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

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This contribution proposes software infrastructure to support new types of learning methodologies and resources based on collaborative knowledge engineering by means of an innovative application framework called the virtualized collaborative sessions framework (VCSF). The VCSF helps meet challenging collaborative knowledge engineering requirements in on-line learning, such as increasing group members' learning performance during the on-line collaborative learning process. In turn, systematic application of the VCSF platform enriched with semantic knowledge engineering technologies enables e-learning developers to leverage successful collaborative learning experiences in a software reuse fashion while saving development time and effort. The framework is prototyped and successfully tested in real environments, thus showing the software reuse capability and the collaborative knowledge engineering benefits of the VCSF approach. The research reported in this paper was undertaken within the *ALICE* project funded through the European 7th Framework Program (FP7).

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

1. Introduction

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

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

In order to overcome these limitations, in previous research we reported on a new collaborative learning methodology called the collaborative complex learning object (CC-LO) (Caballé *et al.*, 2012) through the development of a system prototype called the virtualized collaborative session (VCS) that enables the embedding and execution of the CC-LO approach (Gañán *et al.*,

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2013). The VCS application creates CC-LOs from the virtualization and registration of live collaborative sessions, which can be augmented by alternative learning paths, cognitive and emotional features, additional content, etc., during an authoring phase (i.e., an expert managing the CC-LO). The registered CC-LOs are eventually packed and stored in the form of a collaborative complex learning resource (CC-LR) (see Fig. 1) for further reuse, enriching live sessions of collaborative learning with balanced levels of interaction, challenge and empowerment (Caballé *et al.*, 2013).

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

In this paper, we propose the provision of software infrastructure to support new types of pedagogically augmented collaborative learning methodologies and resources by means of an innovative application framework (Schmidt, 1995) called the virtualized collaborative sessions framework (VCSF). A first step towards this direction was proposed by Gañán *et al.* (2013). The VCSF supports the entire process of creation, management and execution of the mentioned SLO and CC-LR resources from any LMS and collaborative learning tool. As part of the process, the VCSF exploits the VCS application and leverages Web semantic technologies (Conesa *et al.*, 2012) to enable e-learning software developers to embed many types of successful collaborative learning experience into different LMSs in a software reuse and systematic fashion. For validation purposes, the paper presents successful experiences, both pedagogical and technical, evaluating our framework into different LMS and e-learning tools to support the virtualization process of live collaborative learning sessions. The ultimate aim is to show the software reuse capability from the systematical application of the VCSF approach as well as the resulting pedagogical benefits, such as increasing students' engagement and learning performance.

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

2. Background and research aims

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

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

In particular, application frameworks promote a standard structure for developing software applications and tools. Programmers find it much simpler to create automatic creation tools when using a standard framework, since this defines the underlying code structure of the application in advance. Developers usually use object-oriented programming techniques to implement frameworks such that the unique parts of an application can simply inherit from pre-existing classes in the framework (Fayad *et al.*, 1999). Application frameworks became popular with the rise of graphical user interfaces (GUIs) and Web applications, which alleviate the overhead associated with common activities performed in web development and creating GUI tools by providing libraries for database access, template frameworks and session management, and they often promote code reuse (Schmidt, 1995). The outcome of our work reported in this paper follows this application framework approach.

However, a revision of the latest research to provide framework support to the development of applications within the field of the CSCL domain shows that the results are still scarce (see the works of Caballé (2008) and Caballé *et al.* (2007) for an extensive overview of related work). The main focus is still on leveraging the great research efforts and technological advances

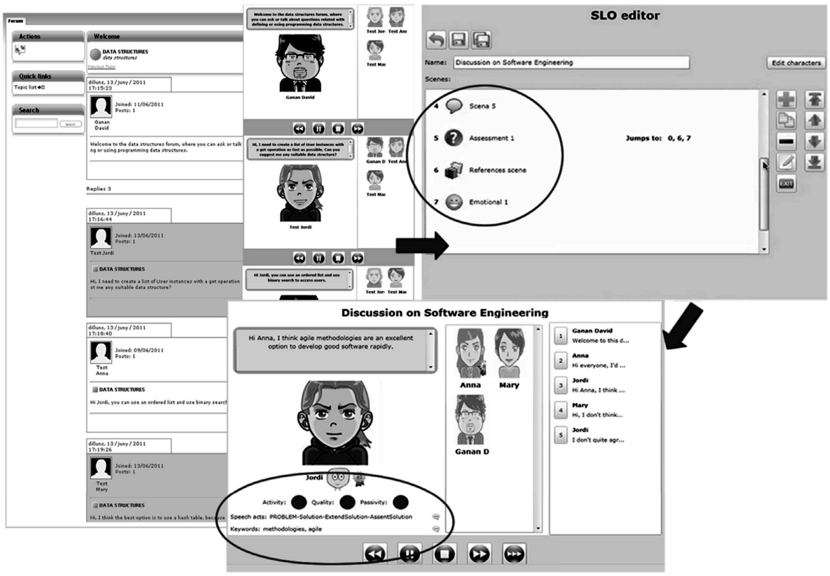

Fig. 1. Process of producing, managing and storing a CC-LR by the VCS system from a CC-LO/SLO (left part), incorporating different types of scenes and author information (right part), such as cognitive assessment and emotional awareness of the original participant and contributions.

within the general computer-supported cooperative work (CSCW) domain (Penichet *et al.*, 2010; Fonseca *et al.*, 2009; Petropoulakis and Flood, 2007; Bao-Qing *et al.*, 2007; Lukosch and Schümmer, 2006). These approaches provide exhaustive support for cooperative work, such as group and workflow management, group editing, document sharing and many types of both synchronous and asynchronous communication (Fonseca *et al.*, 2009). However, many of them are not even prepared to support essential collaborative learning features, such as collaborative knowledge building and scaffolding as well as specific monitoring and assessment of the learning process (Dillenbourg, 1999a). Representative researchers (Stahl, 2006) argue whether intrinsic CSCL requirements should be considered from the very beginning of the development and not as an extension to experimented CSCW tools for work (Bentley *et al.*, 1997).

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

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

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

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

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

3. Research methodology

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

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

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

3.1.1. Conversion layer. The Conversion layer of the VCSF defines a generic converter component that can be particularly implemented for specific data sources from forums and chat tools of different LMSs. As shown in Fig. 2, the input collaborative session from those data sources is read by the converters' components and represented using the CS^2 common specification, which is based on semantically-interlinked online communities (SIOCs) and friend-of-a-friend (FOAF) ontologies. CS^2 can be stored or imported from files in the collaborative session markup language (CSML) format, which is in turn based on the RDF representation for the SIOC ontology (see the work of Conesa *et al*. (2012) for an exhaustive procedure view).

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

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

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

The CC-LR outcome allows representing collaborative learning objects with a storyboard structure (SLO) whose model is depicted in Fig. 4. In this model each step of the collaboration is represented by a different

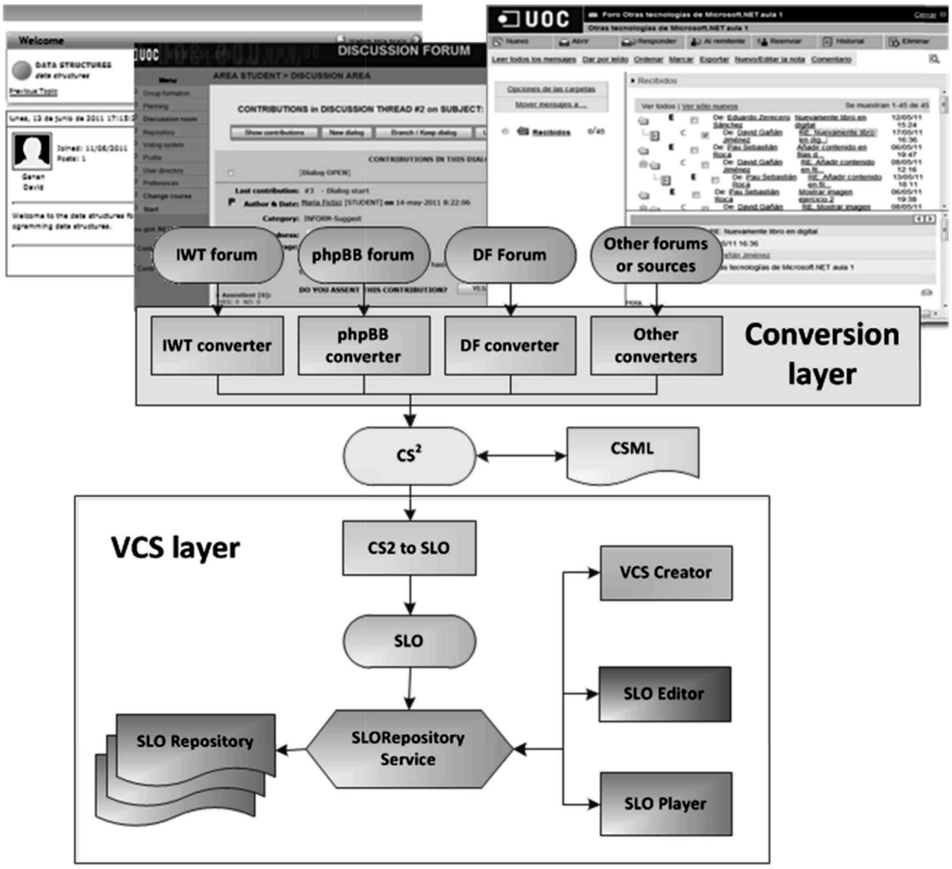

Fig. 2. VCSF general architecture, which is compatible with multiple forums.

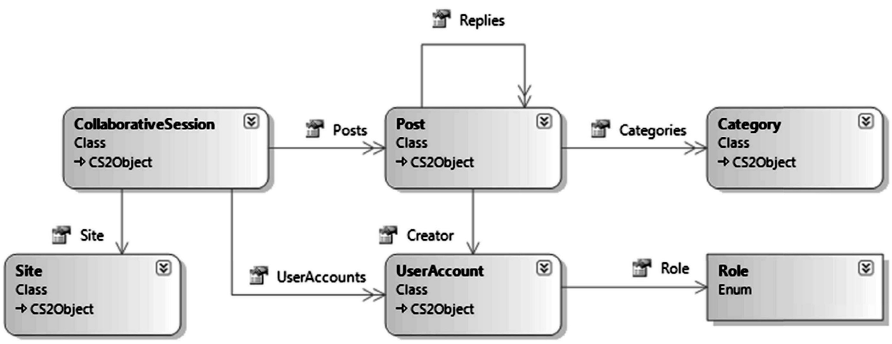

Fig. 3. CS^2 data model.

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

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

- *SLO Repository:* This is a core component of the system, which takes care of managing the storage of a previously created SLO for reutilization.

- *Tools:* Represented by rectangles in the diagram, they enable the user to interact with the system, by creating, editing or playing SLOs.

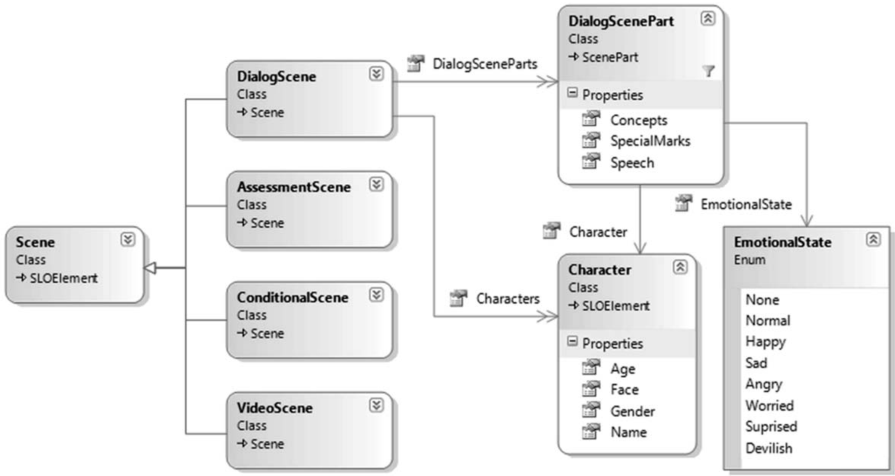

Fig. 4. SLO model classes.

- *Services:* Represented by the hexagonal shapes in the diagram, they offer different generic functionalities to the system that are used within the tools and other components.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The teacher can run an automatic post tagging system included in the SLO Editor, which automatically assigns a tag to each original post by processing the corresponding text following a machine learning approach (see Fig. 5 and also the work of Caballé *et al.* (2009) for the complete procedure). The teacher or learning designer can also manually edit this tag to best express the posts' original intentions. Immediate time assessment is implemented in the VCSF as a set of specific scenes with test questions about the discussion topic and appropriate feedback from the test results. Assessment scenes are created and handled by the SLO Editor tool, which permits the teacher to edit the test questions and answers as well as define a set of feedback rules that change the flow of the SLO depending on the result obtained in the test (Fig. 6). Hence, whether the answer is right or wrong, the student may be redirected either to the next scene or to a previous scene, respectively. In the case of failing the same test repeatedly, the student is redirected to a special scene with complementary material on the test topic, thus filling the knowledge gaps.

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

Similarly to the cognitive assessment perspective, the VCSF approaches emotional awareness also from two time dimensions, namely, deferred and immediate times. Emotional awareness in deferred time shows the emotional state of each participant while posting the corresponding message to the live collaborative session (see Fig. 1). This emotional state is calculated during the conversion from CS^2 to SLO, in which case the CS^2 contains emotional state information from the live collaborative session. The SLO Editor tool also enables

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

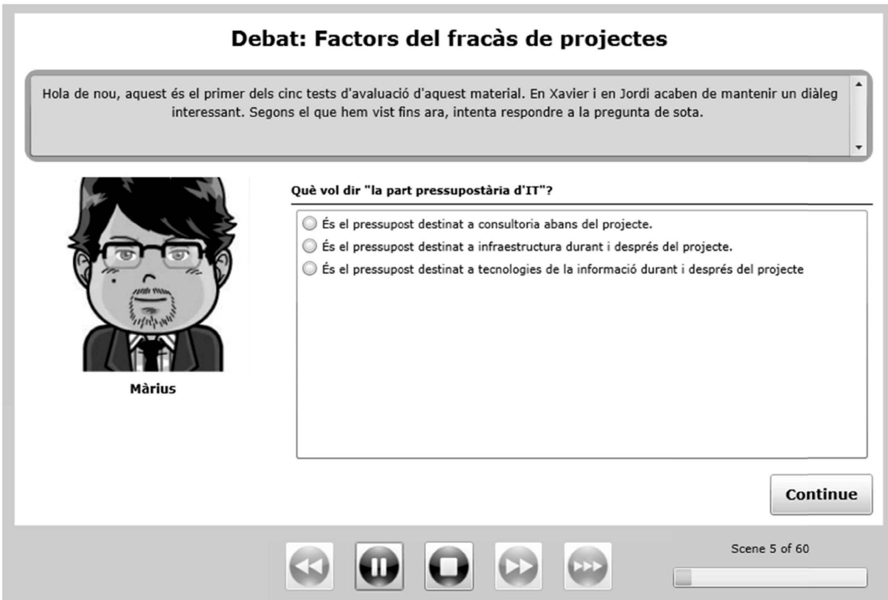

Fig. 6. Immediate assessment scene during the reproduction of an SLO.

the teacher to set up the emotional state of the participants in each dialog in order to best transmit the original participants emotions.

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

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

Following the architecture of the VCSF (see Section 3.1.1), the only component that had to be developed from the scratch during the integration process

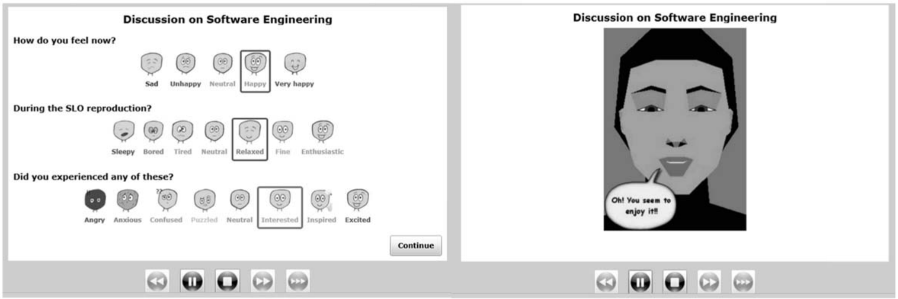

Fig. 7. Immediate emotional awareness: a student marks his/her emotional state (a), a virtual agent provides an empathetic response (b).

was the corresponding converter for the data sources of each web forum. The rest of the components of the VCSF were integrated transparently into the web forums of the LMS.

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

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

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

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

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

4. Experimentation and validation

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

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

4.1. In-class experimentation. For the in-class experiment, a CC-LR was developed by the VCSF. Firstly, the data source of a live collaborative learning session was derived from a typical discussion forum used to support in-class discussions at the Open University of Catalonia (UOC). Then, we used the VCSF to generate an animated SLO from the forum tool showing how people discussed and collaborated, how discussion threads grew and how knowledge was constructed, refined and consolidated (see Fig. 1). By the VCS tools this SLO was then stored for further reuse in the form of a CC-LR and augmented by

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

the Editor with emotional and assessment information, as explained in Section 3.3.

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

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

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

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

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

To investigate the emotional state of the students using the new system (Section (ii) of the questionnaire), we included the twelve items of the computer emotion scale (CES) (Kay and Loverock, 2008). The CES is used to measure emotions related to learning new computer software. Research showed that the twelve items describe four emotions:

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

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

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

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

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

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

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

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

CC-LR as a valuable resource. In this section we evaluate the level of worthiness of the CC-LR enriched with emotional information supported by the VCS as an educational tool. To this end, we collected quantitative and qualitative data in Section (iii) of the questionnaire from 17 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 of the expected scores for each question ($n = 29$; $df = 1$; $p < 0.05$ for the calculated X^2).

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

1. What do you think in general about the video-discussions?

2. Compare the video-discussions with traditional teaching material and tools (books, web pages, forums, blogs, etc.), and indicate pros and cons of the video-discussions.

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

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

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

In particular, for Question 1, students valued the CC-LR enriched with cognitive and emotional aspects with a very good score ($M = 7.28, SD = 1.53, Md = 7$) with $X^2(1)$ = 16.04, $p < 0.001$, the highest score of all the questions. Most students found the video-discussions didactical and useful since they are based on opinions and experiences from other students, thus helping to understand the topic of the discussion for people with a similar background and perspectives. In the same line, students found it interesting to know how other students collaborated in previous in-class discussions from past editions of the course. Moreover, some students indicated that the video-discussion allows watching how knowledge is constructed step by step in a real situation instead of having to believe the knowledge construction process without real evidences.

Finally, most students found it specially useful and interesting the test questions added in certain points of the material so as to self-evaluate their own progress by the feedback provided. On the other hand, a few students felt some confusion of having different opinions from each character, thus having doubts on which character was right. Only very few students complained on technical issues that made it uneasy to study with this resource, while others found the format of the video-discussion monotonous and preferred to study with traditional material (books and text-based learning units). Finally, students did not fully understand the purpose of the emotional scenes nor how this information could help their learning progress in the material.

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

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

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

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

5. Conclusions and further developments

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

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

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

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

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References

Abad, C.L. (2008). Learning through creating learning objects: Experiences with a class project in a distributed systems course, *Proceedings of the 13th Annual Conference on Innovation and Technology in Computer Science Education, ITiCSE'08, Madrid, Spain*, pp. 255–259, DOI: 10.1149/1384271.1384340.

Abdullah, S. and Abbas, M. (2006). The effects of inquiry-based computer simulation with cooperative learning on scientific thinking and conceptual understanding, *Eurasia Journal of Mathematics, Science and Technology Education* **4**(4): 387–398.

Al-Khalifa, H.S. and Davis, H.C. (2006). The evolution of metadata from standards to semantics in e-learning applications, *Proceedings of the 17th Conference on Hypertext and Hypermedia, HYPERTEXT'06, Odense, Denmark*, pp. 69–72, DOI: 10.1145/1149941.1149956.

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

Babič, F., Wagner, J. and Paralic, J. (2008). The role of ontologies in collaborative systems, *6th International Symposium on Applied Machine Intelligence and Informatics, SAMI 2008, Herl'any, Slovakia*, pp. 119–124.

Bao-Qing, G., Xiu-Fen, F. and Su-Xia, X. (2007). P2P distributed cooperative work model based on JXTA platform, *in* M. Xu, Y. Zhan, J. Cao and Y. Liu (Eds.), *Advanced Parallel Processing Technologies*, Lecture Notes in Computer Science, Vol. 4847, Springer, Berlin/Heidelberg, pp. 658–665.

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

Brase, J. (2005). *Usage of Metadata*, Ph.D. thesis, Universität Hannover, Hannover.

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

Caballé, S., Jiménez, D.G., Dunwell, I., Pierri, A. and Daradoumis, T. (2012). CC-LO: Embedding interactivity, challenge and empowerment into collaborative learning sessions, *Journal of Universal Computer Science* **18**(1): 25–43.

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

Caballé, S., Mora, N., Feidakis, M., Gañán, D., Conesa, J., Daradoumis, T. and Prieto, J. (2013). CC-LR: Providing interactive, challenging and attractive collaborative complex learning resources, *Journal of Computer Assisted Learning* **30**(1): 51–67.

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

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

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

Czarnecki, K. and Eisenecker, U.W. (2000). *Generative Programming: Methods, Tools and Applications*, Addison-Wesley, New York, NY.

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

Dillenbourg, P. (1999b). What do you mean by collaborative learning?, *in* P. Dillenbourg (Ed.) *Collaborative Learning: Cognitive and Computational Approaches*, Elsevier, Oxford, pp. 1–19.

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

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

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

Fayad, M.E., Schmidt, D.C. and Johnson, R.E. (1999). *Building Application Frameworks: Object-oriented Foundations of Framework Design*, John Wiley & Sons, Inc., Hoboken, NJ.

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

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

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

Gamma, E., Helm, R., Johnson, R. and Vlissides, J. (1995). *Design Patterns: Elements of Reusable Software Architecture*, Addison-Wesley, Reading, MA.

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

Goodsell, A.S., Maher, M., Tinto, V., Leigh Snith, B. and MacGregor, J. (1992). *Collaborative Learning: A Sourcebook for Higher Education*, Pennsylvania State University, University Park, PA.

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

Kay, R.H. and Loverock, S. (2008). Assessing emotions related to learning new software: The computer emotion scale, *Computers in Human Behavior* **24**(4): 1605–1623.

Lukosch, S. and Schümmer, T. (2006). Groupware development support with technology patterns, *International Journal of Human-Computer Studies* **64**(7): 599–610.

Mora, N., Caballe, S., Daradoumis, T. and Ganan, D. (2012). Towards a multi-fold assessment approach to enrich the virtualization of collaborative learning, *6th International Conference on Complex, Intelligent and Software Intensive Systems (CISIS), Palermo, Italy*, pp. 935–940.

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

Mosley, P. (2005). A taxonomy for learning object technology, *Journal of Computing Sciences in Colleges* **20**(3): 204–216.

Penichet, V.M.R., Lozano, M.D., Gallud, J.A. and Tesoriero, R. (2010). Requirement-based approach for groupware environments design, *Journal of Systems and Software* **83**(8): 1478–1488, DOI: 10.1016/j.jss.2010.03.029.

Petropoulakis, L. and Flood, F. (2007). Design and development of a general purpose collaborative environment, *International Journal of Computer Applications in Technology* **29**(1): 2–10, DOI: 10.1504/IJCAT.2007.014055.

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

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

Schmidt, D.C. (1995). Using design patterns to develop reusable object-oriented communication software, *Communications of the ACM* **38**(10): 65–74.

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

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

Wilson, R. (2004). The role of ontologies in teaching and learning, *TechWatch Reports*, TSW0402.

Zarraonandía, T., Dodero, J., Díaz, P. and Sarasa, A. (2004). Domain ontologies integration into the learning objects annotation process, *Proceedings of the Workshop on Applications of Semantic Web Technologies for e-Learning*, Maceió-Alagoas, Brazil, pp. 35–40.

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

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