand the VCS voice due to syntax problems of the text message source. This will be easily solved in the next development steps by the incorporation of the VCS Editor. Finally, some students indicate the benefits of the VCS tool for disable students.

The analysis from comparing participation with and without the use of the VCS tool scoped Questions 2, 3 and 4. All of them had similar results (M = 4.28–4.34, SD = 2.63–3.07, Md = 5). On the one hand, students indicated that the VCS did not foster their participation because the VCS allowed them to read the messages but not to write. Also, they mentioned that if the video format had been the only option to follow the discussion, they could have found harder to participate in the whole collaborative activity. On the other hand, students pointed out that by listening to the messages they could take notes on the contributions in real time, thus enhancing the participation. In addition, the students could follow the discussion faster with the VCS, thus leaving time for further participation and they also reported to associate faster the main discussion concepts by combining the text in each scene balloon with the characters' voice rather than just reading the text posts in the standard forum. Finally, the students could follow the discussion more effectively, especially in large discussions, by avoiding the page navigation required by the text-based forum and also for review and summary purposes of the most relevant contributions.

Some students reported performance and efficiency problems during the execution of the VCS tool while others approved the general performance of the system (M = 5.68, SD = 1.67, Md = 5). Also, students reported to have technical problems with the Microsoft Silverlight plug-in while others neglected to install it (e.g., Linux users). Students indicated that for short threads it was more efficient to read messages in the text forum than watch them in the VCS.

Finally, students found many advantages of the VCS by exploiting its potential appropriately (Question 6: M = 5.2, SD = 2, Md = 5). In particular, they commented that the VCS would be more useful if performance and visualization could be improved. Most interestingly, they proposed to 'store' or 'backup' the storyboard format of the discussion in a repository in order to be able to reuse the most relevant contributions in video or audio format later on by students of next courses. These comments are in line with the actual extension of the VCS for the next development steps in the ALICE project that students felt as the next logical step. Also they proposed to link the VCS tool with the IWT forum in order to directly post a message to the forum in response to a contribution read in the VCS. Students indicated the VCS to be particularly useful for large discussions, which can be followed more fluently and comprehensively. Finally, students proposed to foster the use of VCS system at a larger scale, in other courses and programs.

Regarding the lecturer in charge of the discussion reported that the VCS tool helped him follow and assess the discussion more appropriately than the standard text-based forum by having direct access to a specific students' contribution. However, the lecturer demanded more monitoring tools for the VCS to sort out scenes by student, date and connection between replies, thus following dialogs within a thread. This is in line with the next development steps of the VCS and the goal to turn the VCS sessions into learning materials so that other students can reuse the knowledge built during the live discussion.

5.2 Motivational aspects

Students' motivation concerning the in-class discussion assignment supported by the VCS tool was investigated by comparing the difference in motivation between the experimental and control groups.

Section (iii) of the questionnaire included a motivation test for both the experimental and control groups, where all students were asked for the amount of motivation they felt when collaborating in the discussion by means of the required tools. The following answer categories were used: 'absolutely unmotivated' (1), 'unmotivated' (2), 'motivated' (3), 'very motivated' (4).

Experimental group scored higher (M = 2.85, SD = 0.69, Md = 3) than the control group (M = 2.14, SD = 0.38, Md = 2). The results of the experimental group are in line with the results reported in Section 5.1. In particular, students found the VCS more attractive and pleasant to follow the discussion than the traditional reading of the text-based messages in a standard forum. In addition, students mentioned that the several options to follow the discussion (text and video) motivated them to participle. Finally, clear indications of amounts of motivation came from enthusiastic students who evaluated the VCS tool as 'fascinating', 'impressive', 'very interesting', 'very useful', and 'inflexion point in e-learning systems'. On the other hand, students who chose not to use the VCS tool due to lack of time or technical problems felt unmotivated.

5.3 Tutor assessment and knowledge acquisition

All students were assessed on summarizing the discussion in both the experimental and the control groups. To this end, Section (ii) of the questionnaire included 3 evaluative questions: 2 first questions to assess the discussion topics and the last question to assess the knowledge acquisition, as follows:

Indicate what are the main factors seen during the discussion, which may lead a software project to fail.

1. Indicate what factors make a project which has been finalized successfully be underused.
2. Comment on what you learnt from the discussion than can enrich your personal knowledge.
3. This part of each questionnaire was addressed by the lecturers of each classroom who used the standard 10-point scale to score the students' responses. Table 3 shows the results.

From the results of Table 3, 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 5.1 where students indicated that the VCS did not foster the quantity and quality of the participation.

Table 3. Results of the discussion evaluation

Evaluative questions	Experimental group (n = 38)	Control group (n = 31)
Question 1	M = 6.84 SD = 1.48 Md = 7	M = 6.93 SD = 1.15 Md = 7
Question 2	M = 7.68 SD = 1.18 Md = 8	M = 6.83 SD = 1.34 Md = 7
Question 3	M = 7.21 SD = 1.45 Md = 7	M = 7.12 SD = 1.14 Md = 7
Overall	M = 7.24 SD = 1.41 Md = 7	M = 6.96 SD = 1.21 Md = 7

In summary, we cannot conclude that the current version of the VCS tool had an impact in the knowledge acquisition of the discussion.

6. Conclusion

In this section the results are summarized and discussed by considering the goals which were determined at the beginning of the study (see Section 3.1). Then, based on these results, further research and technological directions are proposed.

In general the students liked the VCS tool and found it interesting to have another option to follow the in-class discussion-based assignments (G3). During this specific assignment, students indicated they could generate the storyboard from the VCS (G1) and it was effective to support the discussion for review and summary purposes (G5). Despite some initial technical problems the majority of students reported to be able to generate the storyboard efficiently (G6) and create, store (transparently) and playback it (usability) as many times as needed (G4). Aspects of the learning process, such as motivation and emotional were validated showing a positive impact of the use of the VCS tool on these aspects (G2). In addition, the VCS were proved to become a useful educational resource. Finally, important gain in knowledge acquisition by using the VCS could not be validated significantly though promising results are expected when this tool is fully featured. In overall, the students' comments gave many hints for possible improvements of the tool, such those comments reported in Section 5.1.

Current research being conducted in the project ALICE aims at identifying the exact processes needed to create CC-LOs, whether the content itself requires creation or rather the CC-LO may be formed by appropriately recognizing the pedagogic relationship between existing technical and conceptual components and consolidating them into the CC-LO. From this pedagogic perspective, future work will aim to develop clear guidelines for the creation and use of CC-LOs both within the application domains of the project itself and by educators on a wider scale.

In addition, the next iteration in the project ALICE will provide a full featured version of the VCS prototype. New and essential functionality will be incorporated, such as the VCS Editor that will allow for building a reusable CC-LO by eliciting the knowledge acquired in previous live collaborative sessions. From this technology perspective, based on the CC-LO approach, we plan to provide a new type of learning resource called Collaborative Complex Learning Resource (CC-LR) that may have an important impact on the knowledge acquisition and in the learning process in general.

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