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Studying the effectiveness of multi-user immersive environments for collaborative evaluation tasks

Carlos-Miguel Lorenzo*, Miguel Ángel Sicilia, Salvador Sánchez

Alcala University, Spain

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ABSTRACT

Massively Multiuser On-line Learning (MMOL) Platforms, often called "virtual learning worlds", constitute a still unexplored context for communication-enhanced learning, where synchronous communication skills in an explicit social setting enhance the potential of effective collaboration. In this paper, we report on an experimental study of collaborative evaluation in an MMOL setting with 21 graduate students enrolled in university courses in technology-mediated teaching and learning. This study was carried out using a prototype of a 3D MMOL platform built around an interactive space called "*MadriPolis*". This space was used to recreate an adequate scenario for a collaborative experience about Learning Object evaluation using the mainstream Learning Object Review Instrument (LORI), which is based on a Convergent Participation Model (CPM). The same experience was carried out using a conventional LCMS (Learning Content Management System) platform with the aim of contrasting the outcomes and interaction patterns in the two settings. This study makes use of Social Network Analysis (SNA) measures to describe the interactions between tutors and learners. By dwelling on the advantages of immersive environments, SNA indexes revealed that these interactions were rather dense and that student participation was rather broad-based in the case of the MMOL. The results suggest that MMOL platforms could be used in collaborative evaluation tasks as a means to enhance both tutor interaction patterns and the strength of the group's relationship.

1. Introduction

Different kinds of virtual environments are being increasingly used by universities and other institutions to enhance the learning experience of their students and staff (Menon, 2010). Collaborative Virtual Environments (CVEs) are nowadays a widespread collaboration and interaction platform for geographically dispersed participants. A CVE has been defined as follows:

> "A computer-based, distributed, virtual space or set of places. In such places, people can meet and interact with others, with agents or with virtual objects. CVEs might vary in their representational richness from 3D graphical spaces, 2.5D and 2D environments, to text-based environments. Access to CVEs is by no means limited to desktop devices, but might well include mobile or wearable devices, public kiosks, etc."(Snowdon, Churchill, & Munro, 2001).

Representational richness can also be extended to cover inputs such as sound and touch interfaces (Bailenson et al., 2008). Bowman proposes the term "Immersive Virtual Reality" (IVR), which can be defined as "complex technologies that replaced real-world sensory information with synthetic stimuli such as 3D visual imagery, specialized sound, and force or tactile feedback" (Bowman & McMahan, 2007). Among existing IVR, a category of virtual reality applications is designed for single user access which can be used in learning settings such as simulation or virtual experiences, as well as exploration of structures, spaces, buildings and other elements (Jackson & Fagan, 2000; Patel, Bailenson, Hack-Jung,Diankov, & Bajcsy, 2006). However, another category of systems is oriented to interaction inside groups of users, leading to immersive multi-user virtual environments that not only enable a perception of virtual presence resembling the real world but

* Corresponding author. Alcala University, Computer Science – Languages Department, Ctra. Madrid-Barcelona Km 33,600, E-28871 Alcala de Henares, Madrid, Spain. Tel.: +34 649585869.
E-mail addresses: carlosmlb@gmail.com, cm.lorenzo@uah.es (C.-M. Lorenzo), msicilia@uah.es (M. Ángel Sicilia), salvador.sanchez@uah.es (S. Sánchez).

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also supports collaborative activities through a number of tools. Virtual worlds can be viewed as a concept closely related to this one (Hendaoui, Limayem, & Thompson, 2008; Livingstone, Kemp, & Edgar, 2008). Unlike immersive multi-user virtual environments, virtual worlds are not only characterized by immersion and a feeling of presence and social interaction, but also by a long-lasting online environment where a large population of users can interact over time, with no time constraints. Recent examples of these environments or Virtual 3D Worlds (V3DW) are built on 3D models and enhanced 3D graphic and audio world presentations, but the human interaction "inside the world" is mainly restricted to a 2D computer screen, stereo sound, keyboard and mouse. This interface and user context is known as 2.5D. Such settings are viewed as not entirely immersive but are closer to technology that is mainstream in the consumer market (such as 3D displays, 3D video consoles or 3D Blu-Rays), and it is likely that such technology, together with improved interfaces, will soon overcome those restrictions (Kappe & Gütl, 2009; Schroeder, 2008; Sivan, 2008).

This is the perspective from which we consider Massively Multiuser On-line Learning (MMOL) platforms: immersive contexts including both a multi-user environment and a rich interface to combine real and virtual reality. However, it is important to bear in mind that we shall study MMOL platforms from an educational perspective which should always have a clear educational purpose. Therefore, for the purpose of this paper we will consider MMOL platforms as mixed reality environments constructed over virtual world servers that provide an interactive learning space by means of 2D, 2.5D or 3D technologies to build and manage collaborative and ongoing online learning environments in which individuals participate using a real or a figurative presence (avatar) (Lorenzo, 2010). The main differences between MMOL platforms and V3DW or immersive multi-user virtual environments are the following: a clear educational purpose, the integration of learning technologies/functions according to a convergent view, and the integration of the "real life learning experience" in the virtual environment (mixed reality environments).

MMOL platforms provide educators and students with the ability to connect and integrate all technologies and pedagogical principles in a way may potentially enhance the learning experience. Thus, the teacher could make use of a rich context to interact and collaborate with the students in a synchronous mode. The synchronous capabilities of MMOL platforms allow for a redefinition of the traditional teacher's role.

On the whole current e-learning approaches are based on the use of LCMSs and mainly rely on communication in asynchronous mode, using tools like forums, e-mail, HTML documents, blogs or webQuests. The collaborative aspects of virtual learning environments engage students in on-line dialog and discussion that is open-minded and cooperative in contrast to off-line debate, which is often narrow-minded and competitive. When used as learning platforms, virtual learning environments enforce student participation in a real immersive context, enabling learners to take a more active role in their learning. Moreover, MMOL platforms afford the means to take advantage of the pedagogical opportunities offered by V3DW or immersive multi-user virtual environments. In order to leverage the combination of communication tools, sense of immersion and opportunities for collaboration described above, social constructivist theories would seem to be the most appropriate (Girvan & Savage, 2010). However, 3D settings are assumed to bring about new possibilities but also new challenges when used as learning environments for online education (Petrakou, 2010). Their most significant contribution is the possibility of building active and realistic knowledge networks between real and figurative persons (avatars) around the world in a multi-user and mixed reality learning context which brings MMOL platforms to a realization of an environment supporting connectivism theory (Siemens, 2008). Additionally, they can provide exploratory learning, role-play simulations and diverse types of scaffolding to accommodate individual cognitive differences, cases in point being Situated Learning (Lave & Wenger, 1991) and Problem-Based Learning based on the educational theories of Vygotsky (Barrell, 1999). Therefore, the pedagogical framework of this new virtual context is based on the broad principles through which these theories are applied specifically to teaching practice. One benchmark is the Four Dimensional Framework – 4DF (De Freitas & Oliver, 2006) that provides a conceptual structure for understanding immersive learning, and has implications upon learning design as a whole.

This paper reports the outcome of a study of MMOL platforms for the specific task of collaborative evaluation. That kind of evaluative task is common in social learning theories in general, and can be applied to a wide range of situations. In our study, we focus on the evaluation of learning objects by means of mainstream evaluation instruments and methods. The approach to the evaluation is based on contrasting the evaluation task in two settings: the MMOL setting and a conventional setting using an LCMS and asynchronous interaction. Provided that the MMOL setting was hypothesized to achieve a better collaborative experience, the assessment employed Social Network Analysis (SNA) techniques to analyze the interaction patterns.

The rest of this paper is organized as follows. Section 2 outlines the main characteristics and functionalities of MMOL platforms that are relevant to the study presented here. Section 3 surveys related work done to date regarding the use of virtual learning environments. Section 4 presents the objectives and setting for the experiences conducted. Section 5 sets out the two case studies of learning experiences used to obtain significant data collections. Section 6 presents and evaluates the data and results from the case studies. Finally, in Section 7 some conclusions are drawn and indications given for future lines of research.

2. Background on MMOL platforms

A generic conceptual architecture of MMOL platforms is depicted in Fig. 1 which conceptualizes an MMOL platform from the perspectives of virtual/real participation on the one hand, and pedagogy on the other. As far as user participation is concerned, the access mode could be full immersive, 3D or 2.5D. The pedagogical framework is based on the use of collaborative and management tools like virtual world servers, collaboration and user profiling tools, storyboard kits and guides. The MMOL platform must be integrated with external services like WebDav, conventional LCMSs, repositories or 3D content creation suites.

Open virtual world servers and optimal render engines are the bedrock of MMOL platforms and, more particularly, the framework for virtual and inter-reality experiences. The server's functionalities need to be adapted in order to construct new convergent learning context. Anyway, one of the critical aspects of expanding the use of virtual worlds is their interoperability capabilities and subsequent, the possibilities they allow for analyzing data represented using common schemas (Lorenzo, 2011). Prominent examples of these virtual servers are:

- *OpenSim* (*http://opensimulator.org/*). The OpenSimulator project is a virtual world server for creating 3D virtual environments. It has been described as a reverse engineered Second Life that allows users to run their own Second Life Island on their own computer, and it is even possible to move objects between OpenSim and Second Life. OpenSim can be run as a standalone application or as a virtual world network in grid mode. Written in C# over .NET framework or MONO Project, it is modular, allowing developers to augment it with new functionalities via plug-in modules (similar to Apache web server). It is a real alternative to Second Life (SL) without a "darker side" (Berge, 2008b).

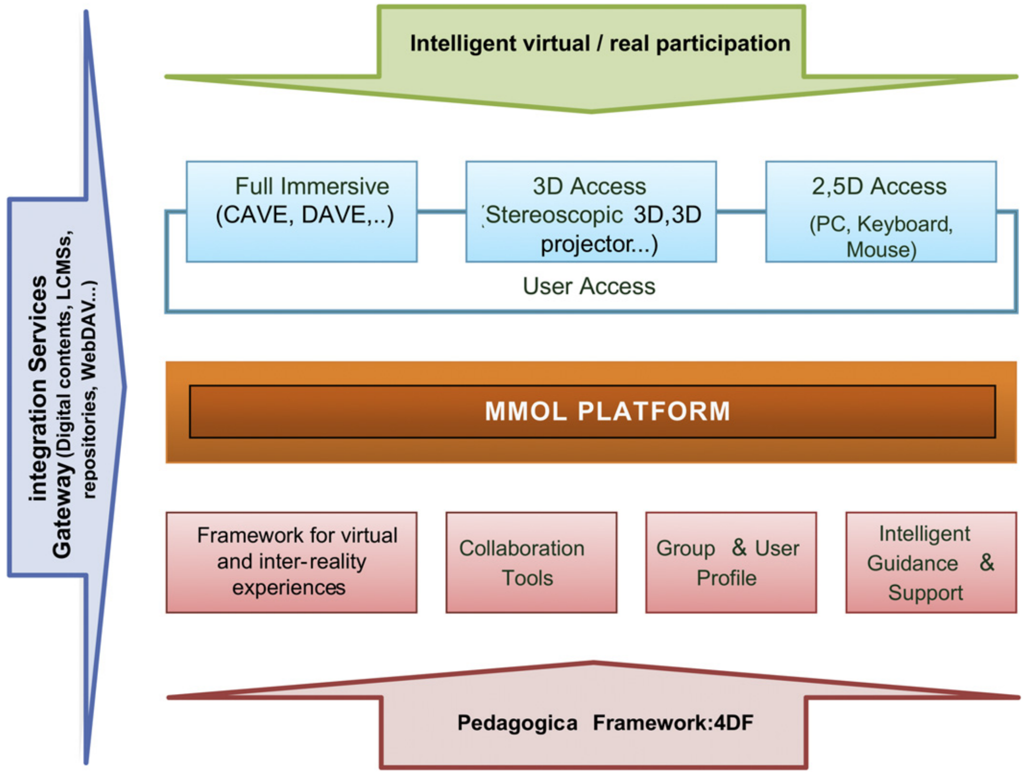

Fig. 1. A generic MMOL platform architecture.

- *Croquet* (*http://www.opencroquet.org*). Croquet is an open source software development environment for creating and deploying deeply collaborative multi-user online applications on multiple operating systems and devices. Developed from Squeak, it features a peer-based network architecture that supports communication, collaboration, resource sharing, and synchronous computation between multiple users on multiple devices. Using Croquet, software developers can create and link powerful and highly collaborative cross-platform multi-user 2D and 3D applications and simulations – thus enabling the distributed deployment of very large scale, richly featured and interlinked virtual environments.
- *Open Wonderland* (*http://openwonderland.org/*). Project Wonderland, based on Sun Microsystem's Darkstar render technology, is a Java virtual world toolkit for creating collaborative experiences. The main strengths of the project, as with many social worlds, have to do with collaboration and information representation through the use of stereo audio, shared applications and video streaming. The project is open source, so developers and graphic artists can extend it with new functionalities in order to create entire new worlds, new features in existing worlds, or new behaviors for objects and avatars.
- *realXtend* (*http://www.realxtend.org*). realXtend is a free open project that extends the feature set of OpenSim in order to support normal 3D meshes, Python and JavaScript languages which have not been available in OpenSim. realXtend could be used as the basis for creating impressive, entertaining, educational and functionally diverse virtual environments and multiplayer 3D games. It includes a robust server (Taiga) and a new browser totally independent of the Second Life viewer (Naali). Furthermore, the server allows integration with useful services, like OpenID authentication, WebDAV inventory, HTTP assets and so on, and supports the Ogre3D rendering engine. The viewer provides anaglyphic stereoscopic and CAVE rendering.

However, technology is not enough to build a virtual learning world. The appropriate educational context includes the following: a framework for virtual and inter-reality experiences, collaboration tools, group and user profile and support. Therefore, MMOL platforms need to include:

- 3D development tools for building realistic scenarios and simulations.
- Script languages to manipulate the behavior and aspect of the in-world object and bots.
- A rendering engine for serious games.
- Toolboxes to describe sessions' storyboard.
- Services to integrate mirror worlds.
- Management tools to manage courses, students, teachers, etc.
- Toolkits to build software augmented reality systems.
- Synchronous communication tools such as live chat, videoconferencing.
- Co-browsing displays.
- Logical interfaces with haptic devices.
- Web Services like LDAP, WebDAV and LCMS integration.

3. Related work

Despite the great diversity of educational designs and the impressive examples of the technological possibilities of virtual learning worlds, academic discussions of collaborative evaluation and their results are still few and far between in the literature. The focus of many studies about virtual learning worlds seems to be the creativity of the learning design in particular scenarios or topics. For example, Mzoughi et al. have applied virtual learning worlds to teaching and learning optics (Mzoughi, Davis, Foley, Morris, & Gilbert, 2007). Merchant has discussed how these technologies can be used to enhance literacy teaching (Merchant, 2010). Wojciechowski et al. have proposed a virtual and augmented reality system for informal education, like museums (Wojciechowski, Walczak, White, & Cellary, 2004). The armed forces, industry, medicine, commerce, organizational governance, design, political science, architecture and libraries are other areas where virtual world teaching can substitute in-the-field experiences (Bouras & Tsiatsos, 2006; Bray & Konsynski, 2007; Brenton et al., 2007; Clarke, 2012; Gerald & Antonacci, 2009; Hewitt, Spencer, Mirliss, & Twal, 2009; Rose et al., 2000; Smith, 2010; Wilson, 2008).

Some authors have provided immersive learning experiences for understanding concepts, exploring and learning, as well as socializing or playing serious games (Bailenson et al., 2008; Jacobson, Kim, Miao, Shen, & Chavez, 2010; Minocha & Reeves, 2010; Petrakou, 2010; Robbins & Butler, 2009; Schrank, 2009; Susaeta et al., 2010). Several others have reconsidered how we learn in these new contexts (Bers & Chau, 2010; De Freitas & Neumann, 2009; De Freitas, Rebolledo-Méndez, Liarokapis, Magoulas, & Poulovassilis, 2010; Girvan & Savage, 2010; Kartiko, Kavakli, & Cheng, 2010; O'Connor, 2010; Wrzesien & Alcañiz, 2010). Other researchers had pointed out instructors' roles and described how they change in the transition from in-person classrooms to teaching online and, in particular, to virtual learning environments (Berge, 2008a). Bronack et al. have examined the tutor's role as a member of a community of practice in which everyone is a potential instructor (Bronack et al., 2008). Lorenzo et al. have analyzed how MMOL platforms can improve teacher skills in areas like cultural diversity, values education and attention to diversity (Lorenzo, Padrino, Sicilia, & Sánchez, 2011). Livingstone has discussed the benefits of integrated collaborative virtual environments for teaching and learning (Livingstone et al., 2008). In a similar direction, Livingstone & Kemp have investigated the use of Massively Multiplayer Online (MMO) games as a learning tool in a traditional college setting (Livingstone & Kemp, 2006). De Freitas has studied virtual worlds as more complex social environments where the tutor's challenges rest with the design and delivery of immersive activities and experiences (De Freitas et al., 2010). Dickey has concluded that these virtual contexts have considerable potential for facilitating collaborations, community and experimental learning (Dickey, 2005). However, in spite of the increasing number of reports available, the use of virtual learning worlds for a specific cooperative task like collaborative evaluation has still not been studied from a comparative perspective.

Nonetheless, some of the abovementioned studies provide the basic grounding for the research presented here. To be more precise, we have summarized the main design and assessment departure points in the following list of aspects enabled by MMOL platforms:

- *Reducing barriers* between students, tutors and instructors (Kemp & Livingstone, 2006)
- *Facilitating collaboration* on 3D artifacts or other content becomes increasingly important in modern working and learning processes (Kemp & Livingstone, 2006)
- *Belonging to a community* creates a virtual social space and can positively impact learning outcomes (De Lucia, Francese, Passero, & Tortora, 2008)
- *Presence* (feeling part of the virtual environment) can effect suspension of disbelief and increase motivation and productivity (Bouras & Tsiatsos, 2006)
- *Interacting asynchronously*. The MMOL platforms allow students to view and access the educational resources; also LCMS when the synchronous time is not necessary (Petrakou, 2010)
- *Multiple communication channels* both verbal and non-verbal communication can increase social awareness and improve knowledge transfer and understanding (De Lucia et al., 2008; So & Brush, 2006)
- *Awareness* of other avatars and other real persons, of the environment and of activities impacts the dynamic of group communication (Bouras & Tsiatsos, 2006)

4. Resources and settings

The mainfocus of our study is the analysis of collaborative contexts in a technology-enhanced immersive learning context, like that provided by MMOL platforms. More particularly, we analyze tutor and learner interaction patterns with the aid of a comparative case study. The aim of this paper is therefore to explore how a specific MMOL platform can facilitate tutor and learner collaborations in a rich virtual learning environment. The educational framework of Sara de Freitas (De Freitas & Oliver, 2006) is our point of departure. The empirical findings are obtained from a case study carried out separately in two platforms, MMOL and LCMS, which in both cases were prepared to recreate an adequate scenario for simulated collaborative evaluations of Learning Objects. The results of these experiences were analyzed using Social Network Analysis (SNA) techniques with a view to evaluating the improvement in the density and centralization indexes in terms of socio-centric networks when using MMOL platform as against conventional 2D LCMSs like BlackBoard, WebCT or Moodle. To examine these hypotheses, a learning experience about Leaning Object (LO) evaluation based on LORI (Learning Object Review Instrument) and CPM (Convergent Participation Model) (Vargo, Nesbit, Belfer, & Archambault, 2003) was set up by deploying realXtend configured specifically for the task.

4.1. Overall description of the settings

The study presented here contrasts an MMOL with a conventional LMS in relation to the task of collaborative evaluation. The rest of this section describes the configuration and design of the two virtual spaces contrasted. In both cases, the purpose of the activity is the same: to perform a collaborative evaluation.

"The process consists of two key components: the Learning Object Review Instrument (LORI) that an individual evaluator can use to rate and comment on the quality of a learning object, and the Convergent Participation Model that brings together a team of evaluators and their individual reviews to create and publish a collaborative LORI review" (Vargo et al., 2003). In its capacity of a learning objects evaluation tool, LORI allows reviewers to rate and comment on nine items (version 1.5): content quality, learning goal alignment, feedback and adaptation, motivation, presentation design, interaction usability, accessibility, reusability and standards compliance. "Convergent Participation is a two-cycle model designed to boost the efficiency and effectiveness of collaborative evaluation. In the first cycle, participants with diverse and complementary areas of expertise individually review a set of learning objects using LORI. The first cycle is completed asynchronously within a period of few days. In the second cycle, the participants come together in a moderated discussion using a synchronous conferencing system. During the discussion, participants adjust their individual evaluation in response to the arguments presented by others. At the end of the meeting, the moderator seeks consent of the participants to publish a team review synthesized from the mean ratings and aggregated comments" (Vargo et al., 2003). We adapted the second cycle to our case studies.

4.2. MMOL setting

4.2.1. The educational framework

In order to create an adequate collaborative evaluation scenario in the MMOL platform we considered the 4DF (De Freitas & Oliver, 2006). The basic scaffold holds good in the four dimensions:

- The first dimension defines the context where learning is undertaken. This context includes the wider historical context as well as the specific learning context.
- The second dimension involves the learner specification or group learner specification: learner profile, pathways or learning background.
- The third dimension focuses upon the internal representational world, how interactive the learning experience needs to be, what levels of fidelity are required, and how immersive the experience needs to be.
- The fourth dimension analyses the pedagogic aspects of the learning activities, and includes a consideration of the kinds of learning and teaching models adopted alongside the methods for supporting the learning processes (De Freitas & Neumann, 2009; De Freitas & Oliver, 2006; De Freitas et al., 2010).

The next table summarizes the 4DF in our MMOL experience (Table 1).

4.2.2. The educational scenario

The MMOL experience uses different pieces of software and dedicated hardware, and therefore needs a high level of technical support. The following setting list includes objects and services for adequate implementation of the internal representational world dimension of the MMOL experience:

- 2.5D access via realXtend viewer 0.42 release and Naali viewer 0.3.1 release.
- 3D access via stereo vision driver and 3D glasses with Naali viewer.
- Framework for virtual and inter-reality experiences constructed with a realXtend/Taiga server 0.2 rc1. The LORI evaluation was conducted within a virtual space named "*MadriPolis*". Figs. 2–5 show the building structure and the collaborative space of "*MadriPolis*".
- Collaboration Tools. In our experience we used the following collaboration tools: chat, voice chat and videoconferencing systems, whiteboard, shared desktop, shared presentation, Google documents and co-browsing tools. The co-browsing viewer (see Fig. 6), for instance, allowed joint navigation through the most relevant pages and contents of the LO under evaluation, while the voice chat allowed students to exchange ideas and opinions synchronously (Fig. 7).

Table 1
Using the 4DF to implement MMOL experience.

1D: Context	2D: Learner	3D: Representation	4D: Pedagogic considerations
On-line postgraduate courses/research about technology mediated learning and teaching.	Graduate students.	MMOL experience uses a medium level of fidelity based upon the use of 2D, 2.5D and 3D animated avatars, bots and contents (see setting list below).	Learning outcomes from this experience would support increased empathy with others and tutor's roll.
Virtual learning world-based.	The tool is used with groups of Masters students and researchers.	MMOL experience uses a high level of interactivity between the media world and the learners' own experiences and knowledge, allowing the student to develop increasing synchronous collaboration capabilities with well-known rules and functionality (see setting list below).	Learning activities for this experience focused upon playing as LORI reviewer and/or tutor coordinator. The student learns through activities based in synchronous role-playing
The experience supports the In-world Convergent Participation Model (Vargo et al., 2003).	The experience can only be carried out collaboratively as part of the pilot experiences. However the students can read and use several contents individually.	MMOL experience includes a high level of realism in terms of the classroom exercise where the participants behave as tutors and/or reviewers.	Briefing/debriefing should have been embedded into how the experience was performed and would have helped reinforce learning outcomes and add greater engagement to the process.
Interactions with virtual world and other participants.	The tool would potentially support a range of differentiated learners with different learning styles.		Simulation embedded as a practical session of the on-line tutor tasks and reviewer's roll.

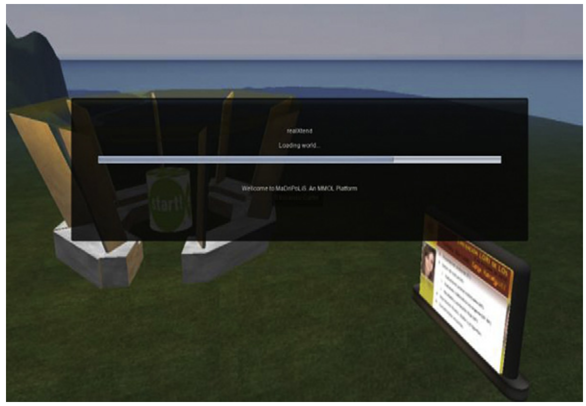

Fig. 2. MadriPolis in realXtend.

Fig. 3. MadriPolisevaluation meeting point.

Fig. 4. MadriPolis collaborative space I.

- Group and user profile. As a derivative of realXtend server, the MMOL platform provided us with two important functionalities: authentication server (keeps records of users and handles authentication) and avatar storage server that stores and delivers avatar data.
- Intelligent guidance. Students could use in-world panels and bots to complete their learning itinerary and read in-world the LORI manual and the Convergent Participation Model document.
- 2D Services Integration Gateway:
  a) Google document spread-sheet to calculate the average values of LORI items (See Fig. 8).
  b) Desktop shared tools to show application procedures.
  c) Co-browsing viewers to surf learning contents as a collaborative experience.
  d) YouTube in-world video browser.
  e) In-world interactive whiteboard.

Fig. 5. MadriPolis collaborative space II.

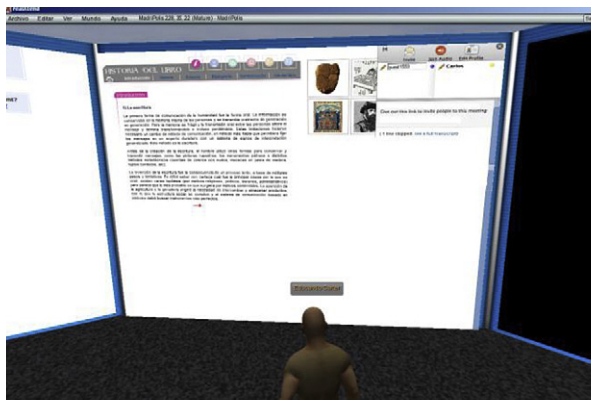

Fig. 6. Co-browsing viewer.

Fig. 7. Shared presentation.

Fig. 8. In-world Google document to determine average values of LORI items.

4.3. LCMS setting

4.3.1. The educational framework

The LCMS server selected was Moodle. This experience was also conducted with 4DF (Table 2).

4.3.2. The educational scenario

The next setting list includes the objects and services for an implementation of the educational scenario in the LCMS of the experience:

- Learning Objects collaborative evaluation course.
- LORI manual and CPM document.
- Link to the URL of the Learning Object under evaluation/to be evaluated.
- Individual participation discussion boards.
- Collaborative participation discussion boards.

The following Fig. 9 shows the 2D course structure and elements.

The LCMS platform has standard tools to facilitate asynchronous capabilities like blogs, discussion boards (forum), internal e-mail or wikis. In this context, the most useful on-line tutor functionality for providing an interactive venue where teachers and future teachers could reflect, evaluate, solve problems or exchange ideas (Pawan, Paulus, Yalcin, & Chang, 2003) is the collaborative discussion boards.

5. Methods and tasks

Case studies provide an opportunity for in-depth exploration of a specific learning activity in action (Stake, 1995). Adopting triangulation and a multiple-case study approach (Stake, 2006) may provide an adequate research strategy for addressing the potential impact of MMOL platform on training future on-line trainers and tutors. We chose two significant cases, each one with two experiences conducted in two different learning platforms: 2D vs. 3D. Both cases consisted of a collaborative Learning Object evaluation based on Learning Object Review Instrument (LORI) with the Convergent Participation Model (CPM) to determine the quality of e-learning resources. The Learning Object evaluated was the same regardless of the platform (MMOL or Moodle), namely a website on the history of books called "Historia del libro" (http://www.ite.educacion.es/w3/novedades/dossiers/libro/) (Fig. 10).

5.1. Case "A"

Case "A" included students enrolled in a Master Degree Program about technology-mediated learning and teaching at the University of Alcala during spring 2010. To date, this Master's has been taken by over 100 students from Spain and Latin America. It is a two year on-line

Table 2
Using the 4DF to implement MMOL experience.

1D: Context	2D: Learner	3D: Representation	4D: Pedagogic considerations
On-line postgraduate courses/research about technology-mediated learning and teaching.	Graduate students.	MMOL experience uses a low level of fidelity based upon the use of 2D interface and contents (see setting list below).	Learning outcomes from this experience would support increased empathy with others and tutor's role.
LCMS (Moodle) – based.	The LCMS is used with groups of Masters students and researchers.	LCMS experience uses a medium level of interactivity between the on-line course and the learners' own experiences and knowledge. The participants could only hold off-line debates (see setting list below).	Learning activities for this experience focused upon playing as LORI reviewer and/or tutor coordinator. The student learns through activities based on asynchronous role-playing.
The experience supports an adaptation of Convergent Participation Model (Vargo et al., 2003) adapted to LCMS communication tools.	The experience can only be carried out as a group activity, but the discussions are always off-line.	LCMS experience includes a medium level of realism in terms of the classroom exercise where the participants behave as tutors and/or reviewers.	Briefing/debriefing should have been embedded into how the experience was performed and would have helped reinforce learning outcomes and add engagement to the process.
Asynchronous interactions with LCMS and other participants.	The tool potentially would support a range of differentiated learners with different learning styles.		Simulation embedded as a practical session of the on-line tutor tasks and reviewer's role.

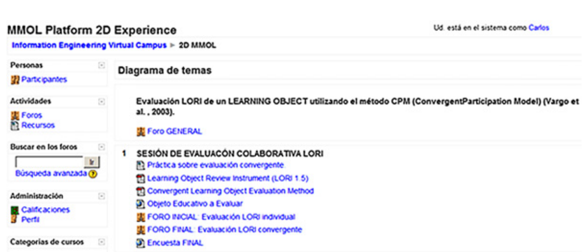

Fig. 9. Course over LCMS.

Fig. 10. Evaluated learning object.

program with no face-to-face contact except for an initial presentation intended to help students become familiar with the use of the platform. This study focuses on eleven part-time, second-year mature students who participated in both experiences: LCMS and MMOL. Students were under no obligation to take part in the study, but once they expressed their interest, an analysis of their skills was carried out to determine homogeneous interaction patterns between members. As the experiences went on, efforts were made to ensure that the students had the same perceptions and ideas of LORI and Convergent Participation Model. The research used online surveys, log events, direct observations and triangulation to collect data analyzed with SNA. The first experience was with the LCMS Platform, the second with the MMOL platform.

As far as the LCMS was concerned, the students possessed good knowledge of Moodle as regular advanced users of this tool. The learning experience was devised to produce structured asynchronous activities which functioned as LORI collaborative evaluation conducted by an elected on-line tutor. The students were free to choose their role: reviewer alone or on-line tutor and reviewer. Three students chose to be on-line tutor. To create similar opportunities for tutor election the students had a prior forum presentation. The elected tutor guided the evaluation experience for one week. The learning activity design included the elements related above.

The experience began with an introduction to the activity in a forum post, where the tutor introduced the most relevant aspects, presented the timetable and answered questions from the learners. This was followed by other forum posts explaining the collaborative evaluation procedure and the beginning of the experience. For two days the students were sent to the specific discussion forums their individual LORI item valuations. After that and for another two days each student commented and reviewed the evaluation of the other classmates. Discussions between participants were moderated and conducted by the on-line tutor in order to unify their arguments (Convergent Participation Model).

The experience concluded with a last forum post published by the tutor with the final LORI item valuations accepted by the group. At the beginning and the end of the experience individual learners were asked to complete an online survey. The interactions between participants were registered in a log events file.

As far as the MMOL platform was concerned, the participants had no previous experience, but most had an acceptable knowledge of video-gaming and other similar 2.5D environments. For this reason, they were only given a 90-min initial session to learn about the realXtend viewer functionalities and interface. This session was also used for their in-world presentation to the group. After two days the students were called to a second 90-min meeting conducted by the elected on-line tutor. The storyboard of the session was an introduction to collaborative evaluation procedure (5 min), individual LO evaluation (20 min), collaborative LO evaluation (30 min), Convergent Participation Model (20 min), general acceptance (10 min) and any other business (5 min). The learning design of this meeting included the elements and resources related above, for example: live chat, co-browsing viewer, in-world shared spread-sheet, in-world shared presentation, etc. As in the previous experience, at the beginning and end of the meeting individual learners were asked to answer an online survey. The interactions between participants were registered in a log events file.

5.2. Case "B"

This case included ten student research assistants enrolled in the Information Engineering Research Unit of the University of Alcala (http://www.ieru.org/) and was carried out in fall 2010. IE is a research group in the Computer Science Department that has extensive expertise in the areas of learning technology (IMS-LD, SCORM), implementation of learning technology interfaces (OKI), semantic Web using ontology languages like OWL or WSML, data mining (Weka) and social network analysis methods and tools (especially Pajek). The voluntary participants were all over 18 years old and shared similar characteristics and knowledge as in Case "A". As there, they became involved in both experiences: LCMS and MMOL. As there too, in the course of the research experiences efforts were made to ensure that the volunteers had the same perceptions and ideas about the collaborative evaluation task. The research used online surveys, log events, direct observations and triangulation to collect data analyzed with SNA. The group of participants was studied previously in order to determine homogenous interaction patterns between members. In this case the order of experiences was altered: now the first experience was with the MMOL platform, the second with the LCMS Platform. This time, the preparatory session about the MMOL platform also helped us to elect the on-line tutor from among participants after their in-world presentation to the group. The participating students explained their on-line tutor skills with the aid of shared in-world presentations. Two learners chose to be on-line tutor and finally one of them was elected by a show of hands. Otherwise both experiences were carried out with the same characteristics, storyboards, elements and times as in the

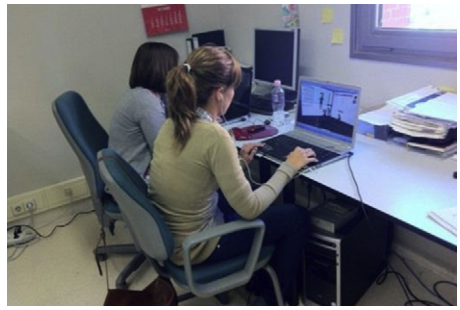

Fig. 11. Researchers participating in the MMOL platform experience.

previous case. The initial surveys of both experiences allowed us to conclude that all volunteers were advanced users of Moodle and that none had experience in MMOL platforms (Fig. 11).

6. Results and discussion

Studying and evaluating real experiences that promote active and immersive education learning is a crucial issue in distance learning. MMOL platforms have introduced new challenges to evaluation, some of which are related to synchronous and asynchronous learner interactions. In the case of the experiences reported in this paper, the evaluation is especially complex because we try to compare two different environments: LCMS vs. MMOL platforms. In order to obtain significant and meaningful results, the method proposed in this section aims to yield a mixed evaluation combining on-line surveys (Appendix A), log events and direct observations with data analysis and social network analysis in a holistic interpretative approach. Fig. 12 represents this evaluation method.

SNA techniques allowed us to study how learners participate and interact with each other and, more particularly, student–tutor interactions. This in turn provides information about the activities of such a community and the way they learn collaboratively. The two platforms selected generate log-files from which information about member activity can be obtained. The in-world/out-world direct participants' observations complete the sources for data collection and permit the values of the surveys to be confirmed or disconfirmed. The information retrieved from platforms, survey responses and direct observations can be treated as relational data and stored away in a case-by-case matrix to analyze interaction patterns and the strength of the relations (Scott, 1991). These relations were considered directed and values. The case-by-case matrix values were adjusted with a triangulation technique that facilitates data validation through cross verification from different sources. For this purpose we focused on the cohesion of the network (Wasserman & Faust, 1997) based on messages or dialogs interchanged between participants, the personal perception of relationships with others, and direct observations. As the emphasis should be on the responsive nature of the communication, we focused on analyzing structures of responsiveness relations between participants (Aviv, Erlich, Ravid, & Geva, 2003).

The first indication of network cohesion is *density*. Density describes the general level of linkage among the nodes in a network. The density of a network is defined as the number of arcs in a network divided by the maximum number of all possible arcs (Scott, 1991). The density is at a maximum when all the nodes are connected to each other.

Another relevant network cohesion feature is *centrality*, the identification of the central participants within the network, i.e., the structural importance of a node. In our study it was very important to determine the position of the on-line tutor in the collaborative evaluation process. For each participant this was done using both Freeman's degree and betweenness. Freeman's degree measures the network activity of the participants, that is, the proportion of all the others with whom they communicate. Since we know the nature of the

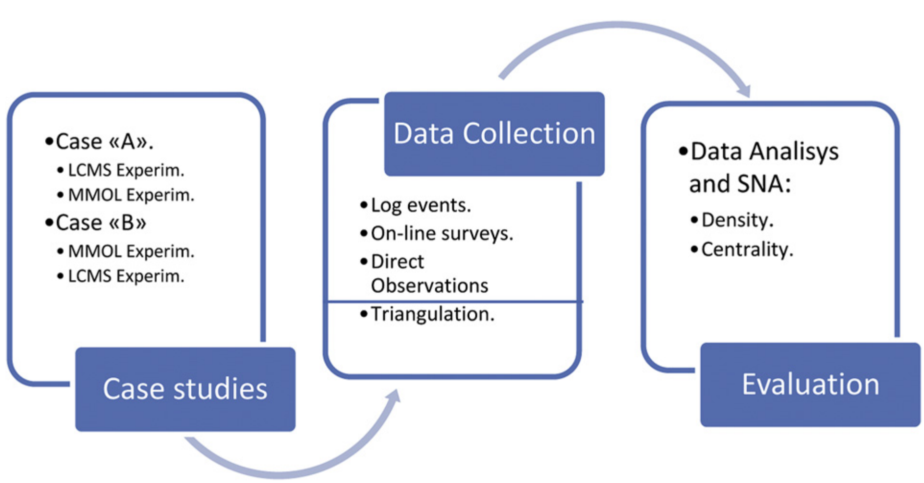

Fig. 12. Evaluation method.

relationship between the participants, i.e., who interacts with whom, the directed arcs specify the orientation of the relationship. This question is of especial interest for the centrality measures as well as for the creation of the sociograms. In a directed case-by-case matrix, a participant can be either adjacent to or adjacent from another node depending on the direction of the arc (Wasserman & Faust, 1997). This means that we can consider these cases separately by differentiating the in-degree and out-degree centrality measures. In-degree centrality is a form of centrality that counts only those relations with a focal individual reported by other group members, and is therefore not based on self-reports unlike out-degree centrality. In our study, in-degree measures provided information about how others assess relationships with a certain participant. Out-degree centrality gives an indication of how a person values their relationship with other individual members of a network. Both measures range between 1 (minimum) and 5 (maximum). These data were contrasted with data collected from other sources. Freeman's betweenness value shows how often a given participant is found in the shortest path between two other participants, this betweenness therefore telling us about the participant's possibility of regulating information flow within the community (Wasserman & Faust, 1997). A participant in such a position in the network is called a broker or a gatekeeper. High betweenness values indicate the extent to which a participant could play the role of a broker or gatekeeper.

6.1. Results

Data analysis and social network analysis were carried out with the aid of UCINET (Borgatti, Everett, & Freeman, 2002). The first measure is density. The density values of Case "A" and Case "B" with the LCMS and MMOL platforms experiences show the overall connection between the participants (results shown in Table 3).

There seems to be a clear difference between the MMOL and LCMS experiences. First of all, the density values of MMOL are higher, indicating that the participants have more connections amongst themselves. Secondly, the density values of both experiences remain stable throughout the two case studies, while the average values rise from 34.56% to 51.27%, indicating that the number of connections between the participants increases when the MMOL platforms are used. Similar results for the LCMS experience have been found by other researchers studying network learning with groups of similar size and in asynchronous learning settings (Aviv et al., 2003; De Laat, 2002; De Laat, Lally, Lipponen, & Simons, 2007; Martínez, Dimitriadis, Gómez, Rubia, & de la Fuente, 2003; Reffay & Chanier, 2003).

To calculate centrality, in-degree and out-degree centrality values need to be obtained for each student (see Table 3–6) first. These indexes emerged from discussion or dialog threads in both platforms and responses to the on-line surveys, and from direct observations for each case and experience. The results yield the visual representation of the learning network (see Fig. 13a–d). Also, in the MMOL platforms we considered the observed gestural postures, gazes and movements. Thus, for instance, in Case "A" student number 1 (elected tutor) was the participant with greater activity in both experiences: 26 messages sent in the LCMS and 35 dialogs, gazes or gestural postures in the MMOL platform. As for in-degree index, this student was not the most significant participant in LCMS experience, although he was the highest valued by peers in the MMOL experience. Student 1 assessed contacts with others in both experiences as follow:

The other participants assessed their relationships with Student 1 in both experiences as follows:

The tables above provide a rapid impression of how the tutors are situated with respect to the relationships with learners. In the MMOL experiences, the tutors have the maximum values of in-degree and out-degree indexes in both cases, as can be seen in the respective columns of Tables 6 and 7. All data indicate a significant enhancement in quality relationships between group members (in particular with

Table 3
Density values of case studies. The last column shows the density increase trend when MMOL is used.

Density	LCMS experience (X)	MMOL experience (Y)	Difference: (Y − X)
Case "A"	0.3691	0.5182	0.1491
Case "B"	0.3222	0.5073	0.1851
Average	0.3456	0.5127	0.1671

Table 4
St A1's contacts with other participants.

	St A2[a]	St A3	St A4	St A5	St A6	St A7	St A8	St A9	St A10	St A11
LCMS	2	3	3	4	2	2	2	2	3	3
MMOL	5	2	3	4	2	2	3	3	4	3

[a] Here and throughout this paper the participants' name has been substituted by the abbreviation "St", the case letter and a number.

Table 5
Other participants' contacts with St A1.

	LCMS	MMOL
St A2	2	3
St A3	2	4
St A4	2	4
St A5	3	4
St A6	3	4
St A7	3	4
St A8	4	4
St A9	3	3
St A10	2	5
St A11	2	4

Table 6
In-degree and out-degree for all participants in Case "A" and both experiences.[a]

CASE "A"											
	St A1[2]	St A2	St A3	St A4	St A5	St A6	St A7	St A8	St A 9	St A10	St A11
LCMS Experience											
In-degree	26	19	24	22	23	18	29	19	17	21	25
Out-degree	26	20	20	21	24	21	22	22	22	21	22
MMOL Experience											
In-degree	39	23	27	28	27	22	31	32	29	31	30
Out-degree	31	29	26	27	29	28	29	30	29	27	29

Maximum
Minimum

[a] Underlining denotes elected on-line tutor in all tables and figures.

Table 7
In-degree and out-degree for all participants in Case "B" and both experiences.

CASE "B"										
	St B1	St B2	**St B3**	St B4	St B5	St B6	St B7	St B8	St B9	St B10
LCMS Experience										
In-degree	24	22	23	21	18	16	19	23	28	22
Out-degree	22	19	29	23	23	16	23	21	20	20
MMOL Experience										
In-degree	24	22	35	22	29	18	19	23	29	30
Out-degree	24	26	37	23	23	21	25	24	24	24

Maximum
Minimum

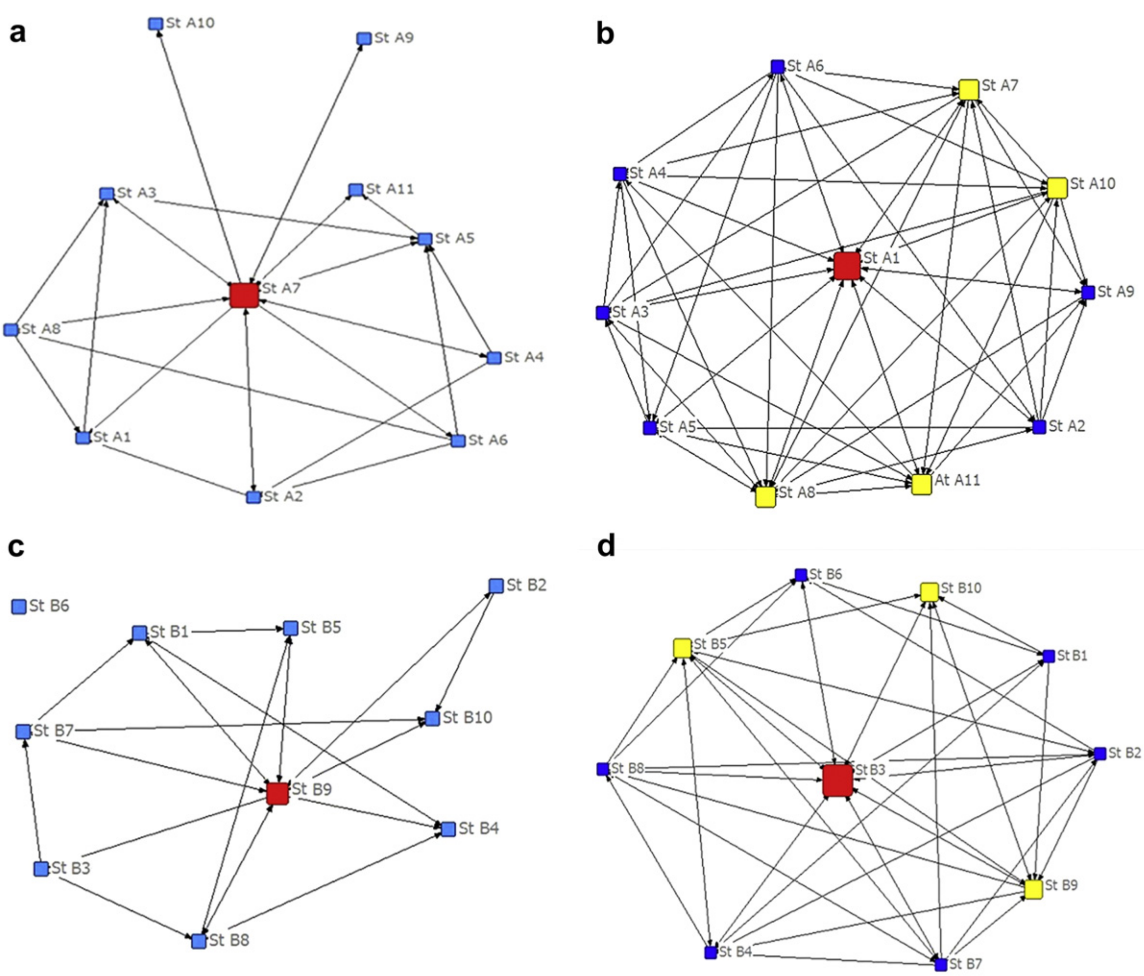

Fig. 13. (a) Distributed-fragmented e-learning structure. St A10 and St A9 are nodes with poor relationships. (b) A diamond shape denotes a distributed-coordinated e-learning structure. The red node represents the elected on-line tutor. Yellow nodes have high betweenness. (c) Distributed-fragmented e-learning structure. St B6 is totally disconnected. Blue nodes have poor relationships with others. (d) A diamond shape denotes a distributed-coordinated e-learning structure. The red node represents the elected on-line tutor. Yellow nodes have high betweenness. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the on-line tutor) when the MMOL platforms were used. To be more precise, in case "A" (first column of Table 6) the in-degree and out-degree increments are 13 units and 5 units respectively. In Case "B" (third column of Table 7), in-degree and out-degree increments are 12 units and 8 units respectively. The results seem to be consistent across the experiences, and the visual representation of the learning network shows how the on-line tutor is situated in the network in a central position (see Fig. 13a–d).

We use the terms "Distributed-fragmented e-learning structure" to label Fig. 13a and c (LCMS experience) because they show that some students became removed from many of the day-to-day workings of the group; this was the case of students A10, A9 and, worst of all, B6. Their lack of participation in the group resulted in disconnections which impacted the rest of the group. In contrast, Fig. 13b and d (MMOL experience), labeled "Distributed-coordinated e-learning structure", illustrate a denser grid topology in which everyone is connected to each other. This means that information interchanges are more effectively channeled and distributed within the group. In relation to Freeman's betweenness value, in all cases the tutor's betweenness value was higher than 23%, so the tutor was the participant with the best chance of regulating information flow within the community. As we said above, the MMOL tutor was the participant with most connections with peers. Other participants in the MMOL experience with a significant number of connections were A7, A8, A10, A11, B5, B9 and B10. Also, the tutor's node has the shortest distance paths between its vertex and all reachable vertexes. Therefore, in all cases the MMOL tutor is characterized by a high betweenness value, the shortest distance path with peers, the highest in-degree and out-degree index values, and the maximum number of connections, which means that this participant played the part of a broker, "hub" or leader.

The other participants' betweenness indexes show how the MMOL platforms supplied a more homogeneous social network where the actors were involved in a greater number of interchanges and peer interaction. In all cases we found more users' betweenness values to be above zero when we used the MMOL platform, to be more precise, 84% and 71% in Cases "A" and "B" respectively. In contrast, the LCMS Platform experiences gave an average value of 47%. Hence, using the MMOL platform meant that there were fewer isolated individuals and greater interaction between users, since there are more paths between nodes.

The results seem to be consistent with the survey responses (see Appendix A). As shown in Figs. 14 and 15, the participants thought that the MMOL experiences offered a rich context of multi-user interactions between peers and tutor, and that MMOL platforms were a useful tool for tutor's tasks and collaborative assignments like the Convergent Participation Model. Also, the participants rated the informal and formal learning in virtual world context as much more fun than 2D contexts.

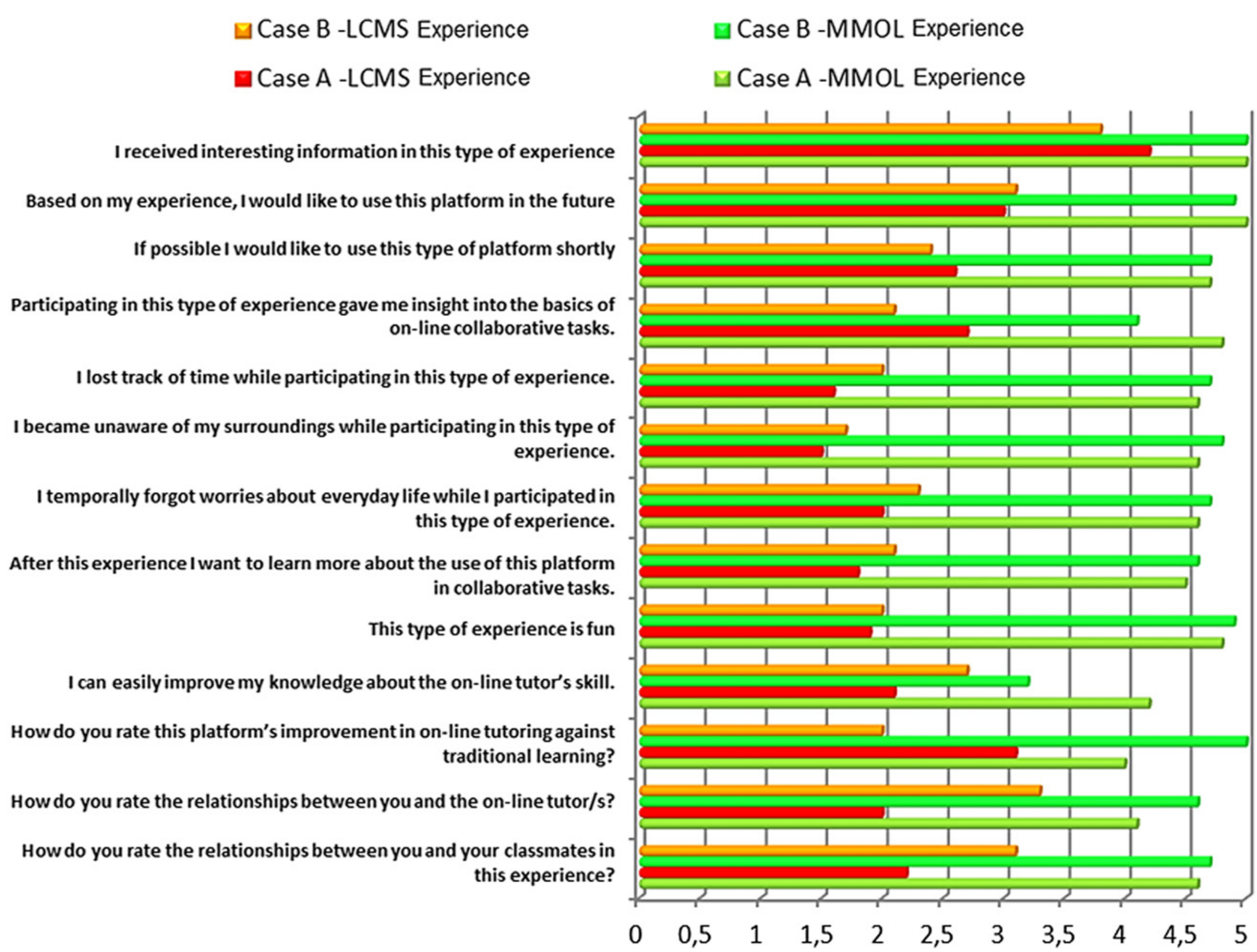

Fig. 14. Survey responses by case and experience.

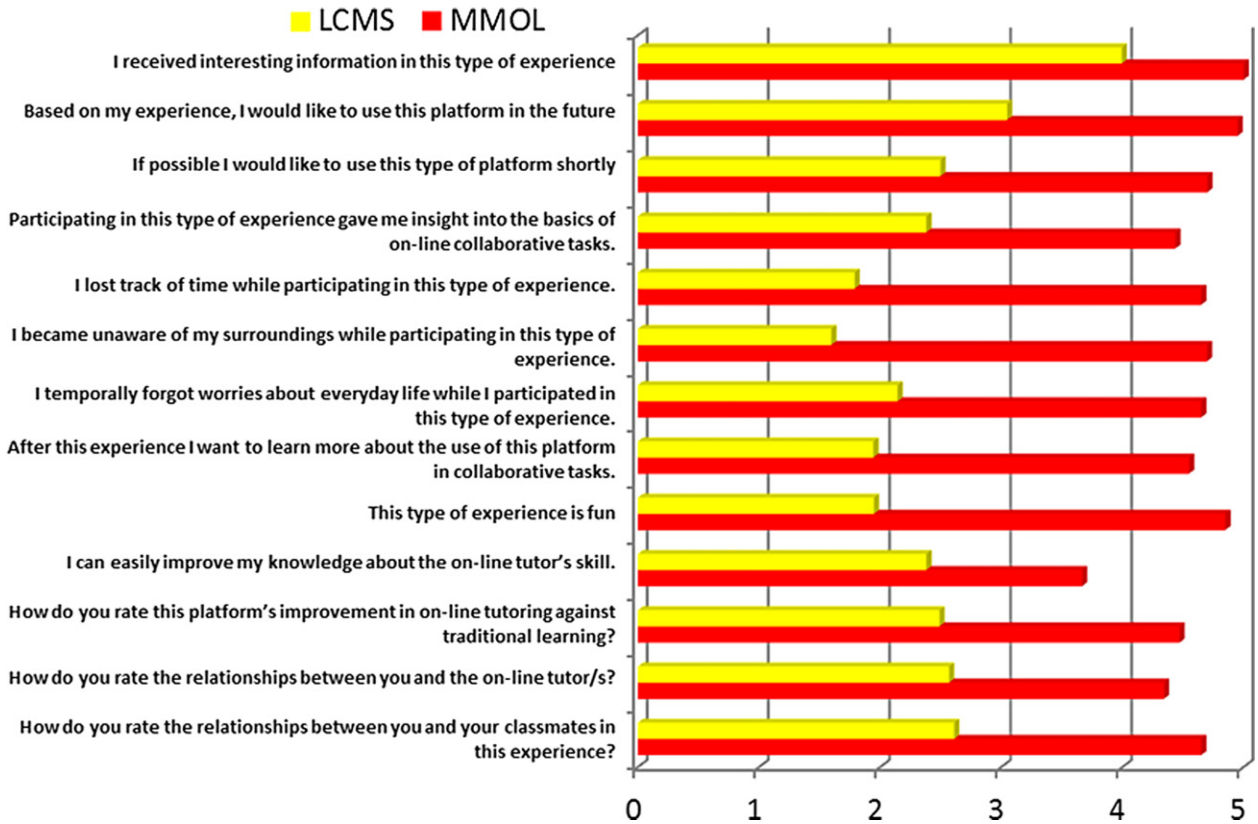

Fig. 15. Survey responses by experience.

7. Conclusions and future work

The collaborative evaluation of learning objects is an instance of a collaborative task. The findings from this study suggest that MMOL platforms can provide better support capabilities for barrier removal between students and between tutors and students. This new learning context provides an interactive learning space with the use of 3D, 2D or 2.5D technologies to build collaborative and ongoing online environments and classrooms in which individuals participate in a real or figurative presence (avatar). Measurements taken from social network analysis, surveys, logs and direct observations help identify tutors as the most prominent actor in these collaborative communities. They play a major role in team coordination, as well as management and information sharing. The interaction patterns among participants make evident more connections between all nodes. In a dense network, as is the case of the MMOL experiences, many participants have connections with each other, and members are likely to influence each other mutually. Knowledge, ideas, and advice are distributed among many participants with the help of a clear broker, "hub" or leader. We have found evidence confirming the hypothesis that MMOL platforms offer the chance for more intense participations among group members than traditional asynchronous settings based on conventional LCMSs. As far as the specific task evaluated is concerned, we can conclude that MMOL platforms appear to be more appropriate for putting into practice learning experiences like the Convergent Participation Model.

However, it is still necessary to consider how these possibilities depend on factors such as suitable training in the virtual context, the adoption of a correct pedagogical framework, and the use of an adequate virtual world server, 3D learning objects, scenarios and storyboards.

The findings derived from this study raise new questions and issues related to collaborative tasks in virtual learning worlds such as: What are the most appropriate learning patterns for MMOL contexts? What are the learner's or teacher's barriers to adopting these new contexts? Finally, how can the quality of 3D learning objects or MMOL platforms be evaluated?

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Appendix A

(We used this questionnaire in both experiences and cases)

Q1. I received interesting information about this type of experience.

Q2. Based on my experience, I would like to use this platform in the future

Q3. If possible I would like to use this type of platform shortly.

Q4. Participating in this type of experience gave me insights into the basics of on-line collaborative tasks

Q5. I lost track of time while participating in the experience.

Q6. I become unaware of my surroundings while participating in this type of experiences.

Q7. I temporally forgot worries about everyday life while I participated in this experience.

Q8. After this experience I want to learn more about the use of this platform in collaborative tasks.

Q9. This type of experience is fun.

Q10. I had fun during this experience.

Q11. I connected with these people...

Case "A"	☐St A1	☐St A2	☐St A3	☐St A4	☐St A5	☐St A6	☐St A7	☐St A8	☐St A 9	☐St A10	☐St A11
Case "B"	☐St B1	☐St B2	☐St B3	☐St B4	☐St B5	☐St B6	☐St B7	☐St B8	☐St B9	☐St B10	

Q12. How do you rate the relationship between you and your classmates in this experience?

Case "A"	St A1	St A2	St A3	St A4	St A5	St A6	St A7	St A8	St A 9	St A10	St A11
Value[1]											

Case "B"	St B1	St B2	St B3	St B4	St B5	St B6	St B7	St B8	St B 9	St B10
Value[1]										

(1) Likert scale ranged from 1 (minimum) –5 (maximum)

Q13. How do you rate the relationship between you and the online tutor/s?

Case "A"	On-line Tutor
Value[1]	

Case "B"	On-line Tutor
Value[1]	

(1) Likert scale ranged from 1 (minimum) –5 (maximum)

Q14. How do you rate this platform's improvement of on-line collaboration against traditional learning (face to face or similar)? (1)

(1) Likert scale ranged from 1 (minimum) –5 (maximum).

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