Operationalization of collaborative blended learning scripts: a model, computational mechanisms and experiments

Mar Pérez-Sanagustín

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Dr. Davinia Hernández-Leo & Prof. Dr. Josep Blat
Department of Information and Communication Technologies

UNIVERSITAT POMPEU FABRA

To my family, parents and sister.
To Uri.

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Abstract

Portable and interactive technologies are changing the nature of collaborative learning practices. Learning can now occur both in and beyond the classroom and furthermore combine formal and informal activities monitored and orchestrated across spatial locations. This rises to a new type of orchestrated learning that we term Computer Supported Collaborative Blended Learning (CSCBL) scripts. This thesis investigates the challenges associated with the design of CSCBL scripts and with the technologies responsible for their enactment. Three contributions are presented. First, a conceptual model that combines 4 factors to be considered in the design of CSCBL scripts. Second, technological solutions operationalizing the aforementioned factors are proposed and evaluated through synthetic experiences. And third, four CSCBL experiments using 4SPPIces. These experiments are analyzed into two interrelated multicase case studies, whose cross-analyzed results provide an evaluation of the model, of the operationalization solutions supporting the enactment of the involved CSCBL scripts and of the educational value of the experiences themselves.

Resumen

La introducción de tecnologías interactivas y móviles está produciendo un cambio significativo en la naturaleza de las prácticas educativas. Actualmente, el aprendizaje mediante colaboración se puede dar en situaciones en que secuencias de actividades formales e informales dentro y fuera del aula se combinan e integran de forma coordinada. Esto da lugar a un nuevo tipo de actividades de colaboración orquestadas en entornos mezclados que llamaremos guiones CSCBL (de su acrónimo en inglés). Esta tesis investiga los retos relacionados con diseño de los guiones CSCBL y de la selección apropiada de la tecnología para su puesta en marcha. De este trabajo de investigación se derivan tres contribuciones principales. Primero, se propone un modelo conceptual que combina 4 factores a tener en cuenta en el diseño de guiones CSCBL. Segundo, se proponen un conjunto de soluciones tecnológicas para dar soporte computacional a los diferentes factores del modelo y dar apoyo a la puesta en marcha de guiones CSCBL. Cada una de estas soluciones se evalúa mediante experimentos sintéticos. Finalmente, esta tesis presenta tres experimentos en que se usa el modelo para proponer actividades de colaboración en entornos mezclados y aplicarlas en entornos reales. Estos experimentos han sido evaluados mediante dos estudios múltiples de casos. El análisis cruzado de los resultados de los casos englobados en cada estudio ofrece una evaluación de la utilidad del modelo y de las soluciones tecnológicas adoptadas para su puesta en marcha.

Resum

La introducció de les tecnologies interactives i mòbils a l'educació està produint un canvi significatiu en la natura de les pràctiques d'aprentatge de col.laboració. Actualment, l'aprenentage de col.laboració es pot produir a través de situacions educatives en què seqüències d'activitats formals i informals dins i fora de l'aula es combinen i integren de forma coordinada. Això dóna lloc a un nou tipus d'activitats de col.laboració orquestrades en entorns mixtes que anomenarem guions CSCBL (pel seu acrònim en anglès). Aquesta tesi investiga els reptes derivats del disseny de guions CSCBL i de la selecció de la tecnologia per a la seva posada en marxa. Es presenten tres grans contribucions derivades d'aquest treball de investigació. En primer lloc, es proposa un model conceptual que combina 4 factors que cal tenir en compte quan es dissenyen aquests guions. En segon lloc, es proposen un conjunt de solucions tecnològiques per a donar suport computacional als diferents factors del model a fi de possibilitar la posada en marxa d'aquestes pràctiques. Cada una d'aquestes solucions s'evalua per mitjà d'experiments sintètics. Finalment, es presenten 4 experiments en que es fa servir el model per a proposar activitats col.laboratives en diferents contextos. Els experiments s'evaluen a partir de dos estudis múltiples de casos. L'anàlisi creuada dels resultats dels casos enmarcats a cada estudi ofereix una evaluació de la utilitat del model per a donar suport en el disseny de guions CSCBL així com de les solucions tecnològiques adoptades per a la seva posada en marxa.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

> It is not always necessary to start with an initial sense of the things to be studied, but rather with a sense of those things that might facilitate learning.
>
> *Aristotle*

This thesis is framed in the domain of Technology-Enhanced Learning (TEL) and, more specifically in the field of Computer Supported Collaborative Learning (CSCL), in which information and communication technologies (ICT) are applied to enact interactions that produce fruitful collaboration. With the new possibilities that the introduction of interactive and portable technologies offers for education, the nature of collaborative practices changes, leading to a new type of collaborative blended learning settings. In these new learning settings, collaboration can occur through sequences of formal and informal learning activities, coordinated, monitored and integrated across different spatial locations beyond the classroom. The main motivation of this dissertation is to explore the possibilities that these new collaborative practices offer for CSCL and the main problem addressed is to investigate how to design and enact them. This chapter presents the main concepts, terms and definitions in CSCL that frame the scope of this thesis. The aims and objectives deriving from this challenge are also presented along with a description of the structure this thesis shall follow.

1 Motivation

Computer Supported Collaborative Learning (CSCL) is a research area that studies how people learn collaboratively through the use of technology (Dillenbourg and Fischer, 2007). One of the major concerns of the researchers and practitioners in this field is how to ensure effective learning outcomes (Kobbe et al., 2007). The notion of "orchestration" has long been proposed in CSCL as a metaphor to describe the achievement of this goal. Orchestration stands for the process of managing a whole learning group in such a way as to maintain progress towards the learning outcomes and the improvement of practice for all (Moon, 2001). Teachers orchestrate their activities at different dimensions in order to achieve certain goals: at a social dimension (individual group or whole-class activities), at a pedagogical dimension (which implies the adaptation of the designed activities to the occurrences of the classroom) and at a technological dimension (coordination of the transactions among software components) (Dillenbourg and Hong, 2008). Therefore, orchestrating a learning process implies that practitioners coordinate and manage all these dimensions simultaneously.

One of the most well-known forms of coordinating these dimensions lies in scripting the learning process. Scripting is a form of orchestration where learning designs are in charge of guiding the sequences of actions and activities that groups and individuals should follow (Haake and Pfister, 2007; Weinberger et al., 2009; Kollar et al., 2006). When the coordination tasks in the CL scripts are computationally-mediated, CL scripts are referred as CSCL scripts.

In the last decade, the introduction of interactive and portable technologies in education has opened up new opportunities for enhancing and scaffolding collaboration (Alavi et al., September 2009; Nova et al., November 2005; Schwabe and Göth, 2005; Zurita and Nussbaum, 2004). However, new opportunities also bring new challenges for CSCL and, particularly, for the orchestration of scripted collaborative activities.

Now, collaboration can occur through combinations of formal and informal activities at different spatial locations beyond the classroom that can be monitored, coordinated and integrated towards innovative educational objectives (Kukulska-Hulme et al., 2007; Kurti et al., 2008; Spikol and Milrad, March 2008) leading to new blended learning experiences. We refer to these novel coordinated learning situations as Collaborative Blended Learning Scripts (CBL scripts).

CBL scripts are defined as the instructional designs that assist practitioners in the orchestration process (organizing and structuring). This guides learners through complex workflows or learning processes that combine formal and non formal activities across spatial locations to improve educational benefits.

These new learning situations challenge the current concept of orchestration and the existing technological approaches that support it. In fact, many issues remain open and unsolved as regards supporting the coordination of activities that use different computing facilities occurring across combined physical spatial locations.

This dissertation takes on the challenge of exploring how to design scripted learning situations adapted to these new blended learning circumstances and identifying suitable technologies for facilitating their orchestration during the enactment.

2 Scope

This dissertation also adopts many of the current terms and concepts in the CSCL literature. To facilitate the readability of this work and better understand its main contributions the following subsections introduce and describe the main concepts and how they are employed in the context of this dissertation.

2.1 CSCL scripts *versus* CSCBL scripts

CSCL scripts are defined as the technological means for mediating collaboration while reducing the coordinative effort both on the teachers' and students' part (Kobbe et al., 2007). By analogy with CSCL scripts, when the orchestration of **CBL scripts** is computationally-mediated we refer to them as Computer Supported Collaborative *Blended* Learning scripts or **CSCBL scripts**. Therefore, in the context of this dissertation we understand CSCBL scripts as *a particular type of CSCL scripts that focus on combining and integrating (blending) spaces and activity types.* We propose introducing the term Blended to explicitly accentuate the importance and complexity that blending spatial locations, formal and informal activities and diverse technologies entails.

There are three stages in the life cycle of CSCL and CSCBL scripts: (1) Design, where the script is defined in general terms (i. e. describing groups, roles...) (Kobbe et al., 2007), (2) Instantiation, where the script is particularized to the specific learning (Hernández-Leo et al., 2006) and (3) Enactment, where the script is actually performed (Hernández-Gonzalo et al., July 2008; Weinberger et al., 2009).

2.2 Operationalization

The process of going from an abstract and technologically independent description of the script (design stage) to the effective (technological) setting presented to the students (enactment) is defined as **"operationalization"** (Tchounikine, 2008). One script can have as many operationalizations as it has technologies capable of supporting its enactment.

Several approaches have been proposed to address the CSCL script operationalization: from devoted tools that fit with the requirements of particular scripts, to configurable tools or computational languages for representing CL scripts so as to be automatically interpreted by engines.

Within these approaches authors propose solutions that can be differentiated by their **degree of operationalization** according to the technological support for teachers and students of the script orchestration during the enactment. Low operationalization refers to those solutions in which only certain script orchestration dimensions (or coordination tasks) are technologically-mediated (Ounnas et al., 2009; Hwang et al., 2008). On the other hand, high operationalization refers to solutions in which the script orchestration is fully mediated by a technological system (Hernández-Leo et al., 2008; Miao et al., 2007).

Although the existing solutions are effective for the design and operationalization of CSCL scripts, they lack on supporting the complexity that CSCBL scripts entail (Alavi et al., September 2009; Park et al., 2010). On the one hand, in CSCBL scripts the space becomes a central factor that can shape users interactions by enabling or inhibiting learning, affecting not only the orchestration processes but also the way in which the learning flow is defined (Ciolfi, 2004; Gee, 2005; Milne, 2006; Oblinger, 2005). Current solutions provide environments devoted to merely specifying the resources and tools within a virtual space but which are not intended to model the physical elements of the learning setting. Moreover, approaches using interactive technologies only address orchestration in a single space (predominantly the classroom). On the other hand, the interplay between formal and informal activities requires complex educational designs capable of integrating both types of activities and diverse technological support with meaningful learning outcomes.

Hence, CBL scripts challenge the current concept of orchestration and the existing technological approaches for their support. New aspects inherent to blended learning situations have direct implications on learners interactions, affecting both orchestration and its operationalization. These are (1) the physical environment and (2) the interplay of different types of learning, formal or informal. New approaches are needed to support the design of CSCBL scripts and of the associated technological settings that operationalize their orchestration.

2.3 Challenges addressed in this dissertation

As in any CSCL practice, CBL scenarios are characteristic for their multidisciplinary nature. This implies the mutual understanding between practitioners (experts in educational issues) and technicians or technologists (aware of the technologies available and their potential) (Dimitriadis et al., 2003) involved in the design and operationalization of CBL practices.

In this dissertation, we assume that conceptual models describing the characteristics of a particular learning practice act as informative frameworks for the design and architectural structuring of technical support systems while achieving a balance between the educational objectives and the technological constraints (Roschelle, 2003; Tchounikine, 2008). From the educational perspective, it is necessary to encourage practitioners to think about practices that involve formal and informal activities in different spatial locations. Technologically, collaborative environments have to be designed to support, structure and coordinate (thus, orchestrate) students and teachers tasks in order to produce potentially effective learning outcomes (Alavi et al., September 2009).

Therefore, *the general problem undertaken in this dissertation refers to assist practitioners and technicians when addressing the design of meaningful CSCBL scripts and of the associated technological setting that operationalizes their enactment.*

3 Objectives and contributions

According to the general problem undertaken in this dissertation and presented in the previous section 1 the global objective of this dissertation is:

To provide and evaluate a conceptual model for assisting practitioners and technicians in the design of meaningful CSCBL scripts and of the technology operationalizing their enactment.

Based on this background the research question to be discussed in this thesis can be formulated as follows: *Is the proposed model descriptive and complete enough to assist practitioners and technicians when collaborating in the design of CSCBL scripts and the associated technological setting that operationalize their enactment?*

This global aim can be further divided into more specific objectives. The derived objectives as well as the original contributions of this dissertation are summarized and schematically represented in Figure 1.1 at the end of this chapter.

- To systematically define CBL and CSCBL scripts according to current definitions in CSCL and to identify the factors intervening in their design.

  To tackle this objective and to avoid the ambiguities detected in the literature concerning the term Blended Learning, the first step we should take is to explain how we use this term in the context of this dissertation. We shall perform a literature review concentrating mainly on three different topics: (1) work and definitions of blended learning, (2) results from experimental research and case studies focusing on introducing innovative uses of technology to augment current educational practices and (3) CSCL research on tools and theoretical approaches that enhance learning by structuring collaboration.

  As a contribution to this objective and based on the extensive literature review, a systematic definition of the concepts of CBL and CSCBL scripts is proposed. This systematic definition, along with the results of the literature review, is the basis for defining the conceptual model 4SPPIces. 4SPPIces provides practitioners and technicians with a guideline in the design of CSCBL scripts and of the associated technological settings that operationalize their enactment. The novelty of this model falls in explicitly introducing the physical space as a relevant factor in conditioning the design of CSCBL scripts in combination with other factors already treated in the literature such as the activity learning flow or the profile of the students participating in the activity.

Part of these contributions is compiled in the conference papers Pérez-Sanagustín et al. (July 2009); Pérez-Sanagustín et al. (July 2009), an article of an magazine Pérez-Sanagustín et al. (2009b) and in a journal paper Pérez-Sanagustín et al. (under revision/b), which is currently being positively considered for publication.

- To provide and evaluate new usage in meaningful and innovative CSCBL scripts.

  Three different CSCBL scripts with different degrees of operationalization are proposed and evaluated into real educational contexts. The first CSCBL script is called Discovering the Campus Together 2009 and takes place during an introductory course for engineering students at the University Pompeu Fabra. The second is proposed as a solution to deal with the requirements observed during a Geography activity at a Secondary School. Finally, the limitations in orchestration detected during the enactment of the first script hint at the need to create a new technological setting for operationalizing its enactment. The result is a new CSCBL script called Discovering the Campus Together 2010 which has the same objectives and a similar learning flow structure that the 2009 edition but with an improved operationalization solution.

  Finally, another case study proposes analyzing the CSCBL scripts designed by different professionals using 4SPPIces.

  The partial results of the first scenario are published in Pérez-Sanagustín et al. (2011) and in the Pérez-Sanagustín et al. (under revision/a) paper, which is currently being positively considered for publication.

- To provide and evaluate different technological solutions for operationalizing the enactment of CSCBL scripts.

  This objective is addressed by analyzing the possibilities and limitations of current educational technologies and the IMS LD standard, in terms of computationally supporting the needs inherent to the enactment of CSCBL practices. First, the importance of the space when designing scripting processes and the suitability of IMS LD for meeting these needs are analyzed. Second, the relationships between the different factors when enacting a CSCBL script are also studied in order to put forward technologies capable of flexibly managing these factors at runtime.

As a contribution to this objective, we present a model that enables the specification of the space as a conditioning factor in the design and enactment of scripting processes. Also, the value of the proposed model is illustrated by a web-based prototype application for the design of learning spaces and their integration with learning flows as computationally represented with IMS LD. Two synthetic experiences are also proposed to analyze the suitability of IMS LD in flexibly and effectively managing particular aspects of the CSCBL scripts during their enactment. Finally, we also describe how different existing technological solutions can be combined to operationalize CSCBL scripts.

The results of these contributions are published in the journal paper Pérez-Sanagustín et al. (2008), the book chapter Pérez-Sanagustín et al. (in press) and the conference papers de la Fuente-Valentín et al. (2010); Pérez-Sanagustín et al. (November 2009,S).

4 Methodology

As we have already explained in the previous section 3 in this chapter, the contributions of this dissertation belong to instructional design and collaborative learning domains. Since the ultimate aim is to transform the way in which collaborative practices are conceived, designed and enacted, these contributions need to be evaluated into actual educational contexts from both a technological and an educational perspective (Zelkowitz and Wallace, 2002). Only a hybrid methodology combining distinct research methods will permit the analysis of the multidisciplinary nature of these contributions from the two perspectives and of their actual effects on real learning scenarios (Andrion, 1993).

Glass (1995) proposes four research phases inspired by examination of the research methods by Andrion (1993): these being the informational, propositional, analytical and evaluative phases. In this dissertation we adopt the Glass approach and perform several iterations over the different phases until the results are attained. Different iterative cycles over these phases permit, apart from validating the findings of the evaluative phase, one to reflect on how these findings alter the outcomes of the other phases. Also, since this dissertation is framed into a research field with a very changeable nature, these iterations allow us to consider the latest advances in TEL. In this sense, the evaluation phase becomes a central part of this iterative process since it is the phase where these advances are examined.

4.1 Review phase

The aim of this phase is to gather information in order to gain an idea of the current knowledge and problems relevant to the domain and to identify and clearly formulate the research objectives of the dissertation. This phase includes two of the research approaches identified by (Glass, 1995): the scientific method (observe the world) and engineering (observing existing solution and analyze them). In particular, this phase consists of:

- Selecting, reviewing and analyzing the literature regarding the problem domain above all in three key areas: (1) work and definitions of blended learning, (2) CSCL research on tools and theoretical approaches that enhance learning by orchestrating collaboration and (3) results from experimental research and case studies proposing innovative uses of technology to enrich current educational practices.
- Participation in two research projects involving multidisciplinary and international research teams: the TENCompetence project (IST-2001-02787) (TENCompetence, 2005-2009) funded by the European Commission and the Learn3 project (TIN2008-05163/TSI) (Learn3 project, 2009-2011) funded by the Spanish Ministry of Science and Innovation. In particular, the TENCompetence project gives significant input to this dissertation regarding advances on educational standards, especially IMS LD (IMS Global Learning Consortium, 2003) and the opportunity of being involved in diverse open workshops organized by the project. Also, the Learn3 project (Learn3 project, 2009-2011) has supplied the requisite environment, tools and opportunities to carry out the four case studies that constitute the evaluation basis for this dissertation.
- Participation in several international conferences and research events whose topics are related to the interests of this research work: the

9th IEEE International Conference on Advanced Learning Technologies (ICALT'09, July 2009), the International Conference on Intelligent Networking and Collaborative Systems 2009 and 2010 editions (INCOS'09, November 2009; INCOS'10, November 2010) and the 5th European Conference on Technology Enhanced Learning (ECTEL'10, September 2010). Also, participation in two different PhD consortiums: the ICALT 2009 (ICALT'09, July 2009) conference and the the Alpine Rendez-Vous 2010 Conference (Alpine Rendevouz, 2009), organized by the STELLAR (Sustaining Technology Enhanced Learning at a LARge scale) European Network of Excellence in TEL (Stellar Network of Excellence in TEL, 2009). Finally, the participation in the JTEL Summer School 2009 (JTEL, 2010) provided the opportunity to contact people in the TEL community with the same research interests and to discuss the work with experts in the field.

- A three-month research stint with the London Metropolitan University Learning Technology Research Group (LTRI) (LTRI, 2011) with the Professors Tom Boyle, John Cook and Andrew Ravenscroft have served to discuss and comment the main proposals of the dissertation.

Moreover, this thesis has been carried out within the Group of Interactive Technologies (GTI) research team of Universitat Pompeu Fabra (UPF, 2011; GTI, 2011). The expertise of this research group in three research areas, 3D Graphics, Interactive and eLearning, and their previous contributions constitute the basis and the support for the research developed in this dissertation.

4.2 Propositional Phase

The propositional phase consists of proposing and/or formulating a hypothesis, method or algorithm, model, theory or solution (Glass, 1995). In this phase, the proposals relate to the identified research questions based on the information collected in the review phase:

- A model called 4SPPIces for assisting practitioners and technicians in the design of operationalized collaborative blended learning scripted activities is proposed. This proposition directly relates to the first objective depicted in Figure 1.1.

- Different computational mechanisms for facilitating the design and enactment of the computer supported orchestration of collaborative blended activities. The approaches use educational technology standards, modelling languages and configurable tools and propose the operationalization of the different factors in the 4SPPIces model.
- Finally, four experiments that practically apply 4SPPIces-based operationalized blended learning scripts are proposed as novel real educational settings.

4.3 Analysis Phase

This phase consists of analyzing and exploring the propositions leading to a demonstration and/or the formulation of a principle or theory (Glass, 1995). Different analytical methods are proposed for each different contribution:

- An analysis of the technology used to support collaborative scenarios in different case studies and current educative standards, in particular solutions compliant with the IMS LD specification, is performed in order to understand their limitations in supporting the characteristics of CSCBL scenarios.
- Also proposes an analysis of how technology is employed in innovative research experiments that enact activities beyond the classroom.

4.4 Evaluative Phase

In this phase, the proposals are tested as to ascertain whether they accomplish the main objectives of the research. In order to do that, the different contributions of the dissertation are evaluated so that one may extract the key conclusions about the two propositions presented in the Propositional Phase (subsection 4.2 of this chapter). Two evaluation methodologies are employed to evaluate the different propositions (Zelkowitz and Wallace, 2002; Dodig-Crnkovic, April 2002):

- To evaluate whether the 4SPPIces model proposed is useful for assisting practitioners and technicians when addressing the design of CSCBL scripts and the technology operationalizing their enactment, we propose two multicase studies each comprising three case studies. The first multicase study (Multicase study Q1) proposes analyzing the usage of 4SPPices from the perspective of the design process of CSCBL scripts. Whereas the second multicase study (Multicase study Q2) is more focused on the operationalization issues proposed for the CSCBL scripts enactment.

Case studies provide valuable information regarding the influence of technology in a particular context and have proved to be very useful in providing answers to How questions (Rowley, 2002). Case studies enable to monitor an authentic situation by extracting information from the data collected that pertains to the different attributes characterizing its development (Zelkowitz and Wallace, 2002). A cross-analysis of the three cases involved in each multicase study will provide multiple perspectives of the same proposition and, therefore, a more robust validation of the model.

Four different experiments in the form of case studies are analyzed in the multicases. Three experiments named "Discovering the campus together 2009", "Discovering Barcelona" and "Discovering the Campus together 2010" (a variation of version of 2009) respectively put a CSCBL script into practice with real students and practitioners. Finally, the remaining experiment is a seminar in which several CSCBL scripts designs created by professionals in media education either with and without the model are analyzed and compared.

Multicase Q1 organizes the four experiments into three cases to analyze the usefulness of 4SPPIces in supporting the design of CSCBL scripts. Mutlicase Q2 incorporates the three experiments that enact a CSCBL script into a real educational context to analyze the respective operationalization solutions for each case. The outcomes of the two multicase studies will serve to show the lessons learned from the use of ICT in blended learning contexts and for the evaluation of the 4SPPIces model and the operationalization solutions.

All case studies use a Mixed Method for combining quantitative techniques and sources generated automatically by the computers, such as closed questions or event log files, with qualitative techniques, such as open questions, discussion groups or observations (Johnson et al., 2007; Maxwell and Loomis, 2003). The interpretation mechanism employed to extract the findings is called the "triangulation" method, used to reinforce each of the interpretations extracted by means of a comparative analysis of evidence provided from different sources (Gahan and Hannibal, 1998).

- To evaluate the the computational mechanisms proposed for the operationalization of the different factors of the model we propose three synthetic experimental environments. A synthetic experimental environment is an experimental model for validating technology known as software engineering replications in a smaller artificial setting that only approximates the environment of the larger projects (Zelkowitz and Wallace, 2002). These types of experiments seek to investigate some aspect in system design or use.

  A first synthetic environment uses IMS LD in combination with a web-based application to evaluate the operationalization of the interplay between the Pedagogical Method and the Participant factor. A second one proposes modelling the Pedagogical Method with the educational technology standard IMS LD for the evaluation of this standard in supporting the adaptability required to enact collaborative blended learning scripts. Finally, we propose a computational language and a authoring tool to graphically represent the space factor.

5 Structure of the dissertation

This dissertation is structured into four main chapters. Chapter 2 presents the domain problem of the dissertation by enclosing the specific challenges that it undertakes. A critical review of the literature and contributions that mainly influence this work serve to identify the main shortcomings of the current solutions for operationalizing the enactment of CSCBL scripts. The terms Blended Learning, CBL and CSCBL scripts are discussed in the context of this dissertation in relation to the existing definitions in the CSCL field.

Chapter 3 presents an overview of the main contributions of this dissertation. First, as a result of the critical literature review, we integrate all the factors considered independently in the literature into a 4-factor conceptual model called 4SPPIces (Pedagogical method, Participants, Space and history for collaborative educational scripts). The objective of 4SPPIces is to assist practitioners and technicians in addressing the design of CSCBL scripts and of the associated technological settings operationalizing their enactment. Second, third-party applications are analyzed and proposed to address the operationalization of the different factors in the model. This analysis leads to the identification of a lack of computational mechanisms to address some aspects considered in the model. Later in this chapter, a number of suggestions to tackle some of the limitations detected are put forward.

Chapter 4 presents four educational experiments that apply 4SPPIces model to design innovative and meaningful operationalized collaborative blended scripts. All the experiments are organized into case studies in which the findings are cross-analyzed to provide an evaluation of the 4SPPIces model and the selected operationalization solutions.

The lessons learned from using ICT in orchestrated collaborative blended learning activities obtained from this evaluation are presented in the conclusions chapter 5. A summary of the main contributions of this dissertation and the future work derived is also presented in this last chapter.

This thesis also includes three appendixes that complement some of the information presented. The first appendix A contains the information regarding the findings of the "4SPPIces seminar" experiment analyzed in chapter 4. For a comprehensive reading, the second appendix B collects a set of selected papers. Finally, the appendix C shows the complete list of publications derived from this dissertation.

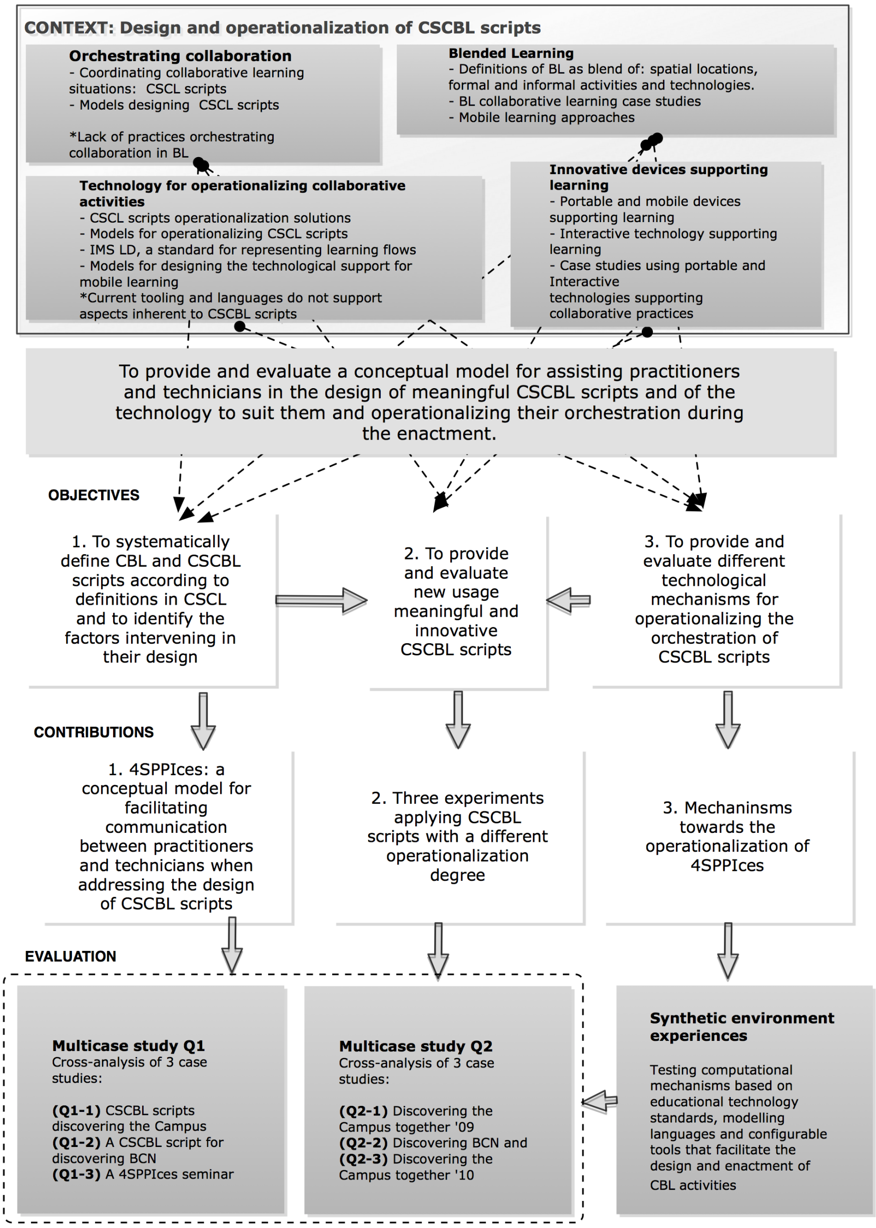

Figure 1.1: Summary of the research context, research questions, main objectives and expected contributions

Chapter 2

Orchestration of CSCL activities in the blend

> I never teach my pupils. I only attempt to provide the conditions in which they can learn.
>
> *Albert Einstein*

This chapter presents the domain problem of the dissertation by encompassing the specific challenges that it undertakes. We shall go through a critical review of the literature and contributions that influence this work by highlighting the ideas, concepts, problems and lack of current technology to support the orchestration of collaborative activities in blended learning settings. First, we discuss what the term Blended Learning (BL) means in the context of the dissertation. Next, the concept of orchestration and scripts as well as the technological approaches developed to operationalize them are assessed . As a result of the literature analysis, and for the purposes of this thesis, we formulate the terms “Collaborative Blended Learning macro-scripts” (CBL scripts) and “Computer Supported Collaborative Blended Learning macro-scripts” (CSCBL scripts). Both terms are used in the context of this dissertation to emphasize the concept of blend in a broad sense: blend of technologies, blend of spaces and blend of activity types (formal and informal). Finally, an analytical review of the existing solutions and models models proposed for the operationalization of scripts and blended learning scenarios is presented.

1 Collaborative Blended learning: mixing and integrating activity types, spatial locations and technologies

Blended Learning is an ambiguous term that can present different definitions depending on the author and the context in which it is applied (Graham, 2005). So and Brush (2008) define BL as “any combination of learning delivery methods, including moreover face-to-face (f2f) instruction with asynchronous and/or synchronous computer technologies” (So and Brush, 2008). Dziuban et al. (2004) refer to BL as “a pedagogical approach that combines the learning possibilities of the online environment, rather than a ratio of delivery modalities” (Dziuban et al., 2004). While other researchers Koper and Tattersall (2005) use the term from a more technological perspective to refer to the combination of f2f with technology-supported activities as well as pure online learning to enrich educational experiences by mixing virtual and real simultaneously (Koper and Tattersall, 2005). Thus, BL is understood as the combination of (1) activities in a virtual space (online activities) with (2) activities in a physical space (f2f technology-enhanced or not). Motivated by this ambiguity, this section goes through the literature and discusses how we understand the term Blended Learning in the context of this dissertation. Different experiences and case studies using interactive, portable and other technological devices for supporting different learning situations are analyzed to delimit the term BL and to understand the main need involved in technologically supporting collaboration in the blend.

We understand blend in a broad sense and from different perspectives:

- Blend of spaces: Recent research in mobile learning has seen advances in the anywhere and anytime capabilities of portable Information and Communication Technologies (ICT). These have provided an opportunity for learning inside and outside the classroom and can be monitored and coordinated across spatial locations (Kukulska-Hulme et al., 2007; Kurti et al., 2008; Spikol and Milrad, March 2008). Researchers in mobile learning assume that “learning flows across locations, time, topics and technologies rather than occurring within a fixed location” (Sharples et al., 2009, 2010). For example, a study by Facer et al. (2004) proposes using mobile phones to support a collaborative experience in which children go to a savannah and are invited to understand animal behavior in direct physical interaction with space. The outdoor activity is complemented with a reflective activity in class. The results show that, despite its complexity, the experience boosted the students motivation and encouraged the acquisition of concepts.

In another study by Ruchter et al. (2010) mobile devices are used by a group of users as a guide to support environmental learning. In the conclusions of this study the authors state that using mobiles leads to an increase in students environmental knowledge and in their motivation during environmental education activities.

In this dissertation, we consider the option to blend spatial locations as an innovative characteristic of current learning scenarios to be incorporated in our approach to BL.

- Blend of formal and informal activities: Different studies show that ICT can not only be a mechanism for motivation but also for bridging the gap between formal and informal education (Cook et al., 2006, 2007). The students' adoption of these technologies make them a good means of supporting individualized and contextualized learning experiences in spaces such as museums (Sharples et al., May 2007). These informal experiences can be the basis for a later definition of formal activities which is better adapted to the students' characteristics.

  Therefore, the blend of formal and informal activities is another characteristic to be considered in our approach of BL.

- Blend of devices: A set of studies on interactive furniture collected in the book "Interactive artifacts and furniture supporting collaborative work and learning" Dillenbourg et al. (2008) shows how embedding technologies into learning settings can expand and organize collaborative experiences in a more intuitive and natural way than traditional computers. These types of technologies transform spaces and, consequentlythe way people collaborate. One of the approaches presented in the book is the use of tabletops. Tabletops facilitate group work by providing a space for collaborative interaction. The study concludes that Tabletops, complemented with supplemental vertical displays such as screen projectors or SmartBoards would provide support for collaboration among groups and within group members.

  A work by Alavi et al. (September 2009) proposes using interactive lamps as a mechanism to make both the teacher and students aware of the progress of the ongoing exercise. These types of solutions increase

> the level of interaction between students and teachers. Furthermore, ubiquitous and interactive technologies are also seen as means of generating "integrated learning" experiences Dillenbourg and Jermann (2007). Integrated learning stands for "the computational integration of the data used and produced across different learning activities. According to that, the authors define integrative scripts as scripts which combine individual, collaborative and collective activities - part of which can be computerized - related via a computational integration of the data used and achieved through different learning activities.
>
> In integrative learning scripts the emphasis lies in the idea that it is thanks to technology that activities occurring within the same educational scenario are related (blended) through the data flow used and produced in each activity. When this happens, we say that the activities are integrated into a unique learning setting. In this context, the blend of technological devices is the means of bridging formal and informal activities across spaces andis thus another of the characteristics to be incorporated to our approach to BL.

Therefore, in this dissertation, we understand blend in a broad sense: blend of spaces, blend of activity types (formal and non-formal) and blend of technologies to integrate the activities. In this PhD thesis we particularly refer to *BL as learning through combinations of formal and informal activities occurring in different spatial locations which are **mixed** and **integrated** into the same learning setting using technology.*

1.1 BL *versus* similar definitions

Recent definitions of mobile learning mention context and mobility as the objects of analysis. The context is considered as an artifact that is continuously created by people interacting with other people in their surroundings and using everyday tools. Mobility enables exploration and conversation, the fundamental processes by which meaning is sought and attained in Mobile Learning. Exploration involves physical movements through a physical or conceptual space and conversations are the bridge that connects learning across contexts (Sharples et al., 2009; Frohberg et al., 2009).

Although, at first sight, mobile learning shares some similarities with our approach to BL, they differ notably in some aspects. On the one hand, our definition of BL incorporates learning across spatial locations but not across contexts. We always refer to spatial locations as the physical spaces in which learners are situated, along with its accompanying characteristics and technologies. While context is something abstract and dynamic that is built up through interactions, for us, the spatial location is static since its structure and available technologies do not change during the learning experience. These physical characteristics and also the characteristics of the technologies available in that space (with their affordances) will condition the way interactions occur but will not change across time. BL focuses on the characteristics of the physical space as a physical static element that enables certain interactions that condition the way collaboration is produced and orchestrated (Pérez-Sanagustín et al., September 2010).

On the other hand, mobile learning focuses on mobility. In particular, mobile learning is defined as "the study of how the mobility of learners augmented by personal and public technology can contribute to the process of gaining new knowledge, skills and experience" (Sharples et al., 2009). BL as we define it implies the blend of spatial locations. Sometimes this type of blending suggests that the learners move across physical spaces using mobile or portable devices. However, our BL definition also includes situations that do not necessarily allude to the mobility of the learners. For example, a situation in which students in two different schools collaborate through multitouch interactive screens (Arroyo et al., May 2010) following the dynamic stipulated by the teacher. BL deals with situations that can both imply or not imply the mobility of the learners.

Finally, mobile learning studies the "process of gaining knowledge through exploration and conversation across multiple contexts amongst people and interactive technologies" (Sharples et al., 2009). The use of ICT is seen by researchers in mobile learning as an opportunity to create learning communities on the move by linking people in real and virtual worlds (Winters, 2006). According to this, mobile learning includes the study of formal and informal experiences occurring in different spatial locations and supported by a variety of technologies. However, the difference with our definition of BL lies in the emphasis on how these experiences are integrated. For us, BL requires an integration of activities through a data flow, while in mobile learning, this integration is not required (see for example Schwabe and Göth (2005)). In this context, technology is not only a means enabling interactions with people and their surroundings but also a means to integrate all these aspects into one unique learning setting. Hence, in the context of this dissertation, we understand mobile learning as a particular type of BL in which the focus is on the mobility of the learners across spatial locations.

1.2 BL: new opportunities, new challenges

BL offers learning opportunities for collaboration that give rise to a new type of learning scenario that we term Collaborative Blended Learning scenarios (CBL scenarios). The main characteristic of CBL scenarios is that learning occurs through collaboration in a mixture of formal and informal activities occurring in different spatial locations that are ultimately supported by technology. Even so, the process of designing these scenarios to achieve effective collaborative learning is challenging. Both the learning flow and the technological support for the enactment have to be designed for promoting and enhancing interactions among learners. Accordingly, the literature highlights three main aspects that should be considered in the design of CBL scenarios in addition to the technology supporting their enactment:

- *Collaboration has to be guided.* Only by choosing an appropriate sequence of activities and a particular role distribution can we elicit the appropriate interactions for generating understanding (Dillenbourg and Fischer, 2007).

- *The use of technology has to be always driven by the educational considerations defined by the collaborative guide proposed.* The technologies employed should be selected not only for the functionalities that they offer, but also for the way in which their functionalities effectively connect activities and spaces to support and enhance the learning purposes (Roschelle and Pea, 2002).

- *The activities and actions of the learners occurring at different spaces should be integrated into the same learning setting.* Activities happening within the same educational scenario are related (blended) through the data flow used and produced in each activity (Dillenbourg and Jermann, 2007). Only with this data flow interconnection can the learners' transitions across learning spaces and activities be achieved. As the recent research by Spikol et al. (2008) suggests "outdoor learning experiences supported by ubiquitous technologies should be combined with learning activities in the classroom to provide learners with meaningful activities".

Designing effective collaboration in CBL scenarios requires selecting the appropriate technology to enable the coordination of learners' interactions across different spatial locations into an integrated learning setting. This must cater for both formal and non-formal activities. Successful ideas in Computer Supported Collaborative Learning (CSCL) and, particularly in orchestration, give clues for questions such as which links should be established between activities and spaces, how they should be coordinated and what types of activities should be developed.

2 Orchestrating collaboration towards effective learning

Computer supported collaborative learning (CSCL) is characterized by being an interdisciplinary field that appropriately combines computer support and collaborative learning to effectively enhance learning (Stahl, 2005). The multidisciplinary nature of this field implies a balance between technology and education when addressing the design of any CSCL practice or application. In this dissertation, we (shall) adopt some of the successful ideas from CSCL to shed light on how CBL scenarios should be defined in order to achieve effective learning through collaboration.

The notion of "orchestration" was firstly proposed by CSCL as a metaphor for classroom interactions that achieve effective learning (Kovalainen et al., 2002). Moon refers to orchestration as "the process of managing a whole learning group in such a way as to maintain progress towards the learning outcomes and improvement of practice for all" (Moon, 2001). However, recent research extends this concept and defines orchestration as the effective design and coordination of learning processes, happening in different educational contexts and social levels (e.g. individually in small groups or as a whole class), and using a variety of resources and tools (both ICT and non-ICT) (Dillenbourg et al., 2009). In other words, teachers "orchestrate activities in different dimensions in order to achieve specific goals: in a social dimension (individual group or whole-class activities), in a pedagogical dimension (which implies the adaptation of the designed activities to the events in the classroom) and in a technological dimension (coordination of the transactions among software components) (Dillenbourg and Hong, 2008). Subsequently, orchestrating a learning process implies that practitioners coordinate and manage all these dimensions simultaneously.

In recent years, orchestration has especially been studied in the context of single educational spaces, see for example Dillenbourg and Jermann (2007). Nevertheless, the intrinsic characteristics of CBL scenarios suggest/indicate new challenges for orchestration. New factors such as the combination of spatial locations and the interplay between formal and non formal activities have direct implications on the way collaboration is organized and structured. On the one hand, interactions among learners and within the environment are now more difficult to control since they occur across spatial locations. Whether physical or virtual, the space (with the elements and technologies therein) becomes a determining contextual factor shaping and conditioning the interactions between learners, which accordingly have a direct impact on the full collaborative experience and its organization (Dillenbourg and Jermann, 2007; Pérez-Sanagustín et al., September 2010).

On the other hand, the integration of formal and non-formal activities is far from simple. The learning flow should be defined as to connect both types of activities and the technology should support this connection. As Jan Derry states, we also need to "get the balance right between formal and informal education" (Winters, 2006).

These factors inherent to CBL scenarios have a direct impact on the different orchestration dimensions. In a social dimension, we should consider the possibility of working in groups involving students at different spatial locations. In a pedagogical dimension, the adaptation of the designed activities becomes more complex since activities occur indoors and outdoors and in different spaces simultaneously. And last but not least, in a technological dimension the transaction among software components becomes even more complex since CBL scripts typically involve a variety of tools and devices.

Current approaches for orchestration should be adapted to capture these new factors that CBL scenarios entail.

3 From CL scripts to CBL scripts: concepts and assumptions

Scripting is proposed in the CSCL field as a form of orchestrating collaboration where predefined learning designs are responsible for guiding the sequence of actions and activities that groups and individuals should follow (Kollar et al., 2006; Haake and Pfister, 2007; Weinberger et al., 2009). These designs are called Collaboration Scripts. Collaboration Scripts are defined in general terms as the instructional means that aim to make the collaboration process more productive (Dillenbourg and Jermann, 2007). When these scripts are employed to facilitate the social and educational processes of collaborative learning by shaping the way learners interact with each other, they can also be called Collaborative Learning scripts (CL scripts) (Kobbe et al., 2007). In other words, **CL scripts** are designs for assisting practitioners in orchestrating (organizing and structuring) collaboration that serves to guide learners through complex workflow or learning processes in order to improve educational benefits (Fischer et al., 2006).

Depending on the aspects of collaboration that are subject to scripting and whether or not the final objectives are mainly cognitive or educational, two types of collaboration scripts are distinguished: micro and macro scripts. **Micro-scripts** are typically designed to support the development of internal representations for particular courses of action in particular situations (e.g., learning how to argue) (Weinberger et al., 2009). **Macro-scripts** are more focused on the coordination of didactic methods that facilitate the generation of educationally productive interactions among learners. These scripts involve the organizational issues of the collaborative learning process such as who collaborates with whom, in which role and what the task distribution among groups is. In other words, macro-scripts aim to structure collaboration by managing resources and deliverables and by defining roles and phases in order to produce specific interactions that lead to situations of effective learning (Dillenbourg and Tchounikine, 2007). This dissertation focuses on CL macro-scripts and will refer to them as CL scripts, for simplicity.

For the particular cases in which CL scripts are proposed to guide collaboration into learning settings that combine formal and non-formal activities across different spatial locations, we shall refer to them as CBL scripts. CBL scripts are a specific type of CL scripts that explicitly state the term *blended* in order to stress the importance and complexity that blending spatial locations and formal and informal activities entails.

Therefore, and by analogy with CL scripts, CBL scripts are an instructional means of facilitating social and educational processes of collaborative learning that shapes the way learners interact with each other in formal and informal activities in different spatial locations. In other words, ***CBL macro-scripts (or CBL scripts)*** *are designs for assisting practitioners in orchestration (organizing and structuring). This serves to gain educational benefits by guiding learners through complex workflows or learning processes that combine formal and non-formal activities across spatial locations.* This dissertation focuses on the study of CBL scripts.

4 Operationalizing orchestration: from CL scripts to CSCL scripts

When a CL script is enacted into a real educational context, we say that its workflow is socially coordinated because the elements defined in its narrative are organized by a person (usually the teacher) (Dimitriadis et al., July 2007). However, there are situations where this coordination is mediated technologically. In these cases we refer to Computer Supported Collaborative Learning (CSCL) scripts. In particular, CSCL scripts are defined as the technological means of mediating collaboration while reducing the coordinative effort both on the teachers' and students' part (Kobbe et al., 2007).

One should note that a social orchestration of a script (CL scripts) does not exclude using technological tools to support certain tasks of the script (i. e. using a simulation tool). But we only refer to CSCL scripts when technology is employed for supporting orchestration tasks (i. e. the technological system shows the students which simulation tool each group needs to use). **CSCL scripts** are a particular type of CL scripts in which technology plays two separate roles: (R1) to provide the technological means required by the script and (R2) to participate in guiding, structuring and constraining the students processes (Tchounikine, 2008).

There are three stages in the life cycle of CSCL scripts:

1. *Design*, when the script is defined in general terms by describing the groups, participants, roles, activities and resources, as well as dissociated mechanisms such as group formation, components distribution and sequencing (Kobbe et al., 2007).
2. *Instantiation*, when the script is related to a specific learning situation, i. e., when the participants are known and the design can be populated (Hernández-Leo et al., 2006).
3. *Enactment*, when the activity is actually being performed (Hernández-Leo et al., 2006; Weinberger et al., 2009).

Although CSCL scripts are always related to a particular technological setting enabling its enactment, researchers address CSCL script design differentiating among two dimensions: the educational (independent from technological issues) and the technological. The process of going from an abstract and technologically independent description of the CSCL script (at design stage) to the effective technological setting presented to the students (at enactment stage) is defined as *operationalization* (Tchounikine, 2008).

4.1 Degrees of scripts operationalization

The current approaches proposed for supporting the design and operationalization of CSCL scripts can be classified into three main groups: (1) devoted tools that fit with the requirements of specific scripts but are not generalizable to others (Berger et al., April 2001; Dillenbourg, 2003), (2) configurable tools that can easily create other tools adapted to specific educational situations based on particular scripts, skeletons or patterns (i. e. Collaborative Learning Flow Patters by Hernández-Leo et al. (2008)) and (3) computational languages for representing CL scripts so as to be interpreted by engines compliant with these languages (Hernández-Leo et al., 2008; Harrer et al., November 2007).

All these approaches differ in the way they meet the operationalization of the CSCL script enactment. In this dissertation we state that the main difference relies on the degree of operationalization, i. e. the type of technological support provided during the enactment to assist teachers and students in the script orchestration.

We define degrees of operationalization according to the technological support provide during the enactment to assist teachers and students in the script orchestration:

- *Low* operationalization: This occurs when certain script orchestration dimensions (or coordination tasks) are technologically-supported, such as grouping students (Ounnas et al., 2009; Hwang et al., 2008). Thus, the script orchestration is partially-technologically mediated.

- *High* operationalization: When the script orchestration is fully mediated by a technological system (Hernández-Leo et al., 2010, 2008; Berger et al., April 2001; Dillenbourg, 2003; Miao et al., 2007).

In accordance with these degrees of operationalization, in this dissertation we shall differentiate among CSCL scripts with a lower or higher degree of operationalization.

By analogy with CSCL scripts, we describe **CSCBL scripts** as *the computational representations of CBL scripts so that they can be automatically interpreted and executed by a technological system facilitating the orchestration process.*

Figure 2.1 shows a scheme of the different definitions given in relation to the degree of operationalization. Usually, technologically-mediated orchestration of the script is complemented with social coordination that is typically performed by the teacher. For that reason, in current educational contexts, it will be difficult to find "pure" CSCL scripts and most of the cases will normally be found within the maximum or lower level of operationalization but not at the extremes.

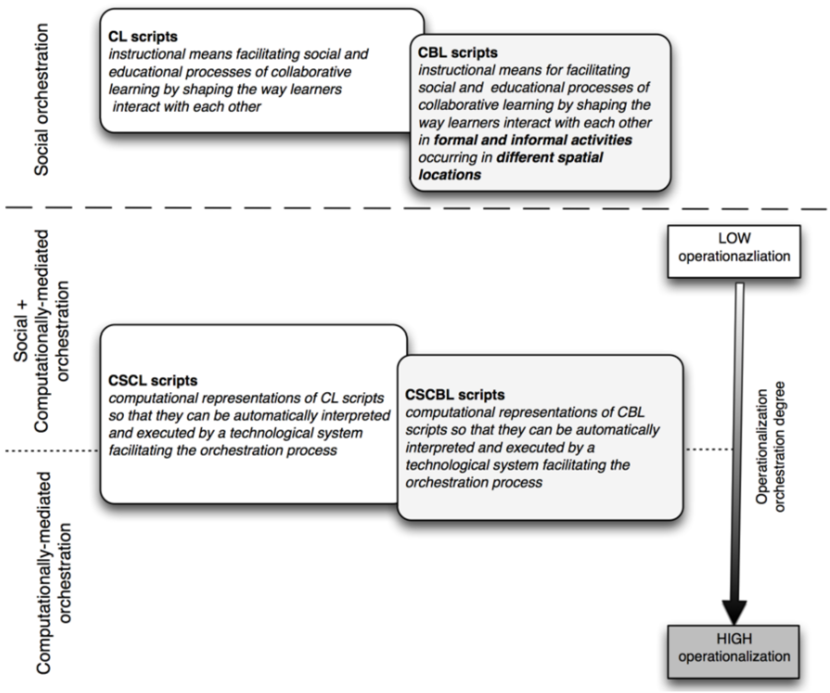

Figure 2.1: CL and CBL scripts are socially orchestrated whereas in CSCL and CSCBL scripts the orchestration is computationally mediated. At the same time we can distinguish between highly or lowly operationalized CSCL and CSCBL scripts.

Therefore, we differentiate between CBL scripts (when orchestration is socially mediated) and CSCBL scripts (when orchestration is partially technologically-mediated) with a higher or lower degree of operationalization. Accordingly, *operationalization* means going from a technological independent description of a CBL script to a CSCBL script and subsequently the appropriate technological setting to provide an automation of the activity workflow, this facilitating the coordination of activities across different social levels and incorporating different software components.

Thus, CSCBL scripts provide the operationalization for both the educational and technological orchestration dimensions of CBL scripts. In the next section we describe the different approaches proposed for supporting the design of CSCL scripts and determine/elaborate its definition in the context of this dissertation.

5 Solutions for the design and operationalization of CSCL scripts and innovative CBL practices

This section presents some of the approaches proposed in the literature to operationalize CSCL scripts. Recent theoretical models, not only related with CSCL scripting but with the design of complex BL situations, are also discussed in this section. Together these have set the basis in inspiring the proposals presented in this dissertation.

5.1 Solutions for the design and operationalization of CSCL scripts

Several solutions have been put forward regarding the operationalization of CSCL scripts. This section reviews, categorizes and organizes these solutions according to the three types of approaches (devoted tools and scripting languages) and also according to their degree of operationalization (Figure 2.2).

5.2 Devoted tools

Devoted tools are developed *ad-hoc* to support a particular type of CL script. Two examples of this approach are the Universanté and ArgueGraphs

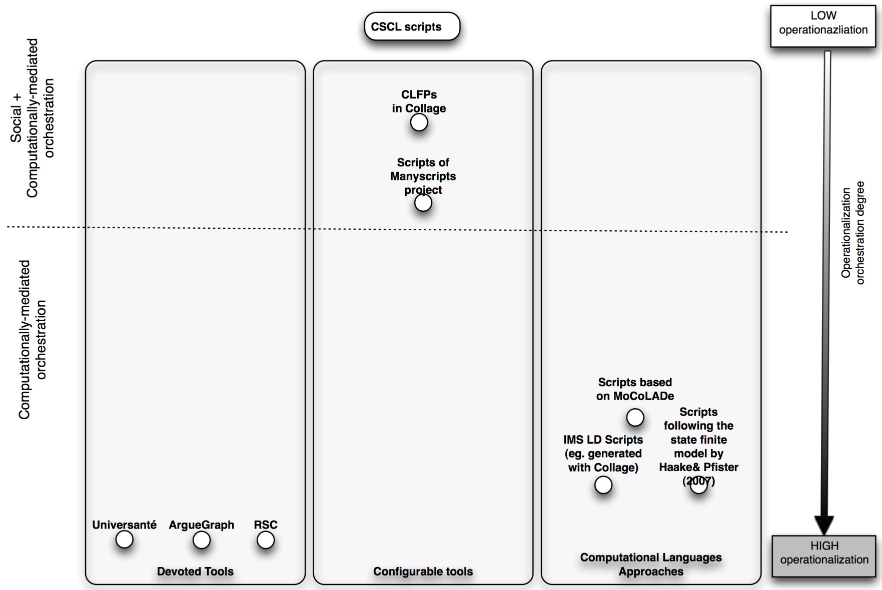

Figure 2.2: Degree of operationalization of the reviewed proposals for CSCL scripts.

scripts. The Universanté script has been used in the health teaching community for medical students from different countries to confront the different national health contexts (Berger et al., April 2001; Dillenbourg and Jermann, 2007). The tool supporting this script is responsible for distributing the tasks among the different groups and providing the virtual spaces for collaboration.

The ArgueGraph script aims at triggering discussion between pairs of students to make them "understand the relationship between learning theories and design choices in courseware development (Jermann and Dillenbourg, 2003). The system provides the teacher with a 2D graph where the students are positioned according to their answers. The teacher forms pairs of students with the most conflicting opinions, corresponding to the largest position in the graph.

Another example is the RSC script (Betbeder and Tchounikine, April 2003; Dillenbourg and Tchounikine, 2007). The RSCL script is a subclass of the project-based family and aims at making a set of students work as a project team by tackling a common goal within a limited period of time. RSC is divided into three phases (Research-Structure-Confront) which can be repeated several times. In the first two phases individual students look for information and structure it in keeping with the tasks. The last phase is a group activity in which students have to put together a collective construction drawn from the individual productions. The operationalization platform suggests the dissociation of an "organizational level" (that allows students to conceptualize their organization as a set of phases) and an "activity level" (that provides the resources and tools required at the organization level).

These scripts are highly operationalized since the orchestration tasks required by the script are fully computationally-mediated. However, the technological support is not usable in any other situation since it fits only with the requirements of these particular scripts. This technological dependency and the aim of involving practitioners in the designs suggested a shift to more configurable tools (Dimitriadis et al., July 2007).

5.3 Computational Languages and Engines

This last approach proposes operationalizing the CSCL scripts by using computational languages to codify them. The result is CSCL scripts that can be automatically interpreted by engines facilitating the orchestration tasks. The aim of these languages is to capture the conceptual level of instructional designs in order to facilitate the exchange of CSCL scripts amongst designers.

One example is the solution proposed by Haake and Pfister (2007). These authors developed the idea of reusing and adapting CL practices by means of a formal model of CSCL scripts represented as an extended finite state automaton and as a web-based tool that supports their automatization and adaptation to any educational context. In this case, CSCL scripts are interpreted by a technological system that fully mediates its orchestration. Hence, CSCL scripts are highly operationalized.

Other authors propose using already existing modelling languages. One of the best-established modelling languages used to develop applications in educational contexts is IMS Learning Design (IMS LD) (Koper and Tattersall, 2005; Koper and Olivier, 2004; IMS Global Learning Consortium, 2003). This specification enables the computational representation of learning flows in accordance with a wide range of pedagogies in online learning.

The IMS Learning Designs can be developed with tools such as Reload (Reload, 2004) or Recourse (Recourse, 2010) and interpreted by the Coppercore engine (CopperCore, 2008) included in players such as SLED (SLED, 2003) or Runtime (Runtime, 2010). In this dissertation, we review some of the solutions offered for supporting the design, instantiation and enactment of CSCL scripts compliant with IMS LD.

As a support for the design time, Hernández-Leo et al. (2006) propose an authoring tool for editing designs based on Collaborative Learning Flow Patterns conforming to IMS LD. As a result, this tool provides the educator with a computational learning flow suitable to be interpreted by a system conforming to IMS LD that organizes groups of students within an activity sequence during the edition time, but not during the enactment. Therefore, no changes in group organizations are possible with this tool.

For the instantiation phase, Hernández-Gonzalo et al. (July 2008) propose an IMS LD compliant tool called iCollage. This is a graphical tool for the establishment and/or allocation of role/group structures aiming at facilitating the creation of instances and population of groups at instantiation time. In this way, groups can be defined and adapted in line with the contextual situation. However, this tool only provides graphical support for the group population according to the previous structures determined during the script editing and fails on enabling modifications during the script enactment.

Finally, the aforementioned tools SLED and Runtime can be employed for CSCL scripts enactment.

5.4 Configurable tools

There are other approaches that propose scripts as sequences of activities without specifying any operationalization solution for their enactment. They are not computationally represented and their enactment is not related to any particular system. These approaches are in he middle between devoted tools and computational languages.

This is the case of the Collaborative Learning Flow Patterns (CLFPs) proposed by Hernández-Leo et al. (2008). CLFPs capture the essence of well-known techniques that structure the flow of learning activities to potentially produce effective learning from collaborative situations. CLFPs describe the general structure of the learning flow, the skeleton or the *core* of the script as Dillenbourg and Tchounikine (2007) describe it (the mechanisms by which targeted interactions occur). This skeleton can be instantiated according to the needs of different educational situations. CLFPs are solutions with a low degree of operationalization since their orchestration is not related to a particular technological system and can be combined with a social orchestration.

Another similar example is the Manyscripts Project CRAFT (2011). The aim of this project is to develop a computational framework for modeling and delivering scripts for CSCL. The purpose of this environment is to spread across the Swiss high school community educational practices that are more innovative than those actually promoted by platforms and standards. The shared scripts are also skeletons not operationalized yet.

5.5 Limitations of computationally representing and interpreting CSCL scripts

The representation of CSCL scripts with a computational language also entails some limitations. First is the lack of flexibility to adapt to unexpected events when enacting the script into a real educational context. Zarraonandia et al. (2006) propose a solution to deal with this limitation concerning CSCL scripts compliant with IMS LD Zarraonandia et al. (2006). The authors propose a mechanism for the introduction of minor variations in the original learning flow during the enactment. This tool permits changing some aspects of the activity such as the title, the resources associated or the structure of the learning flow. Nevertheless, the group hierarchies and the roles defined during the edition phase cannot be changed. Many other approaches volunteered for adapting CSCL script enactment are reviewed in Magnisalis et al. (2011).

Second, the limitations of the specification for representing group structures (roles, hierarchies...). Some authors propose alternatives to deal with this last issue. Harrer et al. (November 2007) determine a set of (or demands) that a language for computationally representing CSCL scripts must accomplish: familiarity, graphical representation, granularity and operational semantics. Based on this idea, Harrer et al. (November 2007) propose a modelling language for collaborative scripts called MoCoLADe (Model for Collaborative Learning Activity Design). For the edition of CSCL scripts compliant with this language they suggest a plugin for another application called FreeStyler. However, since this visual editing tool cannot be integrated into any other learning engine to be interpreted, the proposal incorporates the option of exporting graphical models into IMS LD documents. In this way, although the hierarchies are lost with the transformation, they can be interpreted and reused by LD players or editors.

Another paper by Miao et al. (2007) proposes a CSCL scripting language as a new specification capable of capturing the main elements of CL practices. Nonetheless, the proposal is neither compatible with the existing specifications nor the most commonly used tooling in the community.

All these solutions are shown in the Figure 2.2 as being highly operationalized since they propose mechanisms that computationally guide the complete activity workflow. However, those approaches that do not lead with the variable circumstances to adapt the script on runtime are located at a lower degree of operationalization since they would demand social orchestration in particular situations.

6 Theoretical models for the design of CSCL scripts and complex CBL practices

This subsection reviews the theoretical approaches used as a reference in this dissertation in regard to the design of CSCBL scripts. First, the SPAIRD model proposed by Tchounikine (2008), the constraint-based framework by Dillenbourg and Tchounikine (2007) and the SWISH model by Dillenbourg and Jermann (2006) set the (or foundation) for considering flexibility as one of the key characteristics to be taken into consideration when designing CSCBL scripts. Second, the models by Sharples et al. (2010) and Spikol et al. (2008), despite being proposed for mobile learning, function to explain how to include space as a conditioning factor of the design. Finally, the 4C/ID Model by Van Merriënboer et al. (2002), set the basis of how to integrate all the issues characteristic of complex instructional mechanisms, such as CSCBL scripts.

6.1 The SPAIRD model and the Constraint-based framework: towards a flexible operationalization of CSCL scripts

When enacting CSCL scripts into real educational contexts, unexpected situations can emerge, forcing scripts to be adapted *on the fly*. If the constraints stipulated by the script are too strong, the script can spoil the natural richness of free collaboration; whereas if the constraints are too weak, the expected interactions might not be produced (Dillenbourg, 2002; Dillenbourg and Fischer, 2007; Dillenbourg and Tchounikine, 2007). Consequently, the design of technological settings for supporting CSCL scripts must be sufficiently flexible to deal with the main aspects that arise from these two aspects.

6.1.1 The Constraint-based framework

Dillenbourg and Tchounikine (2007) support the idea that, due to the unpredictability of the script during the enactment phase, the teacher and the student must be able to modify some script features. They propose a conceptual constraint-based framework that defines flexibility in terms of intrinsic and extrinsic constraints. The intrinsic constraints arise from the principles on which the script has been based and must be respected in order to achieve a fruitful collaboration. The extrinsic constraints arise from those elements induced by the technology of contextual factors (limitations in the number of students, evaluation elements, etc).

The proposed dissociation of constraints marks the boundaries of flexibility for both teacher and students, and provides the basis for a computational platform of interaction. This platform should be sufficiently flexible to maintain interaction patterns in the light of extrinsic constraints, without violating the intrinsic constraints in each of the phases of the script development process (edition, instantiation and enactment).

What Dillenbourg and Tchounikine propose for CSCL scripts operationalization is to handle multiple representations of the same script: the script to be executed; the interaction patterns or emergent organization of teams; the intrinsic and extrinsic constraints that result respectively from the pedagogical design; and (from that) the decision and the visual representations of the script by the students and teachers.

Figure 2.3 shows graphically the conceptual framework for managing flexibility by analyzing whether the difference between the script and the actual interaction pattern violates the intrinsic constraints. According to the ideas in this framework, the same authors propose a design model called SWISH that stands for the words Split Where Interaction Should Happen (Dillenbourg and Jermann, 2006). The model is proposed as a mechanism to deal with unexpected situations and to elicit fruitful interactions (e.g., when the teacher identifies cognitive conflicts that would benefit from a debate) by splitting tasks at certain points identified during the process.

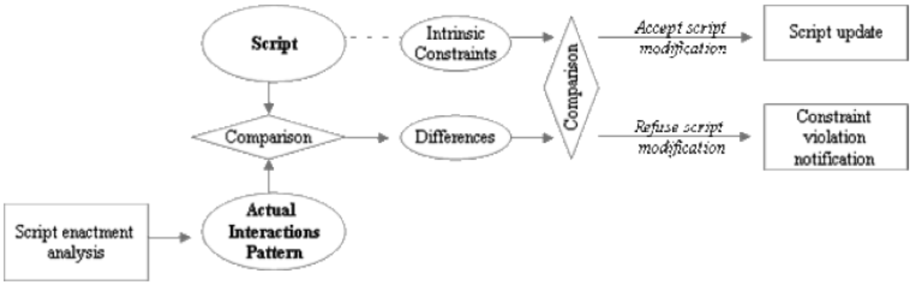

Figure 2.3: The constraint-based framework for script operationalization (extracted from Dillenbourg and Tchounikine (2007))

Therefore, on the one hand the constraint-based flexibility framework stresses the need to design flexible technological settings for the CSCL script operationalization capable of dealing with the unexpected situations inherent to actual educational context. While on the other hand, the SWISH model Dillenbourg and Jermann (2006); Dillenbourg (2004) accentuates the importance/urgency of monitoring what has and will happen and being prepared to react in consequence (or prepared for all eventualities).

6.1.2 The SPAIRD model

All these flexibility ideas are captured in the SPAIRD (for Script-PlAtform Indirect Rational Design) model by (Tchounikine, 2008). The SPAIRD model is an operationalized-oriented conceptualization of the relations between macro-scripts and technological settings (Tchounikine, 2008). This model is proposed as "a basis to facilitate collaboration between (non-technical) educators and computer scientists to address CSCL macro-scripts operationalization and make operationalization decisions when selecting, customizing or constructing the scripts' technological setting". Tchounikine defines operationalization as the process of going from an abstract description of a CSCL script to an effective setting. In this dissertation, we use operationalization in the same way as this author and furthermore add the differentiation between high and low operationalization degrees.

The SPAIRD model disentangles five notions to be considered when addressing the technological setting for CSCL script operationalization: (1) the issues, perspectives and models related to the script components (structural model), (2) the script implementation, (3) the platform specification, (4) presentation of the scripts to students and (5) the design rationale (learning hypothesis, pedagogic principles and design decisions). All these notions are captured into four different submodels represented as four different blocks (see Figure 2.6). The dissociation into different submodels makes explicit issues that are often kept implicit or mixed, such as the script dimensions and the technological setting, each of which can be used to influence student perception and enactment.

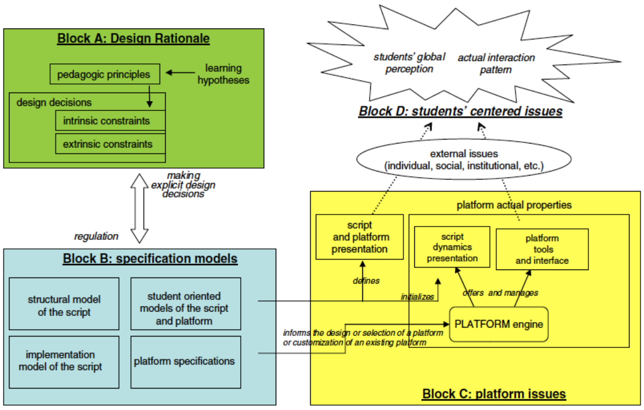

Figure 2.4: The SPAIRD model is proposed for guiding the design of technological settings for CSCL macro-scripts operationalization. Block A: the design rationale; Block C:models of the script to be elaborated; Block C: platform issues; Block D: students' perspective (extracted from Tchounikine (2008)).

The Tchounikine proposal refers to the operationalization of CSCL scripts from a conceptual perspective. This author proposes the SPAIRD model as a descriptive and informative framework for the design and architectural structuring of technical support systems. Two main ideas derived from his work are adopted in this dissertation and appropriately adapted to the context of CSCBL scripts.

First, there is the idea of conceptual models being used as an approach to support and facilitate communication among technicians and practitioners. This would lead to a balance between the educational objectives and the technological constraints (Tchounikine, 2008). Models act as the bridges for reaching a common understanding between communities. Second, they represent the idea of specifying issues concerning both the most educational dimensions of the scripts and the most technological into one unique representation. Both dimensions are interrelated and a dialectical relationship among them is required if one is to end up with meaningful, feasible and innovative educational scenarios supported by technology.

6.2 Frameworks for designing innovative mobile learning activities

Sharples et al. (2010) proposes a framework to structure and analyze Mobile Learning. In this piece of work Mobile Learning is defined as "the processes of gaining knowledge through conversations across multiple contexts amongst people and personal interactive technologies". This framework expands the activity model via Engestrom's activity model (Engestrom, 1987) to tackle the interdependencies between learning and technology.

The framework comprises six factors (subject, object, context, tools and communication) analyzed under two perspectives or layers: the technological and the semiotic (see Figure 2.5). The technological layer depicts learning as an engagement with technology, in which tools such as computers and mobile phones function as interactive agents in the process of gaining knowledge, creating a human-technology system with which to communicate, mediate agreements between learners (as with spreadsheets, tables and concept maps) and aid recall and reflection (as with weblogs and online discussion lists). The semiotic layer describes learning as a semiotic system in which learners' object-oriented actions (i. e. actions that promote an objective) are mediated by cultural tools and signs.

Both layers can be analyzed independently as two different frameworks: (1) a semiotic framework that promotes discussion with educational theorists in order to analyze the activity and discourse of mobile learning and (2) a technological framework for software developers and engineers that puts forward requirements for the design and evaluation of new mobile learning systems. Nevertheless, the layers can also be superimposed to examine the holistic system of learning as an interaction between people and technology.

A recent paper by Frohberg et al. (2009) employs this framework to evaluate and categorize different kinds of mobile learning projects found in the most prominent Mobile Learning research literature. In this study, the authors stress the semiotic layer and interpret technology as the facilitator . From this perspective, the authors point out that assembling all the factors

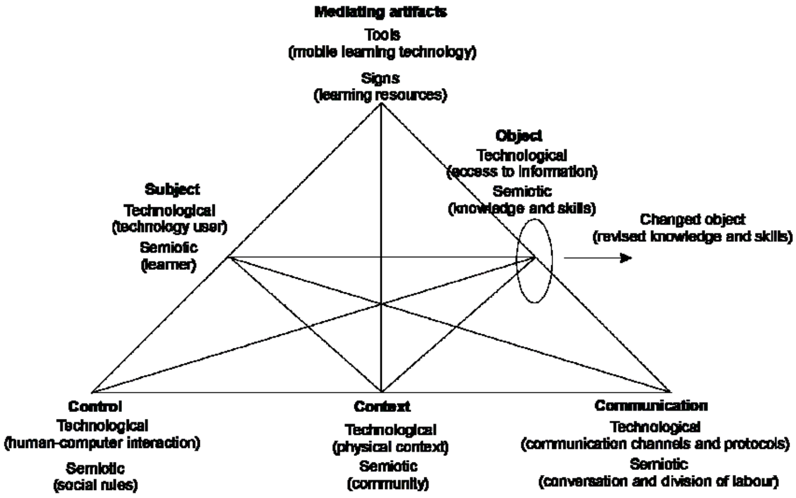

Figure 2.5: A framework for analyzing mobile learning.The semiotic and the technological layers can be analyzed independently or superimposed (extracted from Sharples et al. (2010))

within the framework produces a complete picture for a specific instantiation project. On the other hand, a dynamic view of a project enables/furthers the development of a new triangle for any instantiation and version. In order to reduce complexity in the analysis of the different projects, the authors propose a core issue to be analyzed on a five-point scale for each of the six factors in the framework: Relevancy of Environment and Learning Issue, Pedagogical Role of Tools, Tightness of Control, Social Setting, Previous Knowledge and Level. The result of this analytical review gives an overview of the design space in mobile learning and allows developersto make better informed design choices.

Sharples et al. (2010) model has been explicitly designed to structure and analyze Mobile Learning, but not to design mobile learning experiences. This last issue is applied in context to the conceptual framework of collaboration by Spikol et al. (2008).

The framework by Spikol et al. (2008) "provides the designer with opportunities to tackle the challenges of designing for innovative mobile learning activities". This framework is composed of three context attributes and one central component (see Figure 2.6). The basic component is the Learning Activity System (LAS). LAS is a computational system and content repository that provides the infrastructure to integrate educational content into the context where the learning activities and collaborations are taking place. The surrounding circle in the graph describes the context by explicitly defining a three-axis structure consisting of three attributes: (1) location/environment attributes (where the user is), (2) activity/task (what the user is doing) and (3) personal/interpersonal attributes (who the user is). Each one of the three context attributes can be combined as part of a pair or as a triplet to provide all the information necessary for the context in which the learning activity takes place.

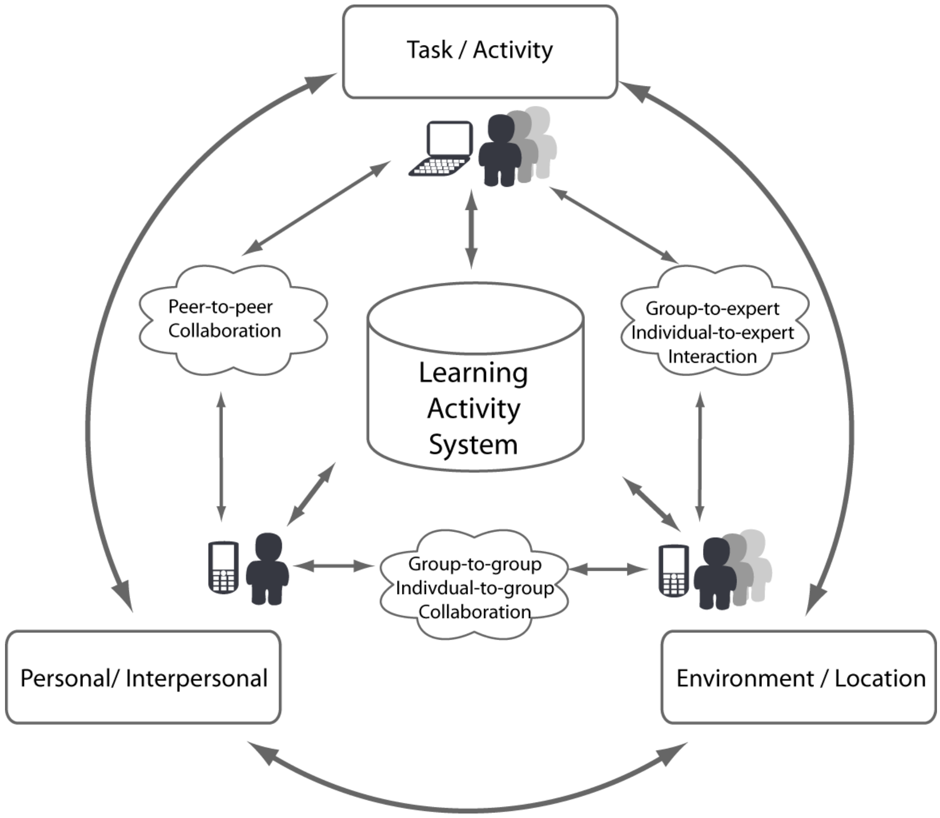

Figure 2.6: Framework for designing mobile learning collaborative activities (extracted from Spikol et al. (2008))

From the viewpoint of of this dissertation we consider mobile learning as a particular type of BL focussing on the mobility of the learner across contexts (see section 1). Therefore, these frameworks are valuable in highlighting the needs to be considered in the design of CSCBL scenarios that share their main characteristics with mobile learning experiences. Moreover, these approaches allow us to understand how the different factors involved, such as in particular types of CSCBL scenarios, have to be combined and integrated.

6.3 4C/ID Model: Designing programs to support complex skills acquisition

4C/ID is a four-component instructional model to design programs supporting complex skills acquisition (van Merriënboer J. G. et al., 2002). The idea behind this model is that environments for supporting complex learning have to coordinate and integrate activities to facilitate the attainment of sets of learning goals. 4C/ID proposes four interrelated components essential in blueprints for complex learning: (a) learning tasks, (b) supportive information, (c) just-in-time (JIT) information, and (d) part-task practice.

In the context of this dissertation 4C/ID is interesting because it stresses the (importance of) coordination and integration of activities for the acquisition of complex skills.

CSCBL scripts are also complex learning situations that demand the integration of activities occurring at different spatial locations and supported with a variety of technologies. Thus, CSCBL scripts require the interrelation of different components according to a set of learning objectives. The 4C/ID model is an example of how different components of a different nature can be interrelated and integrated to facilitate the achievement of sets of learning goals.

7 Summary

CSCBL scripts are described in the context of this dissertation as particular CSCL scripts in which collaboration through sequences of integrated formal and informal activities across different spatial locations. A review of the literature in the CSCL field shows that, although there are already approaches for operationalizing the orchestration of CSCL scripts to enable its automatic or semi-automatic enactment, they lack of consideration for the (fundamental) characteristics of BL.

These two characteristics are: (1) the physical environment and (2) the interplay of different types of activities, formal and informal. Both characteristics directly affect the way collaboration is produced and structured in CSCBL scripts and should be considered when designing these scripts. Moreover, these characteristics have other implications on aspects implicit to any type of scripts such as its structure or the way students are organized along the activity.

Research on theoretical models sheds light over how to consider all these aspects in a holistic and integrated manner. The constraint-based flexibility framework and the SPAIRD and SWISH models underline the importance of designing flexible systems in order to be able to support the unexpected events typical in the enactment of CSCL scripts in real educational contexts. Models of mobile learning hint at how to consider the space where the activity occurs as a conditioning factor in the design of CSCBL scripts and its relation with activities and technologies. Finally, the 4C/ID model stresses the (importance of) coordination and integration of activities for the acquisition of complex skills. This last model suggests how integration among activities and supported by a variety of technologies should be carried out in CSCBL scripts.

Each of these models incorporates some of the factors characterizing CBL activities, such as the the importance of the locations where learning activities occur or the flexibility that orchestration systems in blended learning settings demands. However, any of these models combine all these factors into a one unique representation stressing their relation with the activity learning flow or the characteristics of the participants involved in the activity.

New models disentangling all the factors intervening in the definition of operationalized CSCBL scripts and integrating them making explicit how they are combined are required.

Chapter **3**

Operationalized CBL scripts

> A concerted effort among leaders in the research and educational community will be needed to drive the raw technologies that will arrive in classrooms towards enough of a common platform that a scale for pedagogical applications becomes feasible.
>
> *J. Roschelle*

This chapter presents an overview of the main research efforts carried in this dissertation for the design of CSCBL scripts through the operationalization of CBL scripts. First, we present 4SPPIces, a conceptual model that defines 4 factors to be considered when designing CSCBL scripts and the computational mechanisms for operationalizing their enactment: the Space (S), the Pedagogical method (PM), the Participants (P) and the hIstory (I). This model aims at being a communication tool for practitioners and technicians when collaboratively designing operationalized collaborative blended learning scripts. Second, different third-party solutions are analyzed as mechanisms for the operationalization of the factors in the model. The model with the analysis of these third-party solutions leads to the identification of a lack of computational mechanisms addressing some aspects considered in the model. This section also presents the contributions proposed to address them.

1 Overview of the contributions

The contributions can be organized into four main sections structured as shown in the schema in Figure 3.1. First, the model 4SPPIces is proposed as a conceptual literature-grounded solution defining the factors that should be considered when addressing the design of CSCBL scripts and the technological support for operationalizing their enactment.

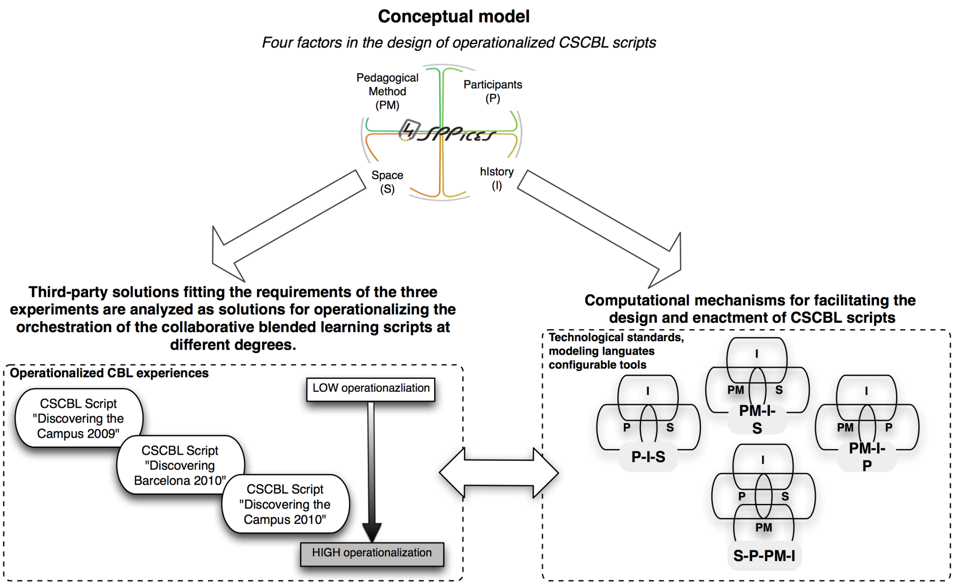

Figure 3.1: The contributions derived from this thesis are: (1) 4SPPIces: a conceptual model considering 4 factors in the design of operationalized CSCBL scripts, (2) operationalization solutions combining third-party developments fitting the needs required by the three CBL activities analyzed in the experiments and (3) solutions addressing the operationalization of triples of factors of the model to lead with those aspects of the model not supported by current technological approaches.

Second, a set of third-party technological solutions are proposed and analyzed as examples for addressing the operationalization of the different factors in the model. It is worth noticing, that the reason beyond analyzing these technologies and not others is related with the characteristics of the collaborative blended learning activities analyzed in the experiments described in the next chapter 4. These technologies were selected because they fitted with the orchestration requirements of these activities.

Third, from the model and the analysis of current technology, we detect some limitations for addressing some of the aspects considered in the model. We propose a set of solutions based on educational standards, modeling languages and configurable tools to lead with these limitations. These solutions has been evaluated in synthetic case studies with real users. The results of these experiments have been published in a conference paper Pérez-Sanagustín et al. (September 2010) (paper I in the Appendix B), a journal paper (Pérez-Sanagustín et al., 2008) (paper III in the Appendix B) and a book chapter Pérez-Sanagustín et al. (in press) (Book chapter in the Appendix B).

2 4SPPIces: factors in the design of CSCBL scripts

4SPPIces is a conceptual model that provides practitioners and technicians with a common language to design potentially meaningful CSCBL scripts and their associated technological operationalizing their enactment.

This model is based on the knowledge coming from the literature review on blended learning, CSCL tools and approaches for enhancing learning by structuring orchestration, and case studies proposing innovative uses of ICT. As a result, 4SPPIces combines 4 factors conditioning the design of CSCBL scripts: the Space, the Pedagogical method, the Participants and the hIstory.

Although these factors have already been considered in the literature, the novelty of 4SPPIces falls on combining them in one unique representation. More specifically, this relies on the explicit definition of: (1) the space as a relevant factor that conditions the design of computationally operationalized blended learning scripts and (2) highlighting the role of the hIstory to explicitly model the relations between the other factors that affect the enactment of the scenario. Existing or forthcoming comprehensive models focused on each factor can be integrated for extending 4SPPIces.

Tables 3.1, 3.2, 3.3, 3.4 organize the literature already presented in chapter 2 according to the main ideas considered in each of the factors comprising 4SPPIces. Figure 3.2 shows a representation of the model whose factors are explained in the following subsection.

Literature study	Interest for the PM Factor
Haake and Pfister (2007)	A formal model of CSCL scripts (represented as an extended finite state automaton) to help teachers and designers to develop, adapt and experiment with CSCL scripts *Definition of the main elements to be considered in the design of CSCL scripts taken as an inspiration to describe the facets of the PM*
Koper and Olivier (2004)	Educational modeling language to computationally formalize learning flows *Computational specification to be considered as the basis for structuring learning flows*
Hernández-Leo et al. (2008)	Collaborative Learning Flow Patterns for structuring collaboration computationally represented with IMS LD *Collaborative Learning Flows taken as a basis for the definition of the PM factor as a sequence of interrelated activities*
Kollar et al. (2006)	Conceptual components in the design of collaboration scripts *Definition of the components and mechanisms to be considered in the design of CSCL scripts taken as an inspiration to describe the facets of the PM*
Dillenbourg (2004); Dillenbourg and Jermann (2007)	Data flow integration *Integration across activities through the data flow taken as a basis for defining the integration of the activities in the PM*

Table 3.1: Review of the literature influencing the Pedagogical Method (PM) of the 4SPPIces model.

Literature study	Interest for the P Factor
Smythe et al. (2001)	IMS Learner Information Package to capture students profile *Package to be considered as the basis for the profile facet definition of the P factor*
Ounnas et al. (2009)	Considering the students profile for supporting the group formation policies *Evidences showing that certain formation policies considering students profile can enhance and promote collaboration. Taken as a reason to include the profile and the group formation profile-based facet in the P factor*
Hwang et al. (2008)	Genetic algorithm to organize cooperative learning groups to meet multiple grouping criteria *Evidences showing that grouping criteria can maximize learning taken as a reason to include the Profile and the grouping formation-profile based facet in the P factor*

Table 3.2: Review of the literature influencing the Participants (P) of the 4SPPIces model.

Literature study	Interest for the S Factor
Ciolfi (2004); Gee (2005); Collis et al. (2003)	Space as an agent able to activate collaborative learning by shaping users interactions *Studies evidencing that the space is a new factor to consider when designing collaborative scripting practices*
Alavi et al. (September 2009)	Interactive table and lamp complements the use of personal computers in an integrated collaborative scenario *Evidences showing that the integration of new devices can complement and enhance collaborative practices by changing learning spaces affordances*
Oblinger (2005)	Space as a determining contextual factor by enabling or inhibiting learning *Evidences showing how the design of the space (including the devices composing the space) have to be considered as a factor that can inhibit or promote certain collaboration practices*
Goodyear et al. (April 2004)	Virtual space as a learnspace *Evidences that suggest that virtual spaces have to be considered as another learnspace where students collaborate and share for complementing face to face activities*
Zurita and Nussbaum (2004)	Devices Mobility influences collaboration *The success of using mobile devices to enhance collaboration in face-to-face practices suggest that whether the devices included in the space are mobile or static affect on how collaborative activities are designed*
Kirschner (2002)	Elements affordances *The way we use the different elements composing the space can define the affordance of learning spaces*
Sharples et al. (2010); Spikol et al. (2008)	Frameworks for designing innovative mobile learning activities *Factors considered in the design of innovative mobile learning experiences in which activities occur across contexts*
Frohberg et al. (2009)	Analytical review and categorization of different kinds of mobile learning projects in the Mobile Learning literature using the framework proposed by Sharples et al. (2010) *Differences and similarities of different mobile learning projects and relevance of the different factors*
Facer et al. (2004); Schwabe and Göth (2005); Sharples et al. (May 2007); Cook et al. (2006, 2007); Kurti et al. (2008); Spikol and Milrad (March 2008); Cook et al. (2009); Ruchter et al. (2010)	Cases study, examples considering other spatial locations beyond the classroom *Review of the literature influencing the Space (S) of the 4SPPIces model.*

Table 3.3: Review of the literature influencing the Space (S) of the 4SPPIces model.

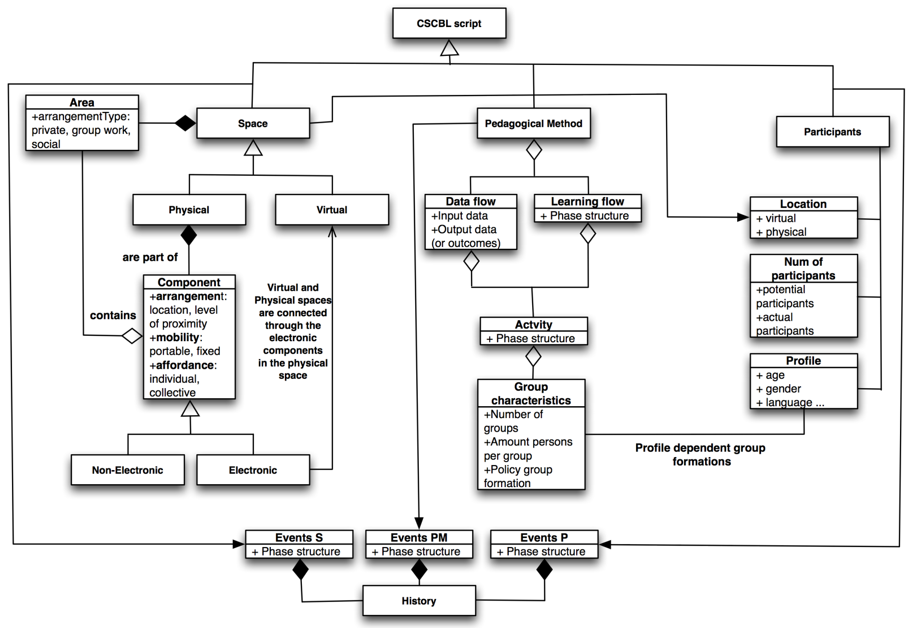

Figure 3.2: 4SPPIces Model: factors and facets and their interrelations

2.1 The space factor

The Space factor (S) defines the space where the learning activity occurs and the elements that compose it.

This factor is inspired in ideas coming from research works on learning spaces and ubiquitous computing. Researchers in these fields consider the physical space as an agent able to activate or inhibit learning by shaping users' interactions (Ciolfi, 2004; Gee, 2005; Oblinger, 2005).

We differentiate the **Virtual** and the **Physical** space (Pérez-Sanagustín et al., September 2010). In virtual spaces (e.g., a learning management system) the participants manipulate virtual elements that are not necessarily located on the same place (e.g., shared documents for collaborative edition, chat rooms). Whereas the physical space is the place (e.g., a classroom) where the participants are located and can physically manipulate the elements of the environment (e.g., tables, whiteboards). Physical spaces are composed by a set of **Areas** that can be of three different types depending on the elements that compose them and the interactions they can elicit: (1)

Literature study	Interest for the I Factor
Dillenbourg and Tchounikine (2007)	Modifications on the fly to maintain the coherence of the script *Operationalization solutions should be developed to flexibly support the unexpected situations occurring during the enactment*
Dillenbourg and Jermann (2006)	Modifications on the fly to maintain the coherence of the script *Operationalization solutions should be developed to flexibly support the unexpected situations occurring during the enactment*
Pérez-Sanagustín et al. (November 2009)	Last minute changes in the space influence the activity enactment *Technological support for CSCBL scripts have to include mechanisms to support quick adaptations of scripts when there is a last-minute change of the space where the activity takes place*
van Merriënboer J. G. et al. (2002)	4C/ID Model: Designing programs for supporting complex skills acquisition *Stresses the coordination and integration of activities for the acquisition of complex skills*

Table 3.4: Review of the literature influencing the hIstory (I) of the 4SPPIces model.

private working areas (reserved for individual or private task), (2) group work area (reserved for working in groups) and (3) social areas (a place for socialization).

The components of an area can be classified depending on their nature as: **Electronic** and **Non-electronic**. Non-electronic components are the type of components that are typically found in learning or working areas and are neither electronic nor interactive (i.e. chairs, tables, blackboards). Electronic components are defined as components with electronic properties that allow users to interact individually with it or with other students. Within the electronic components we include the technology available in the particular learning context for both supporting the means required by the script and the orchestration needs.

Both virtual and physical spaces are connected through the electronic components of the physical space. A physical **Component** such as a device is the means for accessing to a service or tool of the virtual space for supporting a particular learning or orchestration task. For instance, a PC is an electronic element that can be employed to execute a simulation application to support the students task or for launching a web-based application for facilitating the teacher to form groups according to students answers to a questionnaire. Both the simulation and the group formation tools are components of the virtual space, whereas the PC is a component of the physical space.

The usage of components in the physical and virtual world are characterized by their (1) **arrangement** (location and organization with respect to the rest of the elements composing the space), (2) their **mobility** (whether they are portable or not) and their (3) **affordance** (describes whether these elements are used individually, collectively or collaboratively). Although no particular spaces such as a classroom or a museum are included in the space factor, each spatial location intervening in the activity is represented through the elements that define it. This issue makes it unnecessary to include as part of this factor a list of potential spaces (museums, classrooms...) because any space can be represented by the facets included in the factor.

2.2 The Pedagogical Method Factor

The second is the Pedagogical Method factor (PM). The definition of this factor is prompted by the ideas that arise from the CSCL scripting field. Experts in this area state that free collaboration does not necessarily produce learning and propose CSCL scripts for reaching these effectiveness (Dillenbourg and Fischer, 2007). As we already seen in section 4, CSCL scripts are computational mechanisms to guide and structure interactions among learners in order to produce effective learning (Weinberger et al., 2009; Dillenbourg and Hong, 2008).

For the PM factor we adopt some of the concepts of the scripting practices and proposes: 1) to structure the activities, occurring in sequence or in parallel, in a **Learning flow**, 2) to differentiate the teachers' and learners' tasks through the **Activities**, 3) to define the **Group characteristics** for each activity and 4) to define the inputs and outputs that will be generated from one phase to another, which corresponds to the **Data flow**. The Data flow facet takes into consideration the ideas behind the concept of integrated scripts. These scripts contemplate a computational integration of the data used and produced across the different learning activities to define an integrated learning experience (Dillenbourg and Jermann, 2007). Therefore, the PM is any didactic description of a sequence of activities that define what learners and teachers should perform, the groups' characteristics for producing the interactions to reach the particular learning objectives and the data flow that assures the activities integration.

We recommend using already existing learning flows such as the CLFP and adapting them to the new blended circumstances in which activities occur across spatial locations. Also, designers can take as a basis a CLFP formally represented with educational modeling languages such as IMS LD (Koper and Olivier, 2004; Koper and Tattersall, 2005).

2.3 The Participants Factor

Third, the Participants factor (P) is dedicated to capture those aspects related with the students participating in the activity. This factor is composed by 4 facets. The first takes into account the number of **potential and actual Number of participants**. This distinction is considered in order to design technological systems able to lead with the unexpected situations regarding the number of participants during the CSCBL scenario enactment (Dillenbourg and Tchounikine, 2007).

The second and third facets are related. On the one hand, the students **Profile** facet takes into account those characteristics of the students that can affect the way in which the activity is structured. For example, we can have advanced and non-advanced students and assign one or another activity to each one. On the other hand, it is possible to group the different students according to the elements defined in their profile such as their language. This is modeled in the Profile-dependent group formation facet.

Finally, the physical **Location** of the students for each activity is also important. Now it is possible to conceive scenarios in which, for example, a group of students from Valencia attends to a class in Barcelona through an audiovisual conference system. Since, in such cases, the dynamic of the collaborative activity changes depending on the location of the students, the Participants factor includes the Location as one of its facets.

2.4 The History Factor

This factor is inspired by the research on CSCL scripts and especially on the flexibility aspects that technologists have to take into consideration when designing the technological settings for scripts operationalization. Particularly, the nature of the hIstory factor has to do more with those issues that, when the activity is enacted, need to be considered for assuring a coherent and integrated learning setting.

Concretely, the hIstory factor (I) is defined for describing ***what happens*** *with respect to the other factor facets as the script evolves from the edition* *to the enactment*. In other words, the hIstory describes the relationships between the facets of a particular factor with the rest of factors facets across the different scripts stages: the edition, the instantiation and the enactment.

Describing these relationships is a way for assisting technologists when identifying the requirements of a technological setting to suit the script operationalization by assuring its consistency across stages, especially during the enactment.

During the enactment unpredictable circumstances require the script to be adapted on runtime, which needs defining a flexible script operationalization. However, since unpredictable variations are beyond the script, its not possible to facilitate a list of aspects to be considered when designing the technological setting for flexibly supporting a CSCBL script enactment. What we can provide are the means for making practitioners and technicians to reflect about the aspects likely to be affected by these variations. This is the role of the history factor. In a way, the hIstory factor models the relationships between factors for assuring an integrated and coherent learning experience by emphasizing those aspects likely to be varied during the script enactment.

The hIstory is characterized by three facets: S events (*what happens* with the Space factor and how it relates to the other factors), PM events (*what happens* with the Pedagogical Method factor and how it relates to the other factors) and P events (*what happens* with the Participants factor and how it relates to the other factors).

Therefore, the idea behind the hIstory factor is to make the users of the model reflect about those relations among factors across the different script stages that can affect the enactment of the CSCBL script in order to build up systems and mechanism to cope them.

Although the history factor is intimately related with rest of the factors, it is included in the 4SPPIces as an independent factor for explicitly modeling the relationships among factors that can condition the design of a flexible script operationalization. This relationships cannot be extracted by considering each factor independently from the rest but by analyzing the factors as a complete and integrated system.

2.5 4SPPIces versus similar approaches

4SPPIces has been explicitly conceived to be employed as a communicative means for practitioners and technicians to collaborate in the design of CSCBL scripts. 4SPPices main purposes are aligned with the objectives of related approaches such as the theoretical models proposed by van Merriënboer J. G. et al. (2002), Tchounikine (2008), Spikol and Milrad (March 2008) and Sharples et al. (2010).

On the one hand, 4SPPIces provides practitioners (without advanced technological skills) with an instrument to think about the key factors that might help on expanding educational practices into CSCBL scripts or creating new ones.

On the other hand, the model also provides system developers or technicians with a framework to systematically analyze CSCBL scripts and identify the characteristics of the technological infrastructure enabling its enactment and facilitating its orchestration.

Approaches such as the one proposed by Tchounikine (2008) for operationalizing CSCL scripts and by van Merriënboer J. G. et al. (2002) for supporting the design of programs for complex skills acquisition, although focussed on other type of learning practices, their objectives are aligned with 4SPPIces purposes.

The two models propose mechanisms to conceive technological environments for supporting the design of particular practices without specifying concrete devices or technological environments. The goal of the 4SPPIces model is aligned with this idea in that 4SPPIces aims at providing the guidelines for practitioners and technicians communities necessary for supporting the design of CSCBL scripts and the technology operationalizing their enactment. What 4SPPIces provides is a schema of the combined relevant factors that intervene in CSCBL scenarios and that condition the design of the technological environment operationalizing their orchestration.

Mobile learning frameworks proposed by Sharples et al. (2010) and Spikol and Milrad (March 2008) already consider the context as part of the new mobile learning scenarios in relation with activities or tasks, users and tools. Although considering similar attributes, 4SPPIces and the frameworks by Sharples et al. (2010) and Spikol and Milrad (March 2008) differ on the focus they have been conceived for and the way these attributes/elements/factors are defined.

Sharples' model has been explicitly designed for structuring and analyzing Mobile Learning but not for addressing the design of mobile learning experiences. 4SPPIces, however, focusses on providing the guidelines for conceiving scripted sequences of collaborative activities and the technological setting to suit them for facilitating their orchestration.

Spikol and Milrad (March 2008) propose a three-axis framework for designing mobile learning collaborative activities that includes the environment/location as an attribute integrated with tasks and users to enhance particular collaboration modes. For these authors the aim is to link collaboration to context "to utilize the fluidity of learners actions, relations, and locations in a way that further defines collaboration and context in relation to mobility" (Spikol and Milrad, March 2008). Nevertheless, the focus of 4SPPIces relies on designing scripted sequences of collaborative activities and how they relate with the characteristics of the physical space and the participants characteristics to understand how these relationships might affect on their orchestration. Moreover, both Sharples et al. (2010) and Spikol and Milrad (March 2008) frameworks provide abstract definitions of the attributes intervening in the activities, whereas 4SPPIces describe each factor through a set of facets to help users in particularizing their designs for a concrete learning context.

Therefore, even though 4SPPIces does not allow ending up with a concrete technological setting, *4SPPIces provides a helpful conceptual tool for systematically describing CSCBL scripts in a first attempt to efficiently introduce a computationally manageable structure for operationalizing their orchestration and facilitating their enactment.* The contribution of the model is more centered on merging the factors highlighting the role of the space and the hIstory when defining collaborative experiences in CBL contexts rather than on being a complete model for a concrete technological setting.

3 Third-party computational mechanisms supporting the enactment of CBL scripts

This section presents how the third-party computational mechanisms fitting the operationalization requirements of the three aforementioned CBL experiences operationalize the different factors in the model.

- **IMS LD units for a PM-focussed script operationalization**:

Different research in CSCL shows that the specification language IMS LD is a good solution for modeling the structured learning flows providing automatic or semi-automatic mechanisms for supporting their orchestration. See for example (Hernández-Leo et al., 2006; Hernández-Gonzalo et al., July 2008; Zarraonandia et al., 2006). In the CBL experience "Discovering the Campus 2010" we use this specification for modeling the learning flow of the PM (explained later in section 3.2 of chapter 4).

- **IMS LD units combined with GSI for a P-focussed script operationalization:** Generic System Integration (GSI) proposes a framework to include any kind of web-based tool in the context of IMS LD courses, making possible to adapt the flow depending on students behavior on the included tool (de la Fuente-Valentín et al., September 2009). In the context of this work, GSI is used to integrate specialized data management tools as part of the learning flow to manage and administer the elements of the P factor. GSI is proposed for integrating an on-line web spreadsheet provided by Google to administer students' data and to automatically create groups and assign them to the correspondent activity. This operationalization solution is focussed on the P factors since the spreadsheet is used to automatically form the groups according to the static constraints derived from the PM that are stored through the I. See (de la Fuente-Valentín et al., 2010), attached as paper III in the Appendix B.

  Other technologies such as Moodle (Dougiamas and Taylor, September 2003) or other Learning Management Systems can be employed also to operationalize the PM.

- **NFC kit for a S-focussed script operationalization**: "NFC is a short-range radio technology that operates on the 13.56MHz frequency, with data transfers of up to 424 kilobits per second. NFC communication is triggered when two NFC-compatible devices are brought within close proximity, around four centimeters" (Ortiz, C. E., 2011).

  In this dissertation, NFC technology is used to augment the information of the space (Ramírez et al., March 2008). NFC interactive tags store information that students access using a mobile phone (NOKIA N6131 and N6212). These tags are employed in this dissertation to relate the P and S factors through the I. When a student interacts with a tag, this information is stored in a log file. From this log files, and since each tag is associated with a particular area of the space, we extract the routes that each student has performed around the space. This information with regard to each student can be used later to adapt the PM factor. See paper Pérez-Sanagustín et al. (2011) (paper IV in Appendix B for more information about the NFC architecture).

- **QuesTInSitu for a S-P-focussed operationalization**: QuesTInSitu (Santos et al., September 2010) is a web-based application that enables the generation of questions compliant with the standard IMS Question & Test Interoperability associated to a geographical coordinate with GoogleMaps (Google, April 2011).

  QuesTInSitu integrates the NewAPIS engine (Llobet and Santos, 2010). Thanks to this engine, the questions are automatically corrected, scored and stored in a database of the application (i.e., who answered the questions and their scores).

  QuesTInSitu includes a functionality to create routes complemented with a monitoring system. Routes are sequences of geo-located questions created and organized by the user. The routes are visualized in a Google maps as a set of markers. Depending on the participants' location students visualize one route or another and answer the set of questions related to this route.

  The monitoring system provides information about the students evolution of these routes at runtime. When a user answers a question the database of the system is updated and the marker associated to this question changes from green to red. The teachers can visualize the progress of the students along the route at runtime by looking at the red and green markers. Clicking on the markers, the teacher can also know who answered the question and the score.

  The monitoring functionality in this tool operationalizes the S and P factors enabling a control of the students' answers associated to a space at runtime. The I factor in this context is in charge of saving the information about the students' answers associated to a particular geographical coordinate.

These technologies are presented because they were proposed as the tooling that best fitted with the requirements of the CSCBL scripts enacted in the experiments "Discovering the Campus 2009 and 2010" and "Discovering Barcelona". However, other possibilities also covering these requirements could had been employed. The effectiveness of these tools with regard to the support provided for teachers and students during the enactment is discussed in the next chapter 4.

4 Configurable tools and modeling languages for the operationalization of CSCBL scripts

The third-party solutions presented in the previous section 3 of this chapter are appropriate for supporting the enactment of the particular collaborative blended learning experiences proposed for the experiments. However, there are some aspects considered in the 4SPPIces model that these approaches cannot deal with. This dissertation proposes a set of contributions to tackle these aspects Pérez-Sanagustín et al. (2008); Pérez-Sanagustín and Hernández-Leo (June 2009); Pérez-Sanagustín et al. (in press,S); de la Fuente-Valentín et al. (2010).

First, modelling techniques and tooling that allow the use of IMS LD in flexible and adaptive blended learning settings are proposed. Second, a prototype that enables partitioners to flexibly manage groups according to the profile of the expected participants is presented. In this case, the operationalization is based on considering the intrinsic constraints of the Pedagogical Method when interplaying with the Participants. Finally, a computational language for representing the physical Space when planning collaborative learning flows represented in IMD LD is proposed. This computational language is also complemented with a authoring tool for enabling practitioners to graphically represent the learning spaces intervening in the learning flow.

These contributions explore different operationalization solutions by considering combinations of three factors: PM-I-P , PM-I-P and PM-I-S.

Within these triplets the hIstory factor is always present since it is in charge of modeling those aspects and relationships with regard to the PM, P and S that will assure a flexible operationalization. At the same time, in each of the proposals, the focus of the operationalization relies on one of the factors more than on the others. This focus will determine how the different factors of the model are related conditioning the resulting operationalization.

In the following we detail each of the solutions proposed.

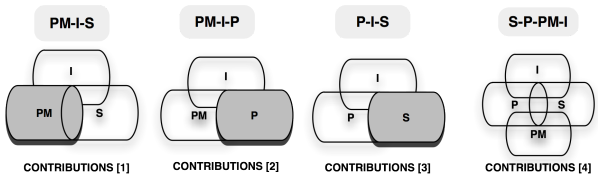

Figure 3.3: The operationalization approaches can be classified into four different types depending on the 4SPPIces factors taken into account and how they relate to each other: a) PM-I-P type, b) P-I-PM type and c) S-I-PM type. Numbers refer to the contributions published related to each type: [1] Pérez-Sanagustín et al. (2008) (Appendix B, paper III) and Pérez-Sanagustín and Hernández-Leo (June 2009), [2] Pérez-Sanagustín et al. (in press) (Appendix B, Book chapter), [3] Pérez-Sanagustín et al. (September 2010) (Appendix B, paper I), and [4] de la Fuente-Valentín et al. (2010) (Appendix B, paper II)

4.1 PM-I-P approaches

PM-I-P approaches propose the operationalization of CSCBL scripts taking into consideration the Pedagogical Method, the Participants and the hIstory factors. The I is in charge of modeling the relationships between PM and the P.

Two different approaches are proposed to address the operationalization of this triplet of factors. These solutions differ on the factor taken as the focus for operationalizing the script orchestration, the PM or the P. In the first cases, the PM is the factor that conditions and drive the relations with the rest of the factors through the hIstory; i. e. the P and I factors change according to the constraints established by the PM (Pérez-Sanagustín et al., 2008). While in the second cases the focus is on the P and, therefore, it is the P which conditions and drive the relations with the rest of the factors through the hIstory (Pérez-Sanagustín et al., November 2009).

In what follows we present how each of these approaches addresses the operationalization of the PM, I and P factors to deal with the orchestration needs of a particular learning context.

4.1.1 PM-I-P approaches focussed on the PM factor

Two solutions are proposed within this type of approach: the meta-Unit of Learning or meta-UoL and the adaptive UoL. In these approaches the pedagogical model is represented using the IMS Learning Design (IMS LD) specification (Koper and Olivier, 2004) which can be used for authoring and delivering learning activities (Griffiths et al., 2007). However, it presents some limitations when UoLs are applied to a blended learning setting.

These two proposals address the flexibility and adaptability requirements that these type of blended learning situations require.

The IMS LD oriented techniques for modeling scripts have been also applied in the real experiment "Discovering the Campus together 2010" in section 3.2.

- **The meta-UoL or an IMS LD template integrated in runtime systems**
  This solution takes as a basis the methodology used in the Agora association. Agora is an association within La Verneda School (Escola La Verneda, 2011) for adult education. Its main objectives are to address social exclusion by providing opportunities for people to train and to update their skills. The methodology used in the training activities of the association are the Dialogic Learning and interactive groups (Elbers and De Haaan, 2004; Renshaw, 2004). The principles of this methodological approach are the democratic participation and stress the importance of dialogue and equal participation also when designing the training activities (Aubert et al., 2004). There are no hierarchies within participants and everybody can participate in the definition of the learning process. Heterogeneous groups of persons with different academic levels and experiences "work together" and "find out" together in a "logical" way guided and coordinated by the trainer.

  In this context, traditional instructional design guidelines are too rigid since motivation and participation of learners become the gist of the learning process. Consequently, new design methodologies to tackle the flexibility requirements of the activity design and also to generate the organizational structures for supporting them are needed.

  The solution proposed is to define a configurable template integrated in runtime systems that can be modified during the enactment. The template is formulated as a meta-UoL which can be interpreted by IMS Learning Design players. The meta-UoL relies on the principles of dialogic learning and interactive groups and is an attempt for guiding the user in the implementation of this methodology. With this template the users can design their own learning practice by selecting and describing (1) the activity to perform (task), (2) the tool support, (3)the input resources (supporting the activity), and (4)the output artifact (resulting from the activity). All participants in the session, trainer and learners, have the same rights of modifying the template either a priori or during the learning process (see Figure 3.4 depicting the factors intervening in the Meta-UoL).

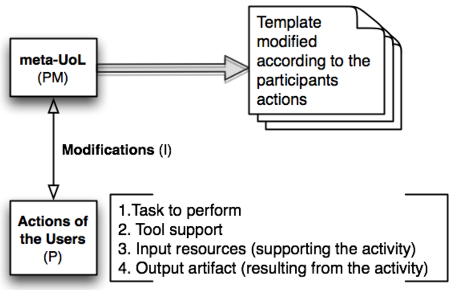

Figure 3.4: Factors intervening in the operationalization of the Meta-UoL.

- **The adaptive UoL**
  The Adaptive UoL was presented in the "Competitive Challenge on Adapting activities modeled by CSCL scripts" at the CSCL 2009 conference as a scripting solution for leading with "on the fly" adaptations during the script enactment. The script was designed in form of an adaptive questionnaires for Algebra students in Computer Science.

  Particularly, the solution proposes to address these adaptation demands is a script represented by a unique Unit of Learning (UoL) conform to the IMS LD specification; so that it can be computationally interpreted by the tools conform to this specification.

  The UoL is previously designed by the teacher: all the themes are defined in advance and also the different questions related to these themes. The activity starts when teacher gives a web address to the students. Each students register to the UoL by accessing to this web page using the LinkTool (Pérez-Sanagustín et al., 2009a). Once registered, they can start the activity.

  The first exercise consists on discussing which the theme that is going to be treated for the questionnaires is. The students use the forum and the chat services for the discussion or can also discuss it face to face in case of sharing the same spatial location. Once selected the theme, the teacher groups the students according to their interests and opinions and provide them with a questionnaire. This questionnaire will be different depending on the theme they choose. The progression over the questions will change depending of the users responses. This is treated using the properties of the UoL.

The UoL also addresses another adaptation problem. If a new student comes late and has to join the activity, he will only register to the system and jump directly to the question indicated by the teacher. Since the progression of the students is codified in an independent run, there is no problem if a new student joins the activity late because he will be provided with a new run. The adaptive UoL was successfully used by the participants of the workshop. Figure 3.5 depicts the factors intervening in the adaptive UoL operationalization.

The operationalization focus of these approaches rely on the PM factor. In both cases, PM is adapted during the enactment according to the interests, demands of the students and, particularly in the second case, to the students' questionnaire answers. The Pedagogical Method is codified with IMS LD and defines a pre-defined sequence of activities likely to be modified according to the Participants' interests and the aspects captured by the hIstory. The flexibility of the operationalization proposed will be determined by those aspects and relationships considered in the I with regard to the PM and P factors.

Even though the variations in PM are influenced by the P and I factors, since the operationalization focus is the PM, these variations are subject only to those aspects already pre-stablished by the PM. Therefore, the PM is the central factor considered for the operationalization since it is the factor that conditions the orchestration tasks during the enactment and the relation with the other factors the most. In other words, the relationships between factors modeled by I will be mainly constrained by the PM in order to provide a flexible operationalization with regard to this factor.

Notice that the meta-UoL and the adaptive UoL were designed to be enacted only face to face in the classroom. When operationalizing the enactment of this learning situation, the space was not a requirement and, therefore not considered as a conditioning factor for the script operationalization.

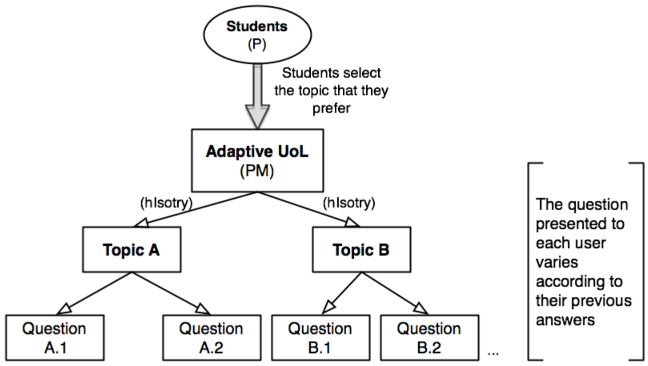

Figure 3.5: Factors intervening in the operationalization of the Adaptive UoL.

4.1.2 PM-I-P approaches focussed on the P factor

Within this type of approaches, this dissertation proposes a flexible solution for managing groping tasks in blended learning contexts. In particular, the solution proposes managing groups of students according to the variability of the context and the intrinsic constraints stipulated by Collaborative Learning Flow Patterns (CLFPs) codified with the IMS LD specification (Pérez-Sanagustín et al., November 2009).

CLFPs capture the essence of well-known techniques for structuring the flow of learning activities to potentially produce effective learning from collaborative situations (Hernández-Leo et al., 2005, 2006). Whereas, the IMS Learning Design (IMS LD) specification allows its formalization into a computer-interpretable design (Koper and Tattersall, 2005; IMS Global Learning Consortium, 2003).

Taking as a basis a constrain-based framework proposed by Dillenbourg and Tchounikine (2007), which defines flexibility as the dissociation between intrinsic and extrinsic constraints (see section 6.1), this work analyzes the flexibility requirements of two representative examples of complex CL (Collaborative Learning) activities: the TAPPS and Jigsaw CLFPs. With the results of the analysis we implement a Web-based prototype to facilitate the teacher in flexibly managing grouping tasks for both examples.

As a basis for the architecture of the Web-based prototype, this solution proposes an operationalization of three of the factors in the 4SPPIces model:

the Pedagogical Method, the Participants and the History (see Figure 3.6 and the book chapter in the Appendix B).

The PM defines the learning flow of the collaborative activity and it is represented here by a CLFP codified in a UoL conforming to IMS LD.

The P factor is directly associated, on the one hand, to the list of potential students that the teacher can upload to the system during the preparation of the group distribution and, on the other hand, to the actual students during the development of the activity.

Finally, the I factor stores the information about the group distribution and the new group configurations that occur during the activity enactment. The I relates the evolution and relationships of the PM and P factors. The I factor is in charge of registering the unexpected events in relation to the P factor that affect the group composition defined in the PM factor as extrinsic constraints. A constraint controller is always listening to the system for notifying the user if any of the intrinsic constraints have been violated. In this case, it will propose an optimal distribution of the participants (P) according to the PM and the I factors. The system will always propose an alternative, except when the actual number of participants configuration makes it impossible to satisfy them. In such cases, the system proposes the best alternative or recommends using another CLFP for this learning scenario.

Notice that, even though the PM is a very important factor for operationalizing the tasks orchestration because stipulates the intrinsic constraints of the group formation, the main interest of this solution is to address the flexibility of the P factor. Therefore, the operationalization focusses on how to address the changes of the P factors during the activity enactment.

4.2 S-I-PM approaches

S-I-PM approaches propose the operationalization of CSCBL scripts taking into consideration the Space, the Pedagogical Method and the hIstory factors. The I is in charge or relating the S and the PM.

In this dissertation we propose an solution that focusses on the S for operationalizing the orchestration of the CSCBL script. The S is the factor that conditions and drive the relations with the rest of the factors through the hIstory; i. e. the PM and I factors change according to the constraints established by the S.

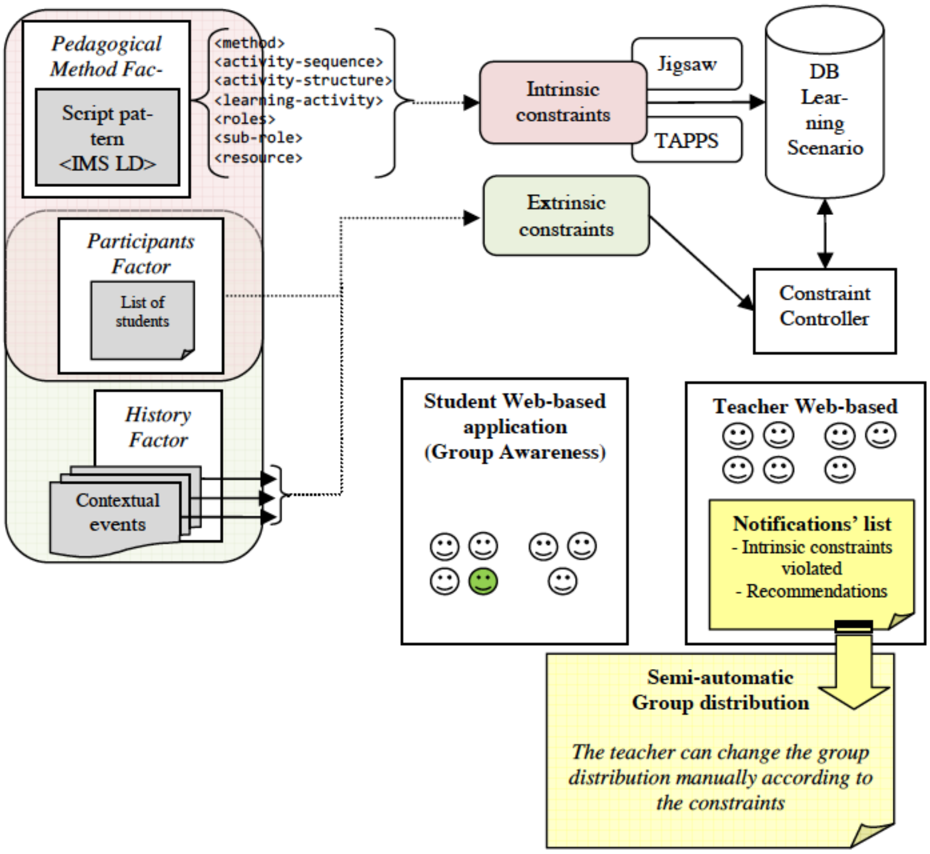

Figure 3.6: Operationalization solution for "Discovering the campus 2010". The three factors are represented: the PM, the P and the I. (see the book chapter in the Appendix B)

In this dissertation we adopt the idea that the space (with the elements, technological or not, in there) is a central factor that can shape users interactions by enabling or inhibiting learning (see section 1 in chapter 2). We contend that the particular characteristics of a space affects not only the orchestration processes but also the way in which the learning flow is defined.

To reflect on the affordances of the technology-enhanced spaces and their limitations whilst designing a collaborative experience means reflecting on the new opportunities that technology offers for generating innovative learning practices. In this context, the space and its elements become essential factors that should be considered during the whole cycle of the scripting process: the edition, the instantiation and the enactment.

According to this idea we propose specifying the space factor in the 4SPPIces model defining those elements that condition the design and enactment of a CSCL script design process when applied to blended learning contexts (Pérez-Sanagustín et al., September 2010) (paper I attached in Appendix B). This specification permits describing physical learning spaces in a formal way. The objective is to enable the design of a complete, abstract and portable description of the main space elements to support the integration of the space as part of a scripting process definition.

Figure 3.7 specifies the space factor as a set of UML classes and a definition of the vocabulary used. This UML representation provides a view of the overall factor in an abstract way for understanding the main components and their relations. The **Physical space** is defined as a set of **Components** (electronic or non-electronic) that users can be physically in contact with, touch and manipulate and which are usually distributed in **Areas** associated to a particular type of task determined by the learning designer.

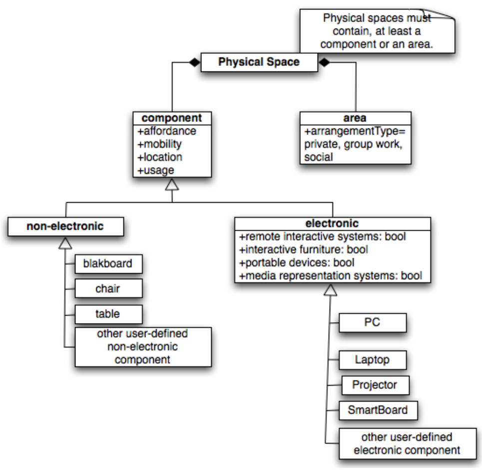

Figure 3.7: Components of the space factor.

As a solution for the design of a CSCBL script taking into account the space and also as an approach for operationalizing its orchestration during the enactment we propose a web-based application developed according to the elements specified. This application provides the user with a graphical interface in which the different elements and components of the space specification are directly manipulated for generating a graphical design of the learning spaces involved in the activity (see Figure 3.8).

This version of the tool was employed for carrying a preliminary evaluation of this formalization of the space by analyzing its potential for representing two different real learning spaces associated to two different actual learning practice enacting the same learning flow. These examples show how the enactment of the same activity can be modified because of the space characteristics in which it takes place. More information about this evaluation process is given in section 5 of this chapter.

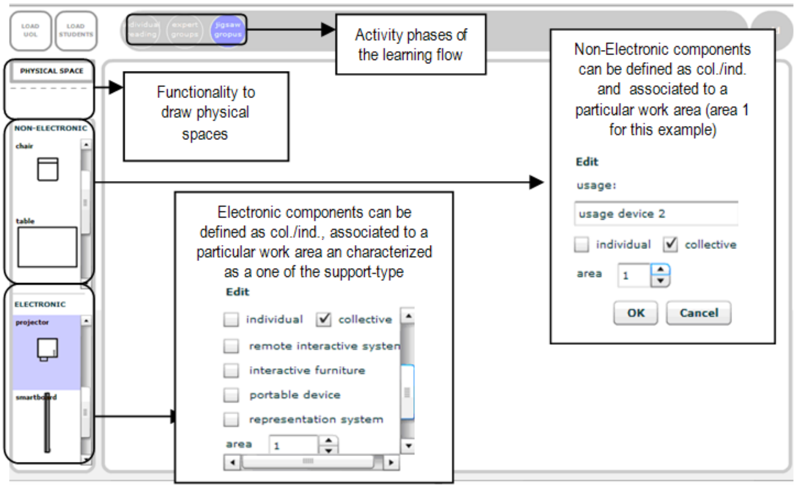

Figure 3.8: General interface of the web-based prototype for operationalizing the Space, the Pedagogical Methods and the hIstroy factors including the functionalities needed to represent the elements and their characteristics defined by the space.

Three main factors are considered in this last version of the operationalization solution: the S, the PM and the I. The S is represented for each activity in the PM. Depending on the characteristics of the space, the tasks, methodologies and procedures defined in the PM phases can be modified. The position of the elements as well as the technology available can affect the definition of the PM. The I is in charge of establishing the relation between these two factors by saving the representation of S associated to each activity in the PM into a XML file.

4.3 S-I-P approaches

S-I-P approaches propose the operationalization of CSCBL scripts taking into consideration the Space, the Participants and the hIstory factors. The I is in charge or relating the S and the P.

As an example of this operationalization approach we use an updated version of the space tool presented in the previous section (4.2). This version includes a section for representing the students in class and organizing them in relation to the space. In this case, the focus of the operationalization approach is also on the S. The S is the factor that conditions and drive the relations with the rest of the factors through the hIstory; i. e. the P and I factors change according to the constraints established by the S.

The focus of this approach relies on dealing with the variabilities emerging from the relationships between the S and the P factors that can affect the orchestration tasks.

Including the list of students that can potentially participate in the activity, the P factors is considered in this work for operationalizing the orchestration of the activity enactment. Moreover, a merge of this proposal with the P-I-PM focussed on the P factor (see section 4.1.2) and establishing a set of constraints associated to the space definition, will enable a better CSBL script operationalization.

5 Synthetic experimental environments with the operationalization solutions

Each of the contributions in the previous section have been evaluated in synthetic experimental environments (Zelkowitz and Wallace, 2002). The use of these software prototypes in realistic settings is usually expensive in terms of time and evaluation. And in this cases, in which the synthetic experiences have been enacted with the real potential users, realistic experiences would have not provided more information about the issues under evaluation.

This section summarizes the main outcomes of these experiments. More information about the evaluation procedure and main findings can be found in the papers associated to each contribution (papers number I, II and III of the appendix B of this dissertation).

5.1 Synthetic experimental environment with the meta-UoL or an IMS LD template integrated in runtime systems

Two members of the Agora association used the meta-UoL to create real-life examples. The meta-UoL was interpreted by SLeD (SLED, 2003) player that works under the Coppercore engine(CopperCore, 2008). Figure 3.9 illustrates the overview of the whole cycle followed by the users to complete the configuration cycle of the template.

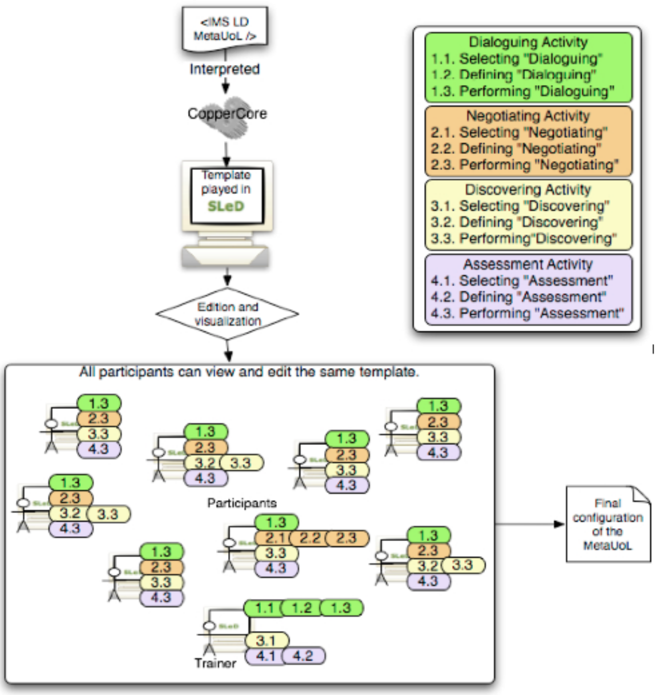

Figure 3.9: Complete cycle of the configuration of the meta-UoL.

The users participating in the evaluation are representative in the context under study because of their expertise in the use of the dialogic learning and interactive groups methodology and in the application of technological support in their educational activities. They propose for the evaluation test two tasks that are usually problematic for the learners: to write a document and to search on Internet. Following the guidance provided by the meta-UoL, the Agora's members created the examples in such a way that they represent the activities and the decisions that they normally perform in their training sessions.

The first user proposed to the participants to write a document and save it in a folder. The main objective was to let participants realize that they can become autonomous users in performing this type of tasks (cultural intelligence and meaning creation in dialogic learning methodology). With this purpose, he chose the self-assessment activity and configured it according to his needs. In the second activity he wanted to increase the level of difficulty and edited a task that consists in creating collaboratively a document about the towns where they were born 3.10. Finally, he defined a negotiation activity in which the participants decide what they want to do in the next session. To support this activity, he recommended the use of the Doodle Web 2.0 (Doodle, 2011) tool as suggested by the UoL (Figure 3.11). These two last activities are typical when using the interactive group methodology. Since, he did not need a forth activity in the UoL, he set the design of the UoL as finished.

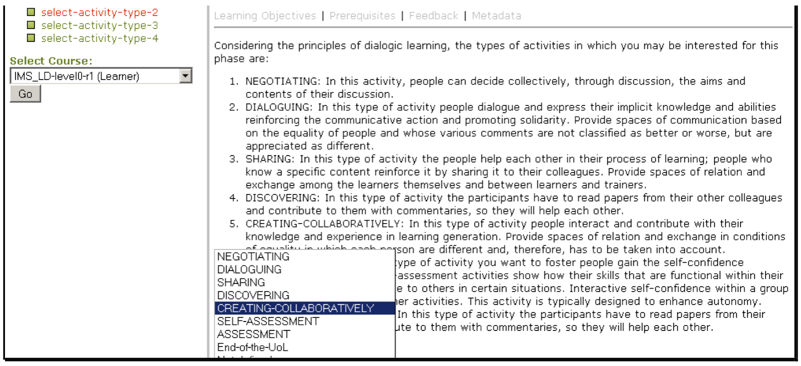

Figure 3.10: The user selects the creating collaboratively activity as the first one of the learning design.

The second user started by proposing an activity of dialoguing for letting the participants talk about the topic to work on in the class. She attached a file with a guide for preparing a learning activity and she asked the participants to provide a file with their ideas. After this, she proposed the participants to use different Internet browsers so that they search for resources to complete their learning design proposal. For this purpose she selected the creating collaboratively activity and propose a list of searchers as supporting tools. As a final result of the class, she asked the participants

Figure 3.11: The user selects the activity negotiation as the third one. He proposes the recommended tool Doodle as the supporting tool.

to provide a document with the result of the searches performed.

After these trials we performed a short questionnaire about the usefulness of the tool and the feedback was overall positive. Users remarked the appropriateness of the list of activities provided to cope with the heterogeneous groups usually attending the sessions. They also proposed to add a data base functionality for searching examples by type of group or activity. Another aspect stressed by the trainers is the flexibility needs of these blended learning situations and the need of tools addressing these needs. Finally, they also found useful to have the possibility of including more than one resource in each activity. More information about this evaluation and the comments of the users are collected in the paper III of the Appendix B.

Therefore, these results show that the meta-UoL is a good solution for operationalizing the PM factor by including the decisions of the users (P factors) when applying democratic methodologies such as the dialogic learning and interactive groups. Moreover, this solution represents the first proposal that successfully integrates authoring with enactment in the context of the IMS LD specification for this type of learning practices thanks to elements considered in the I factor about the PM and the P factors.

5.2 Synthetic experimental environments with a solution for managing groping tasks in blended learning contexts

The main aim of the controlled case study was to understand the effectiveness of the proposed solution to support the group formation management in front of a manual process. The main questions of interests were:

1. Do the users find helpful to have a semi-automatic tool for the group management in collaborative activities?

2. Is the tool flexible enough to freely adjust the groups to the unexpected situations?

3. Does the tool support correctly the whole process and in which situations?

Two different scenarios were prepared for he controlled case study: one for the Jigsaw CLFP and the other for the TAPPS CLFP. Both scenarios described a CLFPs in the context of an e-Learning course of 13 students. The task of the proposed to the teacher consisted in organizing the students in groups according to the restriction imposed by the collaborative activity proposed. The scenarios were delivered in a document containing an introduction to the context and the description phase by phase of the CLFPs pattern that should be applied. For analyzing the strategies used during the whole process we proposed two different tasks:

1. To prepare the group distribution of the potential students from a list according to the requirements of the activity before the class.

2. To adapt the groups previously defined to a set of unexpected situations that were described in the scenario as a simulation of the type of events occurring in real educational contexts (i.e. one of the potential students leave the class at the second phase of the activity or a new student joins the class when the activity have already started).

In all cases, the restrictions imposed by the CLFPs needed to be accomplished. Since the focus of the study was to understand if the tool facilitates the group management in comparison with a manual process we asked the users to perform the two tasks twice, firstly by hand and secondly using

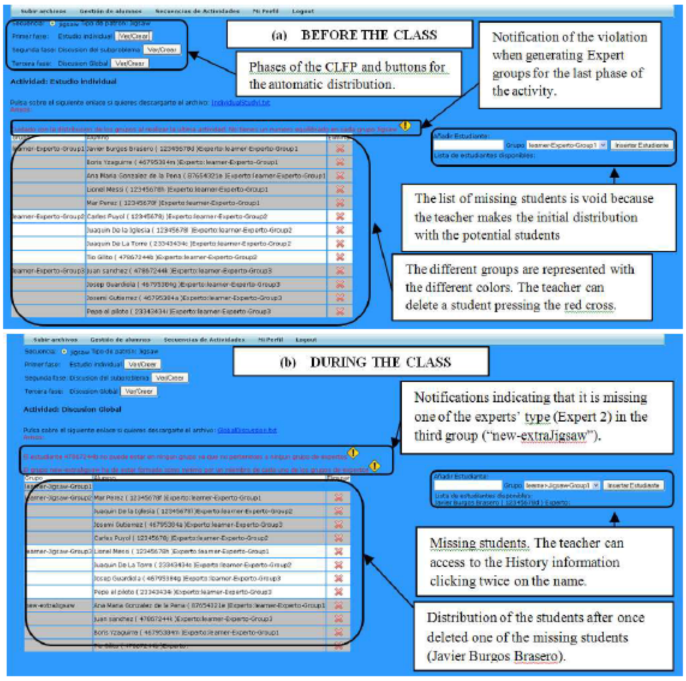

Figure 3.12: Interface of the Groping tool, an operationalization solution for flexibly managing groups of students.

the tool. Therefore, the evaluation process was divided into 3 phases: (1) familiarization with the CLFP and the context, (2) group management by hand and (3) group management using the tool (Figure 3.12 shows an image of the interface of the tool).

5 university teachers with 1 to 8 years teaching experience participated in the controlled use case. 2 of them were experts in CSCL practices whereas the other 3 had never prepared a collaborative activity following a CLFP. We assigned the Jigsaw scenario to the 2 experienced users and to 1 inexpert and the TAPPS for the remaining 2.

During the whole process the users were guided through the different situations by a template with a set of steps. For each step they were asked to explain the strategies followed for the group management and their final students distribution. All the resulting strategies and distributions were collected. Also, two different researchers were recording the observations on how the participants planned their group distributions and their spontaneous comments. Finally, the users answered a test with close and open questions in which they compared both, the manual and the technologically-supported processes.

All the quantitative and qualitative data gathered during the controlled case study (Process and outcomes described by users in a template, the observations from the researchers and the final questionnaires) were analyzed following a mixed method evaluation and triangulated to extract the main conclusions (see methodology in section 4.4 of this dissertation).

After the analysis the results show that such type of solution is useful mainly in two cases: 1) when performing complex collaborative learning activities in which there are many constraints to control and 2) when preparing activities with a big number of students. The evaluation also evidences that the introduction of a notification system and the hIstory (I) of the students is a good mechanism for guiding the users along the best solution for solving the non-fulfilled constraints.

For more details about the partial results of the controlled case study see the book chapter included in the Appendix B of this document.

5.2.1 Synthetic experimental environments with the solution considering the space factor in CSCBL scripting practices

For evaluating the solution for the Space factor operationalization we analyzed the usage of the tool proposed into two learning situations. Both learning situations corresponded to the same session of a e-Learning seminar at the Autonomous University of Barcelona of the academic years 2009 and 2010.

The activity prepared for this session consists in making the students reflect about the future of educational technologies. With this purpose, the teachers propose the reading of the "Horizon Report" (Johnson et al., 2009, 2010) of the corresponding year. Since this document is divided in three parts (1 year or less, 2 to 3 years and 4 to 5 years), teachers organize a Jigsaw activity for collaborative working on the different sections of the paper.

The activity is divided into three different phases: (1) an individual activity in which each student reads one of the parts randomly assigned by the teacher, (2) an expert group phase in which students having read the same part prepare a poster with the main ideas of this part and (3) a jigsaw group phase in which experts in different parts are joined together to explain the poster to the rest of the group members.

The first academic year that this experience was carried out, the activity took place in a room including two different areas: an area with three rows of tables with PCs facing a blackboard and with a screen projector, and a second area with three separated round tables for working in groups. Due to the arrangement of the space, the teachers organized the second and third parts of the activity in the following manner. Students accessed and read their assigned report parts from the PCs but for the expert group phase, each group was allocated to one of the tables situated in the work group area and worked together on their poster (see Figure 3.13). For the jigsaw group phase, students rotated through the different tables listening to the explanation of their colleagues using posters. In each rotation one of the owners of the poster had to stay at their table to explain it to the students coming to the table.

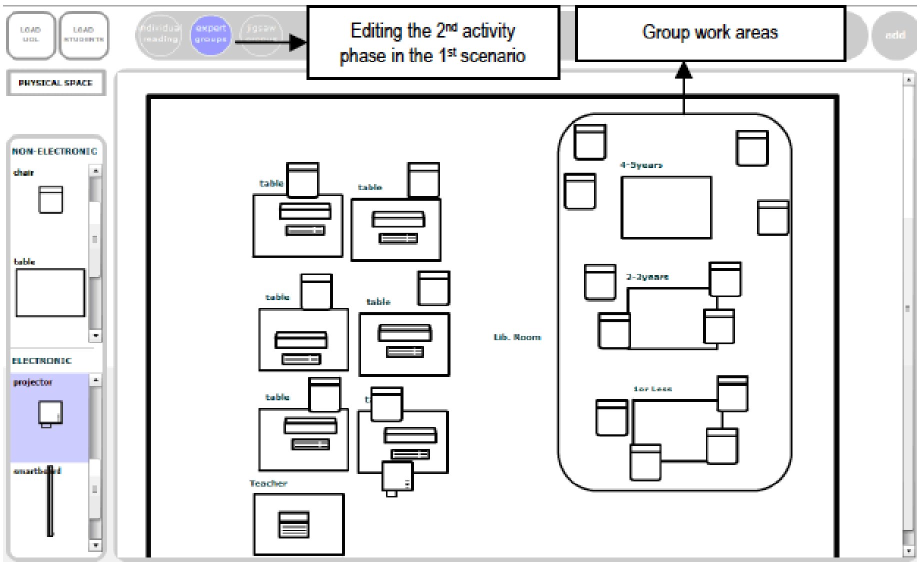

Figure 3.13: Representation of the space for the learning flow in the second phase of the first learning situation (first academic year).

The second academic year, the activity took place in another classroom. The room was composed of a set of aligned tables with PCs in rows facing the blackboard with a projector without any appropriate place for working in groups. In this case, the teachers decided to assign one of the rows of tables to each expert group for the poster preparation. However, due to the difficulty for the students moving from one table to another the jigsaw activity was modified. Each of the expert groups presented their poster in front of the whole collective class, without forming jigsaw groups and rotating from one poster to another. One of the groups decided to prepare a presentation (instead of a poster) and presented it using the projector (Figure 3.14). This turned out to be a good idea because the posters of the other two expert groups were difficult to read from the tables.

In this situation the differentiation between electronic and non-electronic component is important, for example, having an electronic portable projector totally changed the arrangement of the students in the classroom and the possibilities of presenting their work and the classroom organization. Students were located in front of the projector, which has to be located in a unique place in the classroom (ie. with a plug in source and a screen).

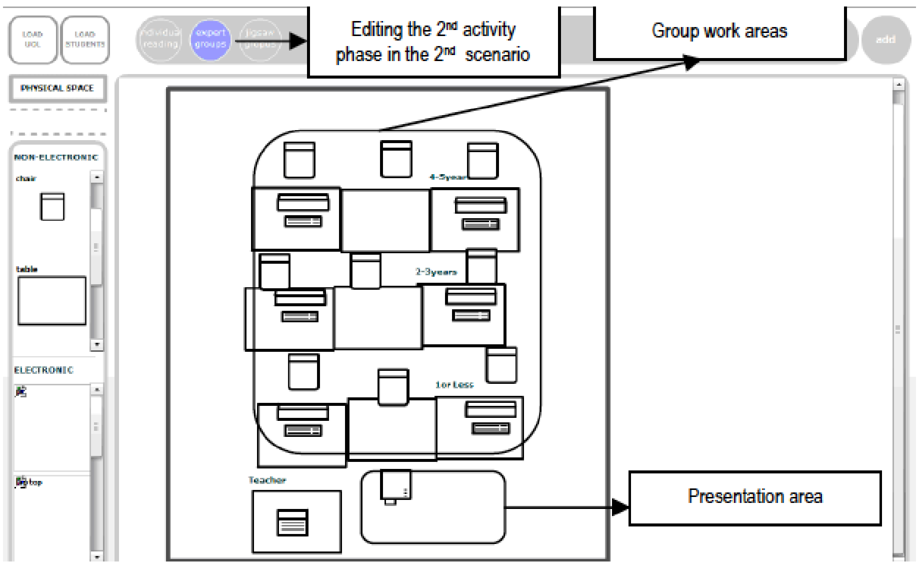

Figure 3.14: Representation of the space for learning flow in the second phase of the second learning situation (second academic year).

These two situations show how the enactment of an activity with the same learning flow is modified because of the space characteristics in which it takes place. In the first situation, the arrangement of the space elements permits the movement of the students around the class facilitating the interaction between the different expert groups. On the contrary, the classroom arrangement of the second situation constrains the students movements limiting the classmates interactions and then, forcing the learning flow to be changed. Therefore, this synthetic experiment shows how the S factor affects on the definition of PM.

Currently, the updated version of the space tool including the representation of the participants is being used by 6 practitioners of a primary school with evaluation purposes. The objective of this experience is twofold: (1) to analyze wether the tool is useful to make teachers reflect about the importance of the space when designing a CSCBL script and (2) to analyze the differences of the designs conceived with and without the tool and see whether the group management of the participants change or not depending on the spatial characteristics. The results of this case study are still under evaluation.

A new version of the tool is currently being implemented. It integrates a plug-in functionality that enables generating an XML file with the description of the space representation. This file can be validated in order to test whether it follows the relationships established in the model and integrated into a Unit of Learning represented with the IMS LD specification. The space specification is included as a new resource type referenced in the *environment* element of the IMS LD specification.

6 Summary

This section has presented the main contributions related with the design and operationalization of CBL activities.

The 4SPPIces model is proposed as an instrument for assisting practitioners and technicians in the design of CSCBL scripts. The model considers four conditioning factors: the Space (S), the Pedagogical Method (PM), the Participants (P) and the hIstory. The novelty of 4SPPIces falls on explicitly defining the space, highlighting the role of the history for modeling the aspects associated to the scripts enactment and on relating all these factors into one unique representation.

This chapter have also presented a variety of solutions for supporting the enactment of collaborative blended learning practices through operationalization of the different factors of the model. On the one hand, some third party computational systems fitting the requirements of the three CSCBL scripts enacted in the experiments have been analyzed. On the other hand, a set of approaches based on modeling languages and configurable tools have been presented as a solutions for solving the detected limitations of current existing solutions in CSCL when addressing the inherent characteristics of blended learning settings. These solutions have been evaluated in synthetic experiences with encouraging results.

Chapter 4

Two multicase studies for the evaluation of 4SPPIces

Not to be absolutely certain is, I think, one of the essential things in rationality.

Bertrand Russell

This chapter undertakes the evaluation of the design process that applies 4SPPIces for creating CSCBL scripts and their associated technology for operationalizing their enactment. This evaluation is addressed through a two interrelated multicase studies comprised of three separated case studies each. The first multicase analyzes the usefulness of 4SPPIces for supporting the design of meaningful and innovative CSCBL scripts adequate for the characteristics of particular contexts. The second multicase focusses on evaluating three different operationalization solutions for supporting the enactment of three CSCBL scripts. Four different experiments organized as case studies are analyzed from different perspectives in the multicases. Three of these experiements put into practice a CSCBL script with a different degree of operationalization into real educational contexts. The first one is designed to assist students in the transition from the high school to the university. The second proposes an extension of an activity of Geography at the secondary school. The third experiment offers a variation of the first CSCBL script for improving certain limitations detected in the first edition. Finally, the fourth experiment, only considered in the first multicase, analyzes how 4SPPIces is useful for enhancing scripted collaborative designs created by professionals in media education. The findings of each case study in the multicases are cross-analyzed to show the applicability of 4SPPIces into different educational contexts and to extract conclusions with regard to the main research question of this dissertation.

1 Evaluation methodology

The main research focus of this dissertation is to understand whether 4SPPIces is useful in assisting practitioners and technicians when addressing the design of meaningful CSCBL scripts and of the technology operationalizing their enactment. To tackle this main objective 4SPPIces-based CSCBL scripts require to be analyzed from both educational and technological perspective. On the one hand, it is important to see whether the CSCBL scripts are meaningful for the educational context they are designed to. On the other hand, it is necessary to analyze if the technological environment designed for the script enactment effectively supports teachers' and students tasks.

At the same time, this main objective can be separated into two different objectives:

1. To understand whether 4SPPIces is a good means for assisting technicians and practitioners in the design of CSCBL scripts adequate to the educational requirements.

2. To understand whether the operationalization solution proposed for the CSCBL script successfully support its enactment.

Only with a holistic analysis of CSCBL scripts from both educational (design) and technological (operationalization) perspectives of these two objectives will provide us with the information for evaluating the usefulness of 4SPPIces when applied to a particular context.

1.1 Case studies: investigation of a phenomenon in its context

The multidisciplinary nature of the objectives under study and their dependence to the educational context require evaluation techniques taking into account the context. The method that better undertakes an investigation of a phenomenon in its context is the case study.

Case studies belong to the observational category of software engineering technology validation models identified by Zelkowitz and Wallace (2002). These authors define within the observational category those models that collect data from projects that have already been completed. They also identify two other categories: historical (collects data from projects that have already been completed) and controlled (collects data from multiple instances of an observation for providing statistical validity of the results).

These two last methods were dismissed for the scope of this study. On the one hand, for adopting historical methods more experiments enacting CSCBL scripts created with 4SPPIces would be needed. On the other hand, employing a controlled method is not feasible because the CSCBL scripts analyzed are all implemented in authentic educational contexts with real users, which makes unfeasible the exact replication of the experiments.

Case studies have traditionally been categorized as lacking of rigorousness and objectivity compared with other research methods. One of the major reasons is the difficult generalization of the results because of the poor controls for later replication. However, case studies provide valuable information regarding the influence of technology in a particular context and have proved to be very useful on providing answers to "How" questions (Rowley, 2002). Case studies enable monitoring an authentic situation by extracting information from the data collected about the different attributes characterizing its development (Zelkowitz and Wallace, 2002).

Stake (1998) defines two different types of case studies depending on their purpose. When the purpose of the case is to learn about the particular case "itself" it is an "intrinsic" case study. Whereas, when the purpose is to have a general understanding about a research or research questions by studying a particular case it is an "instrumental" case study. Instrumental case studies, beyond learning about the educational situation itself, are instruments for researchers to understand the implications of specific interventions in the context of the particular case.

Therefore, since the main aim is to evaluate the implications of applying 4SPPIces to a particular learning context, the instrumental case study is the evaluation method that better fits our research scope. This evaluation method will help on analyzing and examining how putting into practice 4SPPIces-based CSCBL scripts affect and transforms actual educational learning contexts.

2 Two multicase studies

In this dissertation we propose evaluating the model usefulness of 4SPPIces applied to different contexts. With this purpose we perform two multicase studies comprised by three case studies each. The first multicase study (Multicase study Q1) analyzes the utility of 4SPPices from the perspective of the design of CSCBL scripts. Whereas the second multicase study (Multicase study Q2) is more focused on the operationalization issues supporting the CSCBL scripts enactment.

The cases in the multicases are instrumental since the serve to understand the intervention of 4SPPIces into an authentic educational context. Each case offers a different perspective of evaluation. The findings of each case will be cross-analyzed to extract conclusions about the main research question pursued with the multicase.

A multicase study is a methodology employed typically by educational researchers. When multicases are instrumental and the objective is to study the effects of the technology in context, multicase studies can be adapted and successfully applied in more engineering-oriented studies (Hernández-Leo et al., 2010). Multicase studies have been also adopted in other disciplines when the valuation involves human-related real experiences (Barnes et al., 2002; Alavi and Gallupe, 2003).

Because of the engineering-oriented and multidisciplinary nature of the object under study and its dependencies on the context, a multicase study appears to be an appropriate methodology for the evaluation. Moreover, we contend that a multicase study analysis is an effective methodology for providing multiple perspectives of the same proposition for a stronger validation.

However, it is worth noticing that we do not apply the multicase methodology orthodoxly. For Stake a multicase study is a large evaluation that require the participation and collaboration of different researchers during a long period of time to study the experience of real cases operating in real situations (Stake, 1998, 2006). In this dissertation, despite of using the methodologies and techniques in multicase studies, we adapt multicase approach to our purposes as an instrument or a mechanism to structure the evaluation phase of this dissertation, to provide a systematic analysis of all the cases under study and facilitate the cross-analysis of their findings. Also, we use the terminology of multicase studies proposed by Stake to facilitate the comprehension of the whole evaluation structure.

2.1 Cross-case analysis procedure

Findings of each of the cases in the multicase treated independently gives isolated information about the quintain driving the multicase in its particular situation through its functioning. However, the main interest of the multicase methodology relies on cross-analyzing the different case findings in the multicase to enrich the understanding of the main research questions.

A cross-analysis allow taking evidence from the case studies to show how uniformity and disparity characterizes the quintain to provide interpretations across cases. In this way, the quintain can be understood by studying the commonalities and its differences across manifestations, represented here as the different cases in the multicase. Notice, however, that the idea is not to find what is common across cases, but what makes them unique in order to get information about the quintain from different perspectives. At this point of the analysis, the situationally of the individual cases is less important that the understanding of the quintain (Stake, 1998).

For the cross-analysis, we take the themes, originated from the quintain, and the findings, which give a perspective of the quintain of the particular activity and context of each case and treat them together for writing assertions or " the findings about the quintain Stake (1998)". Each assertion needs to be based on evidence, which correspond to the data behind the findings of each case.

The procedure for systematically carry out the cross-analysis consists on applying the findings of situated experiment to the research questions derived from the quintain. Or what is the same, to organize each of the findings in a matrix with the themes themes (formulated as research questions) of the multicase. This matrix also rates the importance that of each finding in relation to the theme. For rating the cases we use the notation proposed by Stake: **H**= high importance; **M**= midding importance; **L**= low importance.

A high mark means that of this theme, the case finding is of high importance. This organization mechanism will facilitate extracting the assertions about the quintain. The cross-analysis of the cases in each multicase study are presented after presenting their findings.

3 Summary of the experiments considered in the multicase studies

Four different experiments analyzed as case studies are the basis to form the cases involved in the multicase study:

- An authentic educational experiment that puts into practice a CSCBL script designed to help students in the transition from the high school to the university by facilitating their first contact with the campus, its services and the university community, methodologies and activities.
- A CSCBL script designed for improving and extending an activity of Geography at the secondary school in which students visit Barcelona in order to reflect about its urbanism and socio-geographical characteristics of the city.
- A variation of the first CSCBL script for improving certain limitations detected in the first experiment.
- A seminar in which different professionals in media education use 4SPPIces for enhancing in collaboration with technicians their scripted collaborative practices previously designed without the model.

These experiments are organized in different cases depending on the multicase in which they are examined. The following sections summarize the context and characteristics of each of the experiences, the methodologies applied for the analysis and the the main findings of each multicase. In section 4 we explain how these experiences are organized in cases for the multicases Q1 and Q2.

3.1 Experiment Discovering the Campus 2009

Discovering the Campus 2009 is an authentic educational experiment that puts into practice a CSCBL script in the context of the Information and

Communication Technologies Introduction (ICTI). ICTI is a compulsory subject for first-year students of three ICT engineering degrees (Computing, Telematics and Audiovisual Systems) offered in the new curriculum of Pompeu Fabra University (UPF). One of the purposes of this subject is to facilitate students a first contact with the campus and its services, the university community, methodologies and activities (the paper is also attached in the Appendix B, paper IV, of this document).

3.1.1 Deployment of the experiment Discovering the campus 2009

The CSCBL script combines individual and collaborative activities conducted in and out of the classroom and structured following the Jigsaw Collaborative Learning Flow Pattern (Hernández-Leo et al., 2008) into three phases distributed along two weeks:

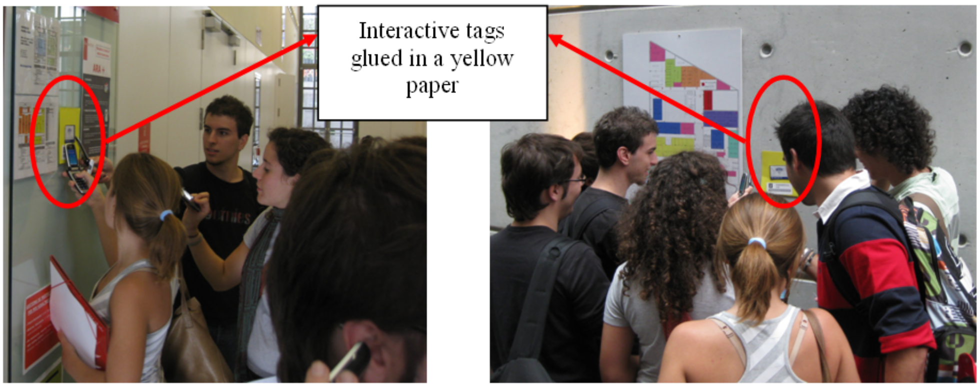

Figure 4.1: Students interacting with the NFC tags during the exploratory activity in the experiment Discovering the Campus 2009.

1. "Discovering the Campus" (adaptation of the individual phase in the Jigsaw CLFP): Students freely explore some selected areas of the campus in order to become familiar with the services provided. At the end of this phase, all the students are asked to fill in an online questionnaire about the different areas visited during the exploration, their preferred buildings and main services.

For the exploration, students had three different options: (1) to access the University Web Page (UPF, 2011), (2) to walk around the campus, read the posters fixed on key areas of important buildings of the campus and ask other students more familiar with the campus, or (3) to participate in an exploratory activity using mobile phones. The students could choose one, two or the three options.

The third choice was especially designed for the ICTI course. A set of 46 interactive tags containing information about the five main buildings of the campus were prepared and distributed along the different areas of the campus by two teachers. Every student was provided with a mobile phone. Students had 20-30 minutes to freely explore the different areas and to discover the information, which was hidden in the interactive tags, using a mobile phone. The stream of tags accessed by each student was stored in a log file in the mobile phones.

After the exploratory activity, students had to fill in a web-based questionnaire in Google Forms (Google, 2011).

2. "Explaining the campus" (adaptation of the Expert groups phase in the Jigsaw CLFP): Students are distributed by the teacher in groups of 4 to 5 people and assigned as experts in one of the five areas of the campus. Each group prepares a presentation about the area they are experts in and uploads it into the Moodle platform (the Moodle platform facilitated by the University). The teachers upload all the presentations into a public repository so that all the students can have access to them.

   The students' expertise is defined by the areas and buildings that each of the students visited (physically or via web) in the first phase. For the students that performed the exploration with mobile devices this information was recovered from the log files. For those who performed the activity via web or walking, the information was extracted from the answers to the final questionnaire.

3. "Reflecting about the campus" (adaptation of the Jigsaw groups phase in the Jigsaw CLFP): Due to the lack of hours for making oral presentations and the huge number of students registered to the subject, this activity is conducted individually.

   Each student reviews the presentations designed by their classmates and fills in a questionnaire of 20 questions about the campus.

241 students ranging in age from 18 to 25 years and three teachers of the ICTI course participated in the experiment. For the exploratory activity, from this 241 students, 74 chose voluntary doing the exploratory activity with mobile phones and the other 167 one of the other of the two options. See in Figure 4.1 a picture of students interacting with the NFC tags.

3.2 Experiment Discovering the Campus 2010

Discovering the Campus 2010 is an authentic educational experiment that puts forward another CSCBL script to deal with the orchestration limitations detected in the first version of the activity Discovering the Campus 2009. Particularly, this experiment is proposed to improve those tasks done by hand by the teacher in the 2009 edition: the expert assignment process, the expert groups management and the activity workflow for distributing the tasks among the different groups. This solution also provides the technological support for facilitating the replication of the experiment with a reasonable cost in future editions making the experiment scalable.

Both the educational objectives of the activity and the context in which the activity is enacted is the same that in the first 2009 edition of the experiment (see Pérez-Sanagustín et al. (2011)). In this case, however, the activity was deployed into four different two-hour sessions for 25 students each instead of being a two-week activity so as to allow all the students to make the exploration of the campus with mobile phones. The main difference with this previous version relies on the way the CSCBL script is operationalized.

Concretely, the CSCBL script proposes a Unit of Learning (UoL) codified in IMS LD complemented with a Generic System Integration system (de la Fuente-Valentín et al., September 2009) to structure the learning flow and automating the task distribution between groups. This solution allows formalizing the learning flow for automating the connection among the phases in the learning flow as well as the students tasks assignments. Other software complements the solution providing the mechanism to analyze the log files and to generate the expert groups automatically. In a Google Spreadsheets Google (2011) generated from this automated process teachers can see and change the expert groups characteristics according to their needs by directly manipulating the values in the spreadsheet. See paper de la Fuente-Valentín et al. (2010), also attached as paper II in the Appendix B of this document.

3.2.1 Deployment of the experiment Discovering the campus ‘10

As in the previous edition of the experiment (2009), the CSCBL script combines individual and collaborative activities conducted in and out of the classroom and structured following the Jigsaw Collaborative Learning Flow Pattern Hernández-Leo et al. (2008). However, in this experiment, the CSCBL script is operationalized through a UoL codified in IMS LD completed with the Generic System Integration combined with Kit Mobile phones and NFC tags. This makes possible to significantly reduce the time for the experiment from two weeks to two hours. Therefore, the workflow changes slightly with respect to the first version of the activity.

The UoL supporting the CSCBL script is designed to support five working groups of five persons in the same session; i.e. 25 students per session. Differently from the previous version, students receive the orchestration information through the computer instead of receiving the instructions from the teacher. However, the script still combines on-line and offline activities occurring around the campus. In the following we detail the resulting learning flow by highlighting those aspects that differ from the previous edition of the activity.

1. “Discovering the Campus”: The UoL define two different roles to define the participants taking part in the course: learners and teachers. These are the roles defined in the UoL. The UoL is presented to the students using the *.LRN* platform (.LRN, 2010). Learners are divided into two groups: one performing the exploration of the campus with the mobile phones and the others using the web. Learners swap activities after 20 minutes. After each of the two exploratory activities, the students perform an online questionnaire. Both, the campus exploration with the mobile phones and the web are the same than in the 2009 edition of the experiment.

   The answers to the questionnaire and the mobile activity logs are stored in a Google Spreadsheet. The log analysis is done automatically and produces a *csv* file with a summary of the events generated by each student. This file summary is uploaded to the spreadsheet and contains for each student: (1) the number of tags accessed per building and (2) the building expertise, which is the building with the maximum number of tags accessed.

2. "Explaining the campus" (adaptation of the Expert groups phase in the Jigsaw CLFP): The students distribution in expert groups is done semi-automatically. The spreadsheets where all the information about the exploratory activity is stored also includes a set of formulae for automatically forming the expert groups automatically by taking into consideration the information of the log files and students' answers to the questionnaires. The final distribution can be manipulated by the teacher according to his/her interests.

   Once the grouping phase has finished and no more group changes are expected, the teacher marks the activity as finished in the UoL. This action synchronizes the UoL with the information in the spreadsheets. Each student is shown with the group s/he belongs to and the activity that they have to perform depending on the building they have been assigned to. All the groups work together in the presentation of the building and upload it into the system.

3. "Reflecting about the campus" (adaptation of the Jigsaw groups phase in the Jigsaw CLFP): In this phase, the teacher only press a button to automatically send the delivery of the previously submitted presentations to the rest of the groups. Students may review all the presentations and access to the final assessment task.

   Differently from the previous edition, the assessment task is questionnaire conform with the IMS Question & Test Interoperability (QTI) specification Students access this test through a link in the UoL. The test is composed of 5 questions: 3 common QTI questions (Multiple Choice, Yes/No and Multiple response) and 2 Google Maps-based QTI questions (Navarrete et al., In press). For these questions, students locate their answer in a Google Maps map.

31 students and 4 teachers participated in the activity enactment. More students were initially registered to the experiment, but the bad weather conditions many drop outs reducing significantly the final number of participants compared with the 74 students that did the explorative experiment with mobiles in the first edition of the activity.

3.3 Experiment Discovering Barcelona!

Discovering Barcelona 2009 is an authentic educational experiment that puts into practice a CSCBL script in the context of a Geography course at a high school in Catalonia. The script is proposed as a solution to deal with the limitations detected in previous academic years, in which students visit Barcelona in order to reflect about its urbanism and socio-geographical characteristics.

Concretely, teachers detected three main limitations from previous practices to be improved: (1) including the visit of more than one district in Barcelona into an activity that has only been doing in one neighborhood of the city, (2) introducing a collaborative component into an activity that is been traditionally individual and (3) introducing the use of technologies into an activity that have traditionally used dossiers to guide and support the students.

The CSCBL script was participatorily designed in collaboration with the teachers of the course using 4SPPIces. 4SPPIces is employed as the collaborative design framework to achieve a CSCBL scenario adapted to the needs of the educational context under study. The resulting experiment combines and integrates individual with collaborative activities supported by mobile and computer-based technologies conducted at the classroom, home and the city.

3.3.1 Deployment of the experiment Discovering Barcelona!

"Discovering Barcelona!" is structured in a learning flow with 4 phases (see paper V in the Appendix B):

1. "Assigning districts": The 34 potential students are distributed into 6 groups of 5 or 6 people. Each group member is asked to answer individually an online questionnaire in Google Forms (Google, 2011) about the different districts of Barcelona at home using their personal PC. The objective is to define the students profile with their initial knowledge from the city is and their main preferences with regard to one or other district. The information obtained from this questionnaire is used to assign the groups to a particular district associating them to an area that they do not already know, in order to maximize their potential learning, as follows: when most of the group members fail the questions about a district, the group is assigned to this district. The groups in this phase are the groups for the following phases.
2. "Discovering the district": This phase is based on the learning flow Collaborative Learning Flow Pattern Guiding Questions (Hernández-

Leo et al., 2008). The idea of this pattern is to provide the students with a list of questions that they should be capable of answering as they advance in the task. These questions are expected to help the student in focusing their attention on the important issues of the task. The questions are distributed and geo-located across 6 different districts in Barcelona forming 6 different routes: Sarrià, Gràcia, Ciutat Vella, SantMartí, Les Corts and Eixample. This means that in the same phase there are 6 groups performing the exploratory activity simultaneously in 6 different spatial locations. The students answer the questions along the route when arriving to the specific geo-located point. Each question has an associated feedback that guides the students to the next question and gives them hints about the urban and social characteristics of the area.

Also, the activity proposes to assign a role to each of the group members as a means to assure an appropriate task distribution, to foster the individual responsibility, mutual support and positive interdependence (Roschelle et al., 2010). The roles agreed with the teachers are: (1) the Mobile Phone Manager (in charge of wearing the device, read the questions to the rest of the group members and answer it according to the whole group opinions), (2) the Guide (in charge of guiding the rest of the group through the streets with a map created for the different districts), (3) the Photographer (in charge of taking representative pictures justifying all the aspects specified by the teacher and uploading them to a web application specially developed for the experiment), (4) the Question Helper (in charge of taking notes of the ideas and comments related with each of the questions of the route) and (5) the Observer (in charge of annotating the main aspects and comments related with the characteristics of the district specified by the teacher such as the morphology of the streets, the number of parks or the public services available).

3. "Reflect about your district and learn about other districts": In this phase the students prepare a presentation about the district they visited. They can use the notes, observations and pictures taken during the route. Each group has to present their work in the classroom to the rest of the students and deliver it to the teacher two weeks after the exploratory activity. The outcomes from the previous phase are used here as an input for preparing the presentation.

4. "Test your colleagues": Students can propose questions about their as-

signed district to their colleagues. Then, they can individually choose any of these questions and answer them as a self-assessment activity. Unfortunately, this phase, although originally present in the scenario designed, was deleted in the last-minute because of time limitations (coincided with the Spanish official end of high school examinations). Therefore, no data about this phase have been considered for the case study evaluation.

Figure 4.2: Students interacting with the GPS mobile phones during the exploratory activity in the experiment Discovering Barcelona.

34 students, 2 teachers (one main teacher and one assistant) of the Geography course and 2 technicians participated in the experiment. Figure 4.2 shows two images of the experiment.

3.4 Experiment Seminar with 4SPPIces

This experiment involves the participation of professionals in media education (as a practitioners) and technicians (as consultants) that work collaboratively in the design of CSCBL scripts. The practitioners are invited to design different collaborative blended learning scenarios with activities involving the use of ICTs. In the first iteration, they do not use the 4SPPIces model, and in the second iteration they do use it.

For preparing the non-4SPPIces-based designs the practitioners use the tool LdShake (Hernández-Leo et al., May 2010). LdShake is a tool for sharing and co-editing any type of Learning Designs.

For creating the 4SPPIces-based designs they use a tool called 4SPPIces specially created for the experiment. 4SPPIces tool is a web-based application that guides practitioners in defining the facets described in the four factors of the model through a set of questions in a formulary that they have to fill. The resulting CSCBL designs can be shared with a technologist or other practitioners in order to suggests the technological support that better fits the objectives of the designs.

3.4.1 Deployment of the experiment Seminar with 4SPPIces

The seminar is structured into two sessions as follows:

- In the first session of the seminar, for the practitioners to get familiar with CSCBL scripted type of activities, they are invited to read two real case studies in which two different CSCBL scripts are enacted. After reading these two cases, they are asked to design in LdShake two CSCBL scripts related with a topic of their interest.

  They have one week to finish their designs.

- In the second session, participants are grouped according to the topics of their designs of the first session and asked to re-design or define a new CSCBL script using the 4SPPIces tool.

  They have one week to finish their designs. During this week, they can share their designs with the technicians registered into 4SPPIces tool to received feedback about their designs and opinions about how they could be improved using different technologies.

  After these week the designers are asked to answer a questionnaire about their experience and make a reflection about the 4SPPIces model.

10 designers and 2 technicians participated in the experiment.

3.5 Alternative deployments: other operationalization solutions

As we already mentioned in the previous chapter 3, the operationalization solutions used for the deployment of the experiments "Discovering the campus 2009 and 2010" and "Discovering Barcelona" were selected according to the requirements stipulated of the CSCBL script enacted. However other operationalization solutions could be employed. In the following, we discuss how some the operationalization solutions that we proposed in section 4 of chapter 3 could adapted to support the particular requirements of the three CSCBL scripts.

The Grouping tool based on considering the intrinsic constrains of the Pedagogical Method factor when interplaying with the Participants factor could have been employed for organizing the group distribution in the "Discovering the campus 2009" experiment. This experiment is based on a Jigsaw CLFP and the Grouping tool considers this pattern. However, some modifications should have been performed on the tool. It should have been introduced a module to enable the teacher differentiating between the building expertise according to the number of NFC tags visited from each building.

In the same way, this tool could have been employed for forming the groups in the "Discovering Barcelona" experiment. However, it should have been modified also according to the intrinsic constraints not only imposed by the script but by the teacher interests.

Also, the 4SPPIce-Space web-based graphical tool could have be modified in order to support the representation of the different buildings in the campus for both "Discovering the Campus" experiments. In this way, it would have been possible for the teachers to situate and organize the different tags around the campus and having a graphical visualization of the students' actions of the the tags distributed at runtime.

In addition, it is noticeable that, the modelling techniques employed for implementing the meta-UoL and adaptive UoL (both compliant with IMS LD) guided the implementation of the UoL proposed for the "Discovering the Campus 2010" experiment. The UoL implemented for this experiment included adaptive structures depending on the roles of the students.

4 Formulation of the complementary multicase studies

This section describes the formulation of the evaluation using and adaptation of the the terminology and structure of a multicase study defined by Stake (1998, 2006) and the one proposed by Hernández-Leo et al. (2010).

4.1 The quintain

Multicase research starts with the ***quintain***. A quintain is an object or phenomenon or condition to be studied Stake (1998). The quintain is "what we seek to understand", the final evaluation goal of the multicase. Cases comprising the multicase are related through the quintain. In other words, the quintain is the umbrella for the cases involved in the evaluation, the concept or idea that holds all the cases together.

In this work, the quintain is directly related with the main objective of the dissertation: **4SPPIces assistance for technicians and practitioners in the design of meaningful and innovative CSCBL scripts and the technology operationalizing their enactment**.

Formulated as a research question, the quintain is: *Does 4SPPIces assist technicians and practitioners when designing meaningful and innovative CSCBL scripts adapted to the needs of actual educational context and on identifying the requirements of the technology for operationalizing their enactment?*.

Two main aspects are addressed in the quintain. On the one hand, the 4SSPPIces assistance for the design meaningful and innovative CSCBL scripts. On the other hand, 4SSPIces assistance for the identification of the technology for operationalizing the CSCBL scripts enactment. In other words, the same quintain can be analyzed from two perspectives: the design and the operationalization of CSCBL scripts.

According to these two perspectives, and following the terminology proposed by Stake (1998), we define two new quintains (or sub-quintains) that allow us to formalize the multicase analysis as a combination of two different multicase studies. The analysis of the cases in each of these these multicase studies is driven by one of these sub-quintains. The results obtained from each multicase study will give information about the main research question in this dissertation.

The two different sub-quintains derived from the quintain are:

- **Sub-Quintain 1 (Q1):** *Does 4SPPIces assist technicians and practitioners when designing meaningful and innovative CSCBL scripts appropriate to the educational requirements of a particular learning context?*

- **Sub-Quintain 2 (Q2):** *Do 4SPPIces-based operationalization solutions successfully support the enactment of the CSCBL script?*

Q1 has to due more with the design aspects of the CSCBL scripts that make them meaningful and innovative for a particular learning context; i. e. whether the CSCBL script created in a collaborative process with technicians and practitioners covers the practitioners' learning expectations and introduces the innovative and motivational aspects of the script compared with other practices.

Q2 is more related with those aspects regaridng the technology operationalizing the CSCBL script enactment; i. e. whether the students' and teachers' tasks have been successfully supported during the enactment.

Therefore, two complementary multicase studies are proposed to investigate the main research question addressed in this dissertation: one multicase driven by the quintain Q1 (Multicase study Q1) and another one driven by the quintain Q2 (Multicase study Q2). Both multicases are complementary since they provide information about the main research focus from two different perspectives, the design and the operationalization.

4.2 Themes, functions and issues

A multicase study is organized around research questions or *Themes* derived from the quintain and the *functioning* relating the multicase studies comprising the multicase with the quintain.

Themes lay the foundations of the conceptual infrastructure for building the study and organizing the case studies comprising the multicase. Themes indicate primary information about the quintain that we seek.

The functioning is what makes each case different to the other and what makes the case interesting to be included in the multicase. Each case gives information about the quintain from the perspective of its functioning. These cases are opportunities to examine functioning, but the functioning is not the case.

In this evaluation, themes are extracted from the two different quintains Q1 and Q2 driving the two different multicase studies:

- **Themes derived from Q1:**

  - **Q1-T1:** Does 4SPPIces assist practitioners and technicians?
  - **Q1-T2:** Are the CSCBL scripts designed meaningful, innovative and adequate to the learning context?

- **Themes derived from Q2:**
  - **Q2-T1:** Does the operationalization solution successfully support teachers' orchestration tasks during the enactment?
  - **Q2-T2:** Does the operationalization solution successfully support students' tasks during the enactment?

For each multicase, case studies intervening in the analysis will be organized according to the themes addressed in the multicase and their functionings.

4.2.1 Functions and Issues

The relation of the case studies comprising the multicase with the quintain is called *functioning*. Each case involved in the multicase is a manifestation of the quintain related with a functioning that reflects its main purpose (its function) within the multicase.

Both Multicase study Q1 and Q2 are comprised by three cases analyzing one or two of the experiments explained in the previous section 3. Each case involve a different functioning within the multicase they belong to.

The functioning of the cases related with Multicase-Q1 is **the usage of 4SPPIces for designing innovative and meaningful CSCBL scripts adequate to a particular learning contexts**. So, each case proposes, analyzes and evaluates wether 4SPPIces support the design of meaningful and innovative CSCBL scripts adapted to different contexts covering the expected learning objectives of the practitioners.

The functioning of the group of cases related with Multicase-Q2 is the **degree of operationalization of the CSCBL script**. In particular, each case proposes, analyze and evaluates the successful and limitation aspects of the solution proposed for operationalizing the CSCBL scripts enactment.

Functionings and cases have also associated an *issue* that reflects the importance of the case within the study. An *issue* is the main research question associated to the case and is always related with its functioning. Issues are not information questions. However, issues have a set of associated topics and information questions that help on conceptually structuring the case and interpreting the study. The functionings with associated issues and cases are organized according to the two themes derived from the quintain of the multicase.

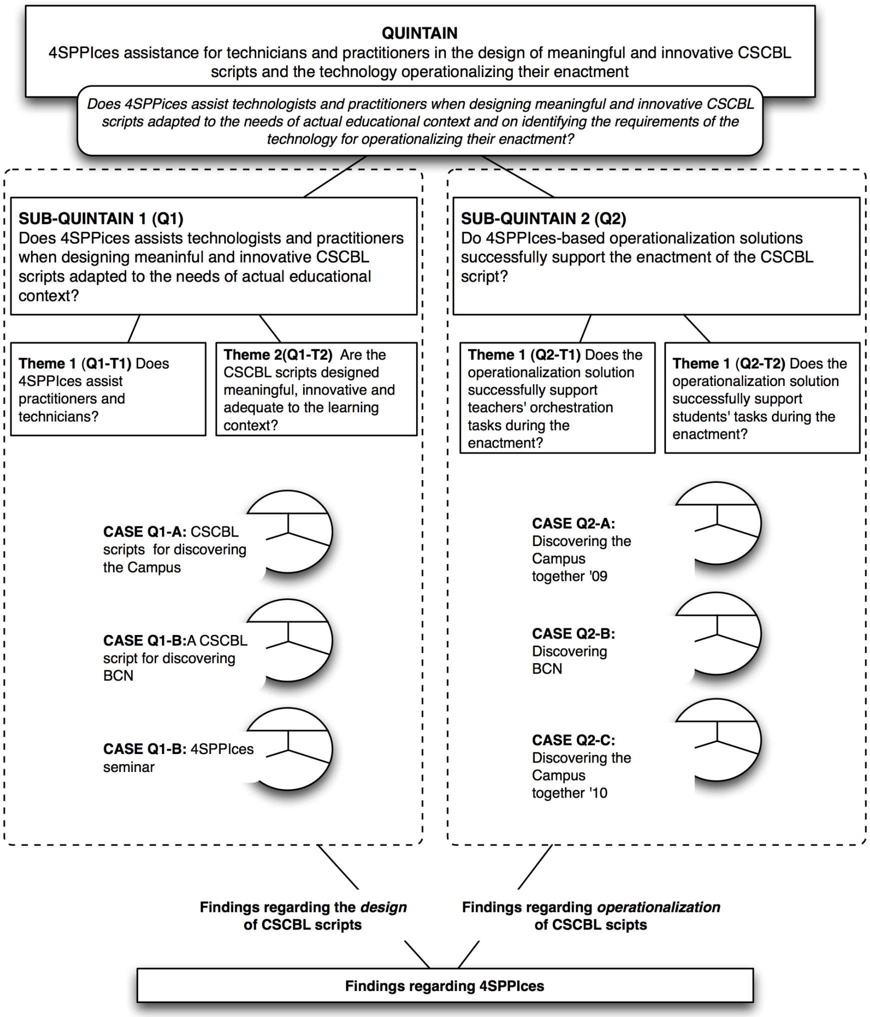

Figure 4.3: Graphical representation of the two interrelated multicase studies. Quintain, themes, functionings and their related case studies.

Name of the experiments and date	Functioning within Multicase-Q1	Functioning within Multicase-Q2	Interveiwees	Deployment & Sites	Materials and computational mechanisms	Data gathering techniques
Discovering the campus '09 (2009 September 23th)	Case Q1-A: Creating a CSCBL script from a scratch with 4SPPIces	Case Q2-A: S-focussed CSCBL script operationalization	241students and 3 teachers	1.Discovering the campus 2.Explaining the campus 3.Reflecting about the campus	Moodle with links explaining each phase and the materials of the experience Kit Mobile phones + NFC tags + Campus Maps	[Quest-Experience-eg], [Quest-Experience-eg], [Observations], [Video], [Quest-Campus-phase1], [Presentations-score], [Quest-Score-phase3],[Quest-Reflection-phase3], [Quest-teachers]
Discovering Barcelona (2010 April 30th)	Case Q1-B: Extending a design with 4SPPIces	Case Q2-B: S&P-focussed CSCBL script operationalization	34 students and 2 teachers	1.Assigning Districts 2.Discovering the district 3.Reflect about your district 4.Test your colleagues	GPS mobile phones + QuesTInsitu for the exploratory activity Moodle with links to the explanations and materials of the activity	[Meetings], [e-mails], [Q-st-route], [Q-st-final], [Q-t-route], [Q-t-final], [Observations], [Videos-route], [Videos-presentations], [Presentations]
Discovering the Campus 2010 (2010 Setember 21st)	Case Q1-A: Creating a CSCBL script from a scratch with 4SPPIces	Case Q2-C: S&P&PM-focussed CSCBL script operationalization	31students and 4 teachers	1.Discovering the campus 2.Explaining the campus 3.Reflecting about the campus	.LRN platform with a link to the UoL Kit Mobile phones + NFC tags + Campus Maps QTIMaps questionnaire	[Students Quest], [Teachers Quest], [Students Tests Marks], [Observations], [Videos], [Students outcomes], [Marks]
4SPPIces seminar (2011 March 22nd and April 4th)	Case Q1-C: Enhancing designs with 4SPPIces	-	10 practitioners 2 technicians	1.Session introducing to CSCBL scripts examples and designing a CSCBL script without 4SPPIces 2.Session introducing the 4SPPIces Tool and designing 4SPPices-based CSCBL scripts	2 documents with the examples of the two CSCBL scripts LDShake and 4SPPIces tool	[LdShake-Designs], [4SPPIces-Designs], [Designers Reflections], [Designers Quest]

Table 4.1: Summary of all cases involved

5 Structure of the two multicase studies

Figure 4.3 shows an schema of the multicase specifying the main research question as the Quintain of the multicase study, the two multicase studies Q1 and Q2 derived from this main research focus with their respective Quintains, the functioning and the associated case studies. Notice that some of the experiments are analyzed twice, once in each multicase.

5.1 Cases involved in the multicases

Table 4.1 shows the summary of the experiments explained in section 3 and how they are organized in the different cases of the two multicases.

5.2 Methodologies applied to the different cases

All the data obtained in each of the experiments involved in the multicase studies has been aggregated and analytically compared using a mixed evaluation method. Also, all 4SPPIces-based CSCBL scripts generated in the different experiments are the result of a participatory design process with practitioners. This section details the characteristics of the Mixed Method and Participatory Design methodologies applied in this dissertation.

5.2.1 Data analysis methods

To understand the impact of using 4SPPIces into the different context of the experiments comprising the multicase studies it is crucial to analyze both the technological and learning objectives. For that, it is required to consider qualitative and quantitative data. Only by considering both types of information can we gain an in-depth understanding of the whole 4SPPIces-based system within its context.

Since we are used diverse case studies as a basis of the evaluation, we require using evaluation techniques taking into consideration the context. To capture information from the context we mix quantitative data coming from closed questions or log files and qualitative data such as observations, comments of the interviewers, open questions. This technique is specially interesting for the experiments that put into practice a CSCBL script into an authentic learning situation (Johnson et al., 2007; Maxwell and Loomis, 2003). The quantitative data are useful for showing trends, and the qualitative data provide an in-depth understanding of the CSCBL script enactment(Cairns and Cox, 2008; Martínez et al., 2006; Morse, 2003).

Mixed methods are applied into three phases:

1. Definition of a scheme of categories: this can be done empirically according to past experiments or theoretically, according to the specific objectives of the experiment. New categories can emerge throughout the study, which means that this initial definition can vary.

2. Data collection: collecting qualitative and quantitative data using different techniques. This should be done before, during and after the experiment and selecting the most appropriate techniques for the categories from the first phase.

3. Analysis and interpretation: this is a cyclical process in which the quantitative data is pre-processed using statistical analysis. The quantitative data supports the arguments interpretation from the qualitative information.

As we work with qualitative data, the critical point comes when interpreting it in order to extract conclusions. In this types of studies, the purpose is not to demonstrate a hypothesis but to detect general tendencies in the use of a technology in a given learning context. For this, we will use a method called triangulation" (Gahan and Hannibal, 1998; Guba and Lincoln, 1981). This method consists of reinforcing each of the interpretations extracted through a comparative analysis of evidence provided from different sources. That is, to analyze each conclusion from a different perspective in order to have several confirmations supported by both qualitative and quantitative data.

Table 4.1 and Figures 4.4, 4.5, 4.6 and 4.7 show the data gathering techniques employed for the mixed method techniques in each experiment.

5.2.2 Participatory Design Method

Participatory Design methodologies imply the use of theories, practices or methods that enable the people destined to use technological solutions to be involved in their design (Ehn, 1993; Bødker et al., 1993). PD is a field of research and an evolving practice among design professionals. Researchers

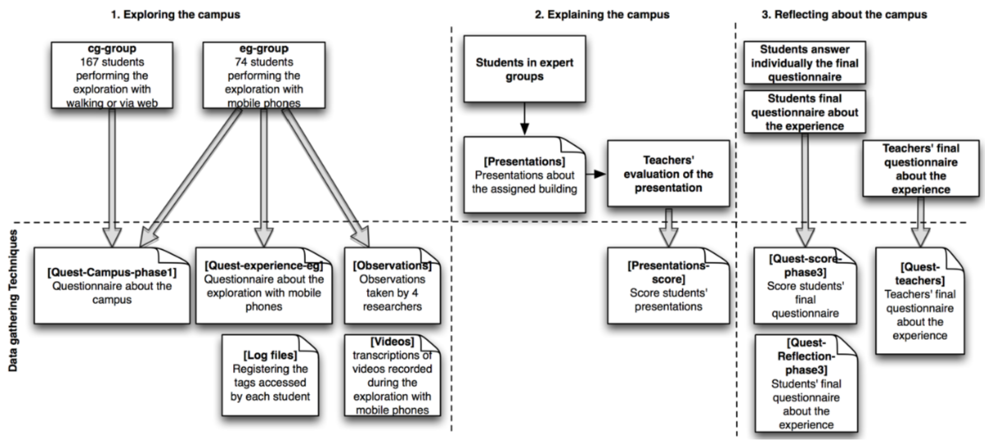

Figure 4.4: Data gathering techniques for the experiment Discovering the Campus 2009.

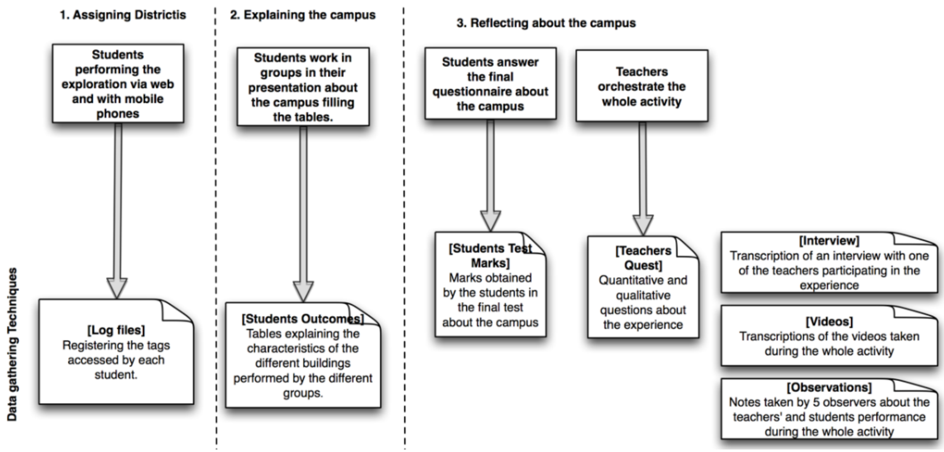

Figure 4.5: Data gathering techniques for the experiment Discovering the Campus 2010.

in this field explore conditions for user participation in the design and introduction of computer-based systems at work (Kensing and Blomberg, 1998). Methodologies in PD imply the use of theories, practices or methods that enable the people destined to use technological solutions to be involved in their design (Ehn, 1993; Bødker et al., 1993). PD can lead to hybrid experiments

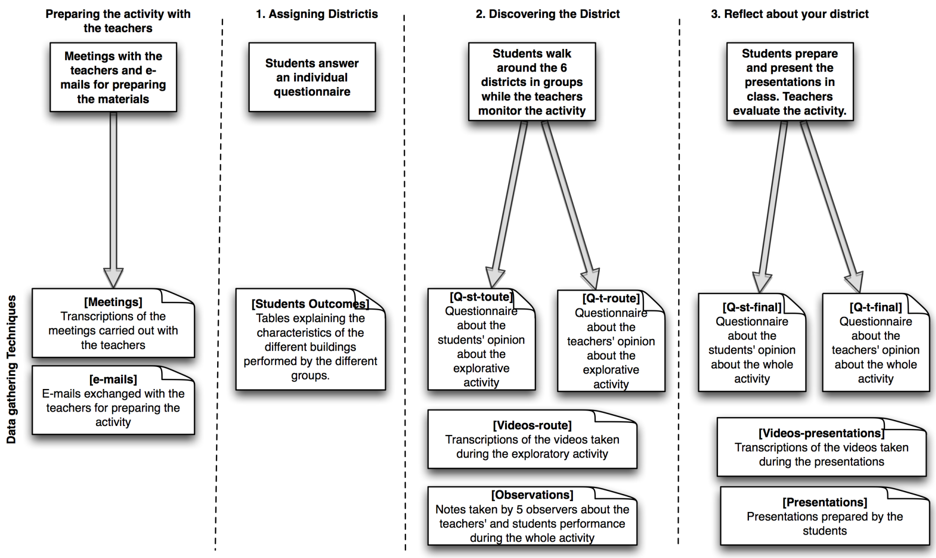

Figure 4.6: Data gathering techniques for the experiment Discovering Barcelona.

that share attributes of both the workers space (in this case the teachers from the high school) and the software professionals space (researchers as technicians) (Muller and Kuhn, 1993).

In this study, 4SPPIces was the communication instrument employed for supporting the participatory design process with the practitioners. Each case study adapts PD methodologies to carry out a design process with practitioners guided by the ideas of 4SPPIces for creating CSCBL scenarios and scripts adapted to its particular context. In all cases the use of the model was transparent for the practitioners except to the experiment "4SPPIces Seminar" in which practitioners employed the 4SSPIces tool for designing their CSCBL scripts. In the rest of the experiments, the model served for structuring the CSCBL scripts, for defining the educational materials needed for the experiment and for identifying the requirements of the technological environment for supporting its enactment.

5.3 Structure Multicase Q1: cases, functionings and issues

The four experiments presented in Table 4.1 are organized in the three case studies comprising this multicase: Case Q1-A, Case Q1-B and Case Q1-C.

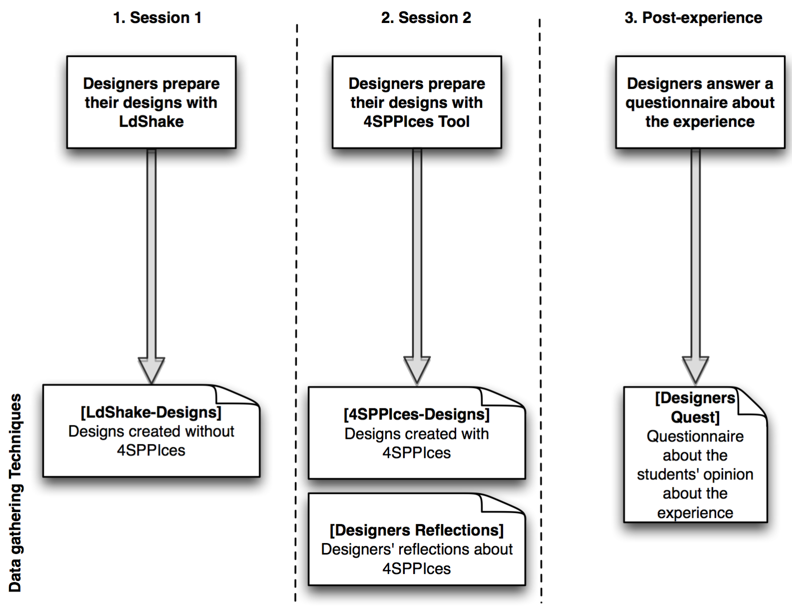

Figure 4.7: Data gathering techniques for the experiment 4SPPIces Seminar.

Each of these case studies has associated a functioning in the multicase Q1:

- **Functioning 1: Creating a CSCBL script from a scratch with 4SPPIces**. The case study associated to this functioning (Case Q1-A: "CSCBL scripts for discovering the Campus") allows us to understand whether the CSCBL script designed deals with the educational expectations of the practitioners producing a motivational and innovative experiences for the students. Particularly, the research issue addressed with this functioning is: *Does 4SPPIces provide assistance for designing a meaningful and motivational CSCBL script dealing with the learning objectives of the practitioners and generating a motivational and innovative experiences for the students?*. Two experiments are involved into this Case Q1-A: Discovering the Campus 2009 and Discovering the Campus 2010.

- **Functioning 2: Extending a design with 4SPPIces**. The case study associated to this functioning is the Case Q1-B: "A CSCBL script for discovering Barcelona". This case study analyzes CSCBL script designed in the experiment "Discovering Barcelona!" focussing on how 4SPPIces is employed to extend an already existing practice to deal with the needs required by the practitioners of the Secondary School. Three main issues are related with the quintain addressed with this case: *Does 4SPPIces assist practitioners and technicians for extending an existing educational practice dealing with the practitioners requirements?*.

- **Functioning 3: Enhancing designs using 4SPPIces tool**. The case study related to this functioning is the Case Q1-C: "4SPPIces seminar". This case study corresponds to the analysis of the experiment "Seminar with 4SPPIces". This functioning is crucial to understand whether 4SPPIces helps on supporting communication among technicians and designers with no technical-skills in improving collaborative scripted designs created without 4SPPIces. Particularly its functioning is related with the following issues: *(1) Does 4SPPIces support the collaboration between practitioners and technicians in the design of a CSCBL script? and (2) Are the collaborative scripted designs created with 4SPPIces meaningful and innovative with respect to those designs conceived without the model? and (3) Are the designs created with 4SPPIces descriptive enough to support future operationalization solutions?*

Figure 4.8 shows an complete schema of the cases involved in the multicase, their functionings and issues.

5.4 Structure Multicase Q2: cases, functionings and issues

Three of the four experiments presented in table 4.1 are organized in the three case studies comprising this multicase: Case Q2-A, Case Q2-B and Case Q2-C. Each of these case studies has associated a functioning in the multicase:

- **Functioning 1: S-focussed CSCBL script operationalization; i. e. providing an operationalization for the enactment of a CSCBL script focussed on the integration of activities occurring across different spatial locations**. This functioning is associated with the Case Q2-A: "Discovering the Campus together '09" (Pérez-Sanagustín et al., 2011). This case proposes a CSCBL script as a solution to help fresh-engineering students in the transition from the high school to the university and corresponds to one of

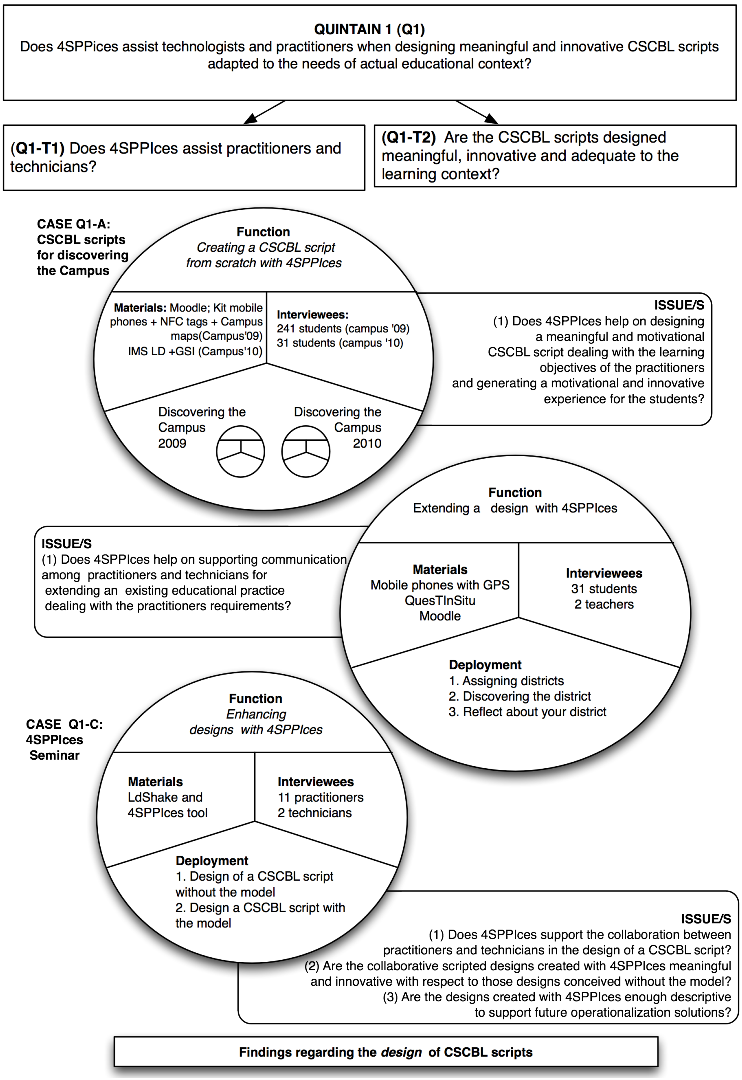

Figure 4.8: Graphical representation of the multicase study Q1. Quintain, themes, functionings, issues and case studies.

the cases also analyzed as part of the Case Q1-A. The operationalization proposed for supporting the enactment of this script focusses on enacting the integration of activities occurring across different spatial locations into the same learning setting. Particularly, the operationalized CSCBL script integrates activities at home, at the classroom and around the campus.

Therefore, this functioning and its associated issue investigates whether 4SPPIces help on identifying the operationalizing requirements for enacting a CSCBL script focussed on the integration of activities occurring across different spatial locations.

- **Functioning 2: S-P-focussed CSCBL script operationalization; i.e. providing an operationalization for the enactment of a CSCBL script integrating activities across different spatial locations and monitoring the participants' activity occurring simultaneously at runtime.** The associated case study to this functioning is the Case Q2-B: 'Discovering Barcelona!'. This case study proposes a CSCBL scenario as an improvement of an existing experiment of Geography at a High School. This case corresponds to one of the Case Q1-B in the multicase but analyzed from the perspective of the CSCBL script operationalization support for the enactment. Six groups of students visit a different are of Barcelona simultaneously, which requires an operationalization enabling the different students to start the activities from different spatial locations (P) and answer those questions situated into the assigned area (S).

  Therefore, the main question is: *Does 4SPPIces help on identifying the operationalizing requirements for enacting a CSCBL script focussed on supporting the monitoring of the participants across spatial locations on runtime?*

- **Functioning 3: S-P-PM-focussed CSCBL script operationalization; i.e. providing an operationalization for the enactment of a CSCBL scenario able of integrating activities occurring across different spatial locations and adapting them as well as of managing groups of participants on runtime**. The case study associated with this functioning is Q2-C: "Discovering the Campus Together! '10". This case is an evolution of the experiment enacted as part of the Case Q2-A within the multicase and also corresponds to one of the cases in Case Q1-A. This case proposes an operationalization of a CSCBL script not only integrating and monitoring activities across spatial locations, but also offering the mechanisms to adapt these activities and manage the groups of participants at runtime according to the pedagogical model.

Again, this functioning goes further in investigating the usefulness of 4SPPIces in supporting the design of CSCBL scripts with complex operationalizations. Particularly, the research issue addressed with this functioning is: *Does 4SPPIces help on identifying the operationalizing requirements for enacting a CSCBL script focussed on the integration of activities occurring across different spatial locations, on supporting the management of the participants and the adaptability of the pedagogical method at runtime?*.

Figure 4.9 shows an complete schema of the cases involved in the multicase, their functionings and issues.

5.4.1 Expected utility of cases

All functioning's and related cases give information about the Themes they are associated to. However, the expected utility of each case for each Theme is not the same. High utility means that the Case appears to be one of the most useful for developing this Theme. In other words, findings of some cases are expected to give more information regarding a particular Theme than others.

Tables 4.2 and 4.3 summarize the themes, associated issues and functions as well as the relevance of each case for each theme in the multicases Q1 and Q2, respectively.

A cross-case analysis of all the cases involved in the two multicases requires comparing and aggregating the findings of the different cases in the multicase analyzed independently. The findings of each case are cross-analyzed in order to extract conclusions about the main research objective defined by the quintains Q1 and Q2. Paraphrasing Stake: "a multicase research starts with a quintain, arranges to study cases in terms of their own situational issues, interprets patterns within each case, and then analyzes cross-case findings to make assertions about the binding" (Stake, 1998).

The following section describes for both Multicase-Q1 and Multicase-Q2, each of the cases involved in the multicase and the main findings obtained from the cross-analysis.

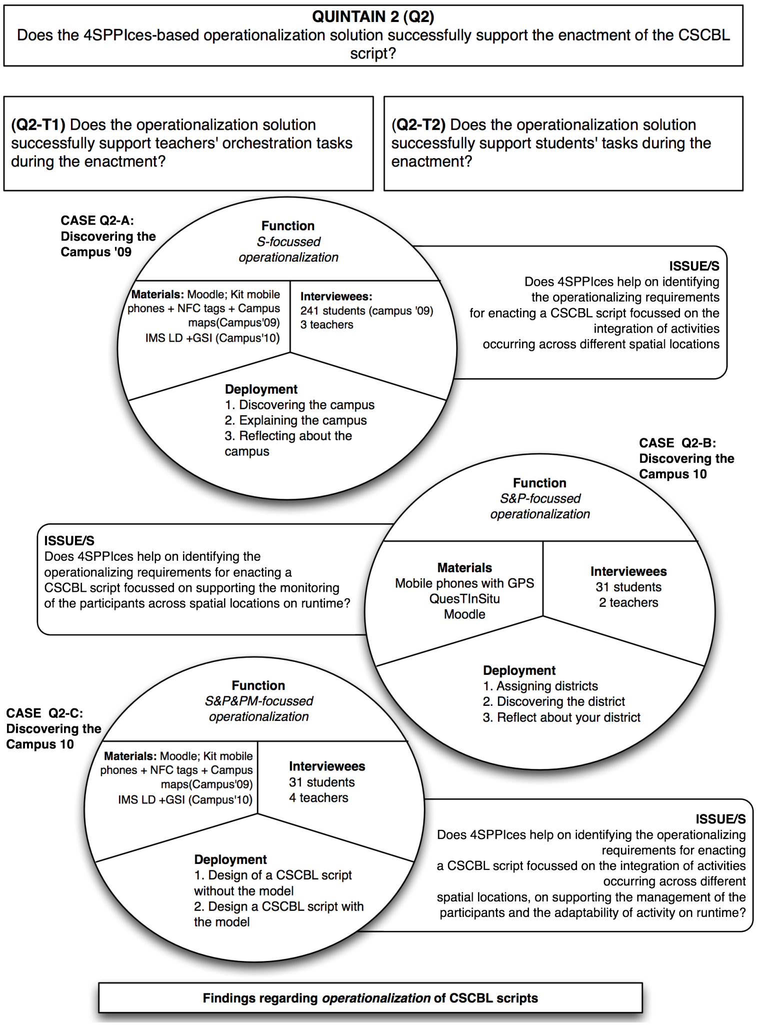

Figure 4.9: Graphical representation of the multicase study Q2. Quintain, themes, functionings, issues and case studies.

6 The multicase study Q1

The four experiments described in the previous section 3 are organized into three different cases in the Multicase-Q1. This section describes each of the cases involved in the multicase and the main findings obtained. Each case has an associated issue to focus its analysis within the multicase. At

Quintain 1: Does 4SPPices assist technicians and practitioners when designing meaningful and innovative CSCBL scripts adequate to the educational requirements of a particular learning context?

Case study	Function	Issue/s	Expected Utility T1-1	Expected Utility T1-2
Case Q1-A	Creating a CSCBL script from scratch with 4SPPIces	Does 4SPPIces help on designing a meaningful and motivational CSCBL script dealing with the learning objectives of the practitioners and generating a motivational and innovative experience for the students?	L	H
Case Q1-B	Extending a design with 4SPPIces	Does 4SPPIces assist practitioners and technicians for extending an existing educational practice dealing with the practitioners requirements?	M	H
Case Q1-C	Enhancing designs using 4SPPIces tool	(1) Does 4SPPIces assist practitioners and technicians in the design of a CSCBL script? (2) Are the collaborative scripted designs created with 4SPPIces meaningful and innovative with respect to those designs conceived without the model? (3) Are the designs created with 4SPPIces descriptive enough to support future operationalization solutions?	H	L

Table 4.2: Summary of the functions and issues of the cases related with Q1. Expected utility of cases. H = high utility; M = middling utility; L = low utility. *Adapted from Stake (1998) p. 49*

the same time, each issue has a set of associated topics particularized into information questions that guides the data analysis. We describe in what follows the findings of each of the cases by answering the information questions derived from the topics.

6.1 Case study Q1-A: CSCBL scripts for discovering the campus

As shown in Table 4.1 this case study comprises two different experiments: Discovering the Campus 2009 (section 3.1) and Discovering the Campus 2010 (section 3.2). Both experiments enact a CSCBL script pursuing the same learning objectives: to facilitate the students a first contact with the university campus and its services, the university community, the methodologies and the activities. For this reason, they are analyzed from the perspective of design within the same case.

Quintain 2: Does the 4SPPIces-based operationalization solution successfully support the enactment of the CSCBL script?				
Case study	Function	Issue/s	Expected Utility Q2-T1	Expected Utility Q2-T2
Case Q2-A	S-focussed CSCBL script operationalization	Does 4SPPIces help on identifying the operationalizing requirements for enacting a CSCBL script focussed on the integration of activities occurring across different spatial locations.	M	H
Case Q2-B	S&P CSCBL script operationalization	Does 4SPPIces help on identifying the operationalizing requirements for enacting a CSCBL script focussed on supporting the monitoring of the participants across spatial locations on runtime?	H	M
Case Q2-C	S&P&PM CSCBL script operationalization	Does 4SPPIces help on identifying the operationalizing requirements for enacting a CSCBL script focussed on the integration of activities occurring across different spatial locations, on supporting the management of the participants and the adaptability of activity on runtime?	H	H

Table 4.3: Summary of the functions and issues of the cases related with Q2. Expected utility of cases. H = high utility; M = middling utility; L = low utility. *Adapted from Stake (1998) p. 49.*

6.1.1 Findings case study Q1-A

The main issue addressed in this case is: *"Does 4SPPIces help on designing a meaningful and motivational CSCBL script dealing with the learning objectives of the practitioners and generating a motivational and innovative experience for the students?"*.

Three focusses with their associated information questions guided the evaluation of this case according to this issue:

- **Topic 1:** For the design of the CSCBL script both experiments propose adapting a Jigsaw CLFP (as the Pedagogical Method factor) by distributing the activity flow in tasks taking place at the campus, at the classroom and at home (S factor). When designing a CSCBL script one of the main aspects to consider is whether the integration of activities across spatial locations is successfully approached to achieve the expected educational objectives. Therefore, the first topic under study is the meaningfulness of the CSCBL scripts generated in terms

Findings	Partial Results	Selected supporting data
Finding I: focus on the meaningfulness of the a Jigsaw-based CSCBL script in terms of learning benefits related to the integration of formal and informal activities across spatial locations	Applying a CLFP to a blended learning scenario using mobile technologies is a good approach for supporting the integration of formal with informal exploratory activities (Campus 2009) facilitating the students to have a first contact with the academic methods and useful services that will help during their engineering studies in the future.	- The scores of the whole activity show that students performing the exploratory activity with mobile phones show better results in average and have developed more original contents in their presentations [Presentations-Score-Phase2, Quest-Score-Phase3].
	Students consider that the experience was useful to learn about the campus services and to locate and orientate around the buildings. Most of them would recommend the activity and would repeat it for learning new things (Campus 2010)	"Because you learn where the buildings are" or "It improves the agility in which you move around the campus" [Campus 2010, StudentsQuest]
		-"You meet people and learn about the buildings in the campus and the services that they offer" or "It is a very interesting experience that helps you on learning about the campus and the people" [Campus 2010, StudentsQuest]
		- 16 students (out of 32) that answered that they would not repeat the experience is because they consider that they already know enough about the campus. Whereas from the 15 students (out of 32) that answered that they would repeat the experience because they want to learn more about the campus. [Campus 2010, StudentsQuest]
	Teachers and students consider that integrating formal and informal activities into the same learning setting enriches the whole experience (Campus 2010)	-Students consider that mixing activity types is a way to enrich the experience because : (1) settle down knowledge about the campus and learn more, (2) have a more varied experience and (3) explore different technological environments. [Campus 2010, StudentsQuest]
Finding II: focus on the meaningfulness of the a Jigsaw-based CSCBL script in terms of learning benefits related group work	Working in groups formed based on the students personal experience is shown to be a successful mechanism for promoting collaboration.	- "Although it was not easy to find my group members, I'm happy with the final assigment because it was easy to work with them and I'm satisfied with the work we did." [Campus 2009, Quest-Reflection-Phase3]
	The grouping policies based on log files are a good method to facilitate the students to meet meet each other	- "To work with my group has helped me to meet colleagues that are currently my work group in other subjects" [Campus 2009, Quest-Reflection-Phase3]
	Students consider working in groups useful for sharing opinions, answering the questions, and meeting new people	- Half of the students (over 32) preferred the group activity because it was very helpful to meet new people; the other half preferred the mobile activity, with no obvious relationship among their preferences and their responses to the other questions [Campus 2010, StudentsQuest]

Table 4.4: Findings Case Q1-A: *CSCBL scripts for discovering the campus* Topic 1- Meaningfulness of the CSCBL scripts. More data supporting this partial results in the CD-Rom attached with the thesis.

Findings	Partial Results	Selected supporting data
Finding III focus on the motivational benefits of the Jigsaw-based CSCBL script	The inclusion of free exploratory experiences technologically supported in a formal sequence of activities fosters the students motivation on the studies, the University services and their interest in technology	-74 of the 241 students accept participating in the exploratory experience with mobile devices voluntary [Campus 2009, Quest-Reflection-Phase3] -47,50% of the students (out of 74) chose the exploration with the mobile devices because they were curious about the technology used and the type of activity [Campus 2009, Quest-Reflection-Phase3]
	Teachers consider that the activity is motivating for the students	"I think that this activity is very motivating for the students and can be specially interesting for subjects such as sciences..." [Campus 2010, Interview teacher]
Finding IV focus on the innovative aspects of the Jigsaw-based CSCBL script with respect to other introductory activities	Students highly appreciate the CSCBL script compared with their previous experiences in terms of innovation, use of supporting technology and discovery	- "I would recommend the activity because it is funny and enriching while helps you on getting familiar with new technologies and to discover things about the campus on your own. " [Campus 2009, Quest-Reflection-Phase3] -46,25% of the students (out of 74) chose the exploration with the mobile devices because considered it an innovative activity [Campus 2009, Quest-Reflection-Phase3] - Students describe the activity with mobiles as: (1) innovative and different, (2) dynamic, (3) interactive, (4) enriching, (5) interesting. [Campus 2010, StudentsQuest]

Table 4.5: Findings Case Q1-A: *CSCBL scripts for discovering the campus* Topic 2 - Innovative and motivational aspects of the CSCBL scripts. More data supporting this partial results in the CD-Rom attached with the thesis.

of learning benefits. In other words, this case is dedicated to analyze whether the students achieved the expected learning outcomes by integrating formal activities in the classroom with informal activities around the campus.

The information questions related to this focus are: (Q1-1) Does the combination of formal with informal activities integrated in the CSCBL script assists students in the knowledge acquisition about the campus buildings and services? and (Q1-2) Does the CSCBL script enacted help students to meet people?.

The findings related to this topic are collected in Table 4.4.

- **Topic 2:** Another important aspect we seek to understand are the implications of our approach with regard to the innovation and motivational effects with respect to other similar introductory activities.

Three information questions are related to this focus: (Q2-1) Does the CSCBL script enacted motivate students with regard to their new educational environment in relation to the University departments and research groups and their engineering studies? and (Q2-2) Which are the innovative aspects of the experience with regard to other similar introductory experiences?

The findings related to this topic are collected in Table 4.5.

Regarding the first topic, finding I in Table 4.4 shows the meaningfulness of a CSCBL script based on a Jigsaw CLFP in terms of learning benefits. The integrated combination of activities in the classroom and in the campus allow students to have a first contact with the services of the campus as well as with the services that it offers. Students stress the benefits related with being directly in contact with the building and the campus areas.

Finding II in shows that this Jigsaw-based CSCBL script proposing a group policy based on the students' experiences is shown a good mechanism to promote collaboration, to facilitate the student to meet each other and to share opinions about the tasks proposed.

In relation to the second topic, findings II and IV in Table 4.5 highlight that the experiment proposed is motivating for the students. On the one hand finding II shows that the inclusion of informal activities in a formal sequences of activities is valued as a positive and interesting aspect for the students and for the teachers. Moreover, the high number of students that voluntary accept to participate in this exploratory activity (74 over 241) support this finding. On the other hand, finding III show that students qualify the activity as different and innovative, dynamic, interactive, enriching and interesting. These students' qualifications with the quantitative results evidence that the CSCBL script proposed is an innovative and different activity compared to similar practices.

6.2 Case study Q1-B: A CSCBL script for discovering BCN

The main interest of the case "A CSCBL script for discovering BCN" is that it evaluates 4SPPIces with regard to the functionting "extending a design". Particularly, this case evaluates whether 4SPPIces can be used as a means for practitioners and educators to collaborate for proposing an extension of a practice that has been detected with some limitations.

Findings	Partial Results	Selected supporting data
Finding V: focus on the the usefulness of 4SPPIces for designing a CSCBL script narrative dealing with the limitations described by the practitioners	The narrative of the CSCBL scenario designed with practitioners, using 4SPPIces as the structuring communication framework, enables visiting more than one district of Barcelona, integrates structured sequences of activities to promote collaboration and incorporates the use of ICT	[Meetings, e-mails and Documentation exchanged and created with the teachers during the design process] (See data in tables in paper V in the Appendix B)
Finding VI focus on 4SPPIces for capturing the educational objectives of the practitioners the CSCBL script	Educational materials and activity contents capture the main aspects underlying the learning objectives of the activity	[Meetings, e-mails and Documentation exchanged and created with the teachers during the design process] (See data in tables in paper V of the Appendix B)

Table 4.6: Findings Case Q1-B: *A CSCBL script for discovering BCN* Topic 1 - Usefulness of 4SPPIces for supporting communication among practitioners and technicians in the design of a CSCBL script. More data supporting this partial results in the CD-ROM attached with the thesis and of the paper IV of the Appendix B.

6.2.1 Findings of the case study Q1-B

The main issue addressed in this case is: *Does 4SPPIces help on supporting communication among practitioners and technicians for extending an existing educational practice dealing with the practitioners requirements?*

This issue can be studied through the analysis of the case from two different topics, one more related with the design process and another more related with the enactment of the script. Concretely:

- Topic 1: This topic relates with the usefulness of 4SPPIces for supporting communication among practitioners and technicians when addressing the design (D) of a meaningful CSCBL script and covering the limitations of previous practices with new learning benefits. This focus relates to the study of the educational characteristics of the CSCBL scenario designed; i.e. whether the main structure of the CSCBL script designed potentially deals with the learning objectives of the experiment defined by the teachers as well as with the limitations detected from previous experiments.

  The information questions related to this topic are: (D1-2) Does the CSCBL designed enable comparing more than one district in

Findings	Partial Results	Selected supporting data
Finding VII: on the 4SPPIces-based CSCBL script to cope with the limitations detected by the teachers in previous editions and the expected learning objectives	Teachers point out that the exploratory activity:1) reinforces students autonomy, 2) to practice technological skills, 3) learning about more districts of the city and 4) practice spatial orientation and help them in their understanding of the urban space and its elements.	- "They could know more the areas of the city. Working with mobile devices allows arriving to another learning objectives such as how to locate themselves in a city, research or a more personal observation of the environment" [Teacher comments]
	Students stress as the learning benefits of the exploratory phase: 1) their freedom and active participation, 2) the dynamism, 3) learning about how to use a GPS, 4) answering the questions in situ, 5) orientation skills acquisition, 6) learning and discovering new location, sociological characteristics, history and infrastructures	- A student when is asked why they think they learn more with this type of experiences "I think that because you do the questions in situ and, on the street, you realize better the important things than when you are doing an exam". [Students final Questionnaire]
	Teachers point out that the exploratory technology-enhanced activity (integrated as part of a learning flow through the CSCBL scenario) allows learning about more districts of the city compared with previous experiences.	- "The teacher thinks that students have learnt urban information in this activity than in an exam. Going to the particular locations and think about the place, make them reflect about what they learn" [Teacher comment]
Finding VIII on the effectiveness of the 4SPPIces-based CSCBL script for promoting collaboration and cooperation between students and the development of teamwork skills	Working in groups with a determined role-distribution supports students interaction by promoting discussions (critical thinking), facilitating decision making processes (communicative skills) and enhancing cooperation between group members.	- "Students comment that the activity enhanced cooperation between group members and relate this with the role distribution policy (if one fails, everybody in the group fails)" [Observations during the route]
	Working directly in contact with the environment enhances students interactions with people in the city making them to practice their communicative and social skills in situations they are not used to.	- "I think that it was a very good idea that every group member had a role because it is a good way of distributed the work in a coordinated way" [Students final Questionnaire]
	Organizing the exploratory phase through a sequence of questions promotes debates and students' reflection.	"Students analyze the characteristics of the street for answering the question and say the street is not too narrow. They discuss about that and answer the question." [Observations during the route]
	All students intervened in the presentations	[Video presentations]
Finding IX on the effectiveness of the pre-test district assignment policy and role distribution to structure collaboration	Students value this way of structuring the activity as very positive to learn how to collaborate.	"I think that it was a good idea that every group member had a role because it is a good way of distributing the work in a coordinated way" [Students final Questionnaire]
	Teachers value to organize the students in small groups.	- "Small groups, separated, which makes the activity more dynamic and agile" [Teachers final Questionnaire]
Finding X on the effectiveness of the 4SPPIces-based CSCBL script to motivate and promote the active participation of the students in an innovative way	Students use adjectives as innovative, different, interactive, dynamic, interesting and funny for describing the experience	- "I liked the activity because it is more enternained than others. Even more, you learn how to work in group in a pleasant and funny way" [Students route Questionnaire]
	Students and teachers see the use of ICT as an innovative aspects compared with previous experiences.	- "I think that these types of activities are a different and an original way of what we normally do. It is more dynamic"[Students final Questionnaire]
Finding XI: on the learning benefits of combining and integrating explorative activities with activities in class	Teacher stress that these types of activities complement the contents worked in class at a more concrete level that they can analyze directly	"This activity is useful to complement the contents about urbanism worked in class" [Teacher route Questionnaire]
	Observations from the presentations evidence that the students have been looking for information using other sources for complementing the ideas gathered during the route	- "Students feel that they learn a lot and that they could see in situ some of the aspects that they worked in class" [Observations during the route]

Table 4.7: Findings Case Q1-B: *A CSCBL script for discovering BCN* Topic 2 - Innovation and added value of the CSCBL script enactment with respect to previous experiences. More data supporting this partial results in the CD-Rom attached with the thesis.

Barcelona? and (D1-4) Does the CSCBL scenario capture the learning objectives of the teachers in this experience?

The findings related to this topic are collected in Table 4.6.

- Topic 2: This second topic has to do with the innovation and added value of the CSCBL script enactment (E); i.e. whether the CSCBL script enactment solves the limitations of the previous practices covering the main learning objectives highlighted by the teacher and adding value to similar experiences.

  Four information questions guide the evaluation of this: (E1-1) Which is the added value of the CSCBL script in terms of learning benefits related with the course contents, collaborative practices and motivational aspects? (E1-2) Does the mixture of formal and informal activities promote students reflection about the contents worked in class? (E1-3) Which is the added value in terms of learning benefits offered by the use of technology in this experiment compared with non-technology enhanced experiences? (E1-4) Is the activity innovative with respect to previous editions and which are the aspects that make it innovative?

  The findings related to this topic are collected in Table 4.7.

Regarding topic 1, findings V and VI in Table 4.6 are based on the data extracted from the participatory design process followed with the practitioners. The analysis of this process evidence that both the narrative of the CSCBL scenario designed as well as the educational materials and activity contents developed for the experiment cover the needs highlighted by the teachers. Moreover, the mails and documents exchanged during the process (available in the CD-ROM and in the paper V of the Appendix B) show how the model helped on structuring the ideas proposed by the teachers and proposing different alternatives for covering what they required.

In relation with topic 2, different findings highlight the added value and innovative aspects of the CSCBL script enacted compared with the previous activities. First, evidences supporting finding VII show how teachers stress that this activity allows visiting more than one district while enhances the students autonomy and practice their orientation skills. From the students side, results show that they appreciate the activity because they learn other things such as using a GPS device or learning about different sociological characteristics of the neighborhood. Second, evidences supporting finding

VIII show the effectiveness of using a role distribution for promoting collaboration and cooperation among students. Third, data related with finding IX, indicate that students and teachers also value positively the group policies proposed. Finally, findings X and XI evidence the added value of the CSCBL script in terms of the motivation effects that it has on the students and in relation to the good learning benefits that the combination of activities in and beyond the classroom provides.

6.3 Case study Q1-C: 4SPPIces seminar

This case study analyzes and compare the designs generated in the experiment "Seminar with 4SPPIces" (see subsection 3.4 in this chapter). 10 professionals in media education and 2 technicians collaborate in the design of CSCBL scripts with and without 4SPPIces. In this case, both designs are compared to extract conclusions with regard to the functioning "enhancing designs with 4SPPIces", i. e. to understand whether 4SPPIces support the improvement of collaborative scripted designs created by non-technological skills without the model.

6.3.1 Findings case study Q1-C

The main issue under study in this case is *whether 4SPPIces is an useful means for supporting practitioner with non-technological skills in the design of meaningful and innovative CSCBL scripts.*

For the study of this issue we analyze the main characteristics of the learning scenarios designed without the model and compare them with similar cases conceived with the model. With this comparison we aim to understand: 1) how a design looks like without the model, 2) how it looks like with the model and 3) which the main differences are between both designs and 4) if these differences are meaningful. Also, a designers reflection about the tool and their answers to a questionnaire about the experiment complete the vision about the utility of the model.

To guide this analysis we define the following topics and associated information questions:

- **Topic 1:** This topic under study aims at identifying the meaningful differences within the designs created without 4SPPIces with those

Findings	Results	Selected supporting data
Finding XII: focus on the characteristics that make 4SPPIces-based designs different	4SPPIces-based designs are better described in more detail in terms of students' and teachers' roles in each phase and materials employed in each activity and technology used for their support.	Tables A.2 and A.3 and original data in the CD ROM.
	4SPPIces-based designs explicit the different locations where the activities take place and their characteristics and relevance for the activity. The space becomes an important factor considered in the activity.	Tables A.2 and A.3 and original data in the CD ROM.
	4SPPIces-based designs explicit the constraints of the activity that cannot be varied during the enactment.	Tables A.2 and A.3 and original data in the CD ROM.
	4SPPIces-based designs are better structured.	Tables A.2 and A.3 and original data in the CD ROM.

Table 4.8: Findings Case Q1-C: *4SPPIces Seminar* Topic 1 - Meaningful differences between designs created with and without 4SPPIces

based on the model. For that, it is important to systematically analyze both those non-4SPPIces-based designs with 4SPPIces-based design and compare them. To make possible this comparison, we propose to systematically review the non-4SPPIces-based designs by analyzing which of the aspects considered in the different factors of the models are taken into account and which are not. In this way, we can understand which of the factors of the model are usually contemplated.

Therefore there is one main information questions associated to this topic: (1) Which are the characteristics of the designs created without 4SPPIces with respect to the different factors that the model includes: S, PM, P and I?. This question can be analyzed through the following questions:(1) Which are the common characteristics of the designs created with and without 4SPPIces?, (2)Which are the main differences? (3) Are the differences significative for the purpose of the model?

The findings related to this topic are collected in Table 4.8.

- **Topic 2:** Another important aspect to consider is how 4SPPIces is perceived by the designers. The perception of the final users is crucial to understand whether the model is seen as a helpful tool and in which the aspects that make it helpful are.

Findings	Results	Selected supporting data
Finding XIII: focus on the usefulness aspects of the model	4SPPIces is seen by designers as a good mechanism for support collaboration with other communities such as technicians by fostering knowledge exchange	- "We could use 4SPPIces for designing the educational process and share with the teachers involved in the experiment, which will help us to improve the designs. It will also be helpful on the use of technology in each of the phases and planning an online test for the students to store the information about the process without printing them" [Designers Reflections-d1]
		- "4SPPIces become an effective tool between teachers and technicians in which teachers complement their educational knowledge with the technicians knowledge about technologies." [Designers Reflections-d2]
	4SPPIces is seen by designers as a good support to reflect about the main elements of an educational activity that is collaborative, that combines activities across spatial locations and that use technological means	- "(...) that 4SPPIces makes us think about all the learning phases and not to forget anything: objectives, how to organize the students, the needed spatial locations, the tools, ..." [Designers Reflection-d1]
		-"4SPPIces helps when designing a learning scenario that: 1)Occurs in more than one spatial location, 2)Students work collaboratively and 3)Makes use of technological means" [Designer Quest-d2]
	4SPPIces supports the design of innovative activities combining activities across spatial locations	"4SPPIces contributes on decentralizing the classroom as the exclusive place for learning and focussing on scenarios that combine formal and informal places. In this way, a museum, a square or a neighborhood become potential places for learning that promote students' movement and freedom, very valued by the students" [Designers Reflection-d2]
	4SPPIces supports the design of experiences focussed on the participants	"Regarding the participants, the model has helped to better describe the students' characteristics and on how important is to "know them" in order to design an activity aligned with their interests "[Designers Quest-d2]
	4SPPIces supports the design of experiences taking into consideration the unexpected situations that can occur during the enactment	"(...) (the model) has helped me to consider unexpected situations and think about alternatives"[Designers Quest-d2]
Finding XIV focus on the context in which the model can be applied	4SPPIces is seen as a means to think about alternatives for unsuccessful learning experiences	"(...) to improve an experience that I carried out in Brazil and that didn't work properly (...) the model could help on involving the teachers we worked with in formatting the activities and to think about the technology usage in each phase (...)" [Designers Reflection-d1]
Finding XV focus on aspects to be improved from the model	To add a section to explain the objective of the experience in few words	"Before start thinking about the phases of the learning flow it is required a section for explaining the objectives of the experience" [Designers Quest-d1] and [Designers Quest-d2]

Table 4.9: Findings Case Q1-C: *4SPPIces Seminar* Topic 2 - 4SPPIces usefulness from the designers' perspective. We have only considered the answers to the questionnaire of designers 1 and 2, authors of the designs being compared. More data supporting this partial results in the CD-Rom attached with the thesis.

> In this case, the information questions are: (1) Which are the usefulness aspects of the model from the the designers point of view?, In which contexts the designers will apply this model? and (2) Which are the aspects that they will improve?
>
> The findings related to this topic are collected in Table 4.9.

7 different non-4SPPIces-based designs and 4 4SPPIces-based designs were generated during the seminar. From these 4 4SPPIces-based designs 2 proposed an improvement with respect to the designs created without the model and the other 2 were created from scratch because the designers were not satisfied with their previous design. Table A.1 shows the designs names as the practitioners wrote them.

All the designs created without the model are examined by mapping their characteristics with the factors described in 4SPPIces. For the purposes of this dissertation, the main interest relies on comparing those designs that were originally created without the model and then improved using it. This corresponds to the pair of designs *Designer1-LdShake2.pdf- "Arte&conocimiento" / Designer1-4SPPIces2.pdf- "Conocer por la arte"* (from designer 1) and *Designer2-LdShake1.pdf- "Sé un artista de vanguardia" / Designer2-4SPPIces1.pdf- "Vanguardismo"* (from designer 2) in Table A.1 in the Appendix A.

To analytically compare these pairs we examine each of the designs by mapping their characteristics with the factors defined in 4SPPIces. For each design (created with and without the model) we briefly describe which its main characteristics are. Then, we analyze which are the differences between the pairs. Since the original designs are in Spanish, Tables A.2 and A.3 of the Appendix A show a summary of the characteristics of each of the scripts and their comparison in for designers 1 and 2, respectively.

From the comparison of the designs in tables A.2 and A.3 we extract conclusions about the characteristics that make 4SPPIces-based designs different from those that do not use the model. These conclusions are summarized in table 4.8 and complemented with the designers' reflections about the model and their answers to the questionnaire about their experience collected in table 4.9.

On the one hand, one of the most noticeable findings of this experiment is that both designers, when using 4SPPIces, emphasize on the spatial locations where the activity take place and how the technology is arranged and used by the students and teachers. Also, more constraints about the activity enactment are given when using the model. Moreover, the way the in which the description of the activity is given and the details about the technology usage, roles and constraints are very useful when identifying and extracting the requirements needed for defining the technological support for the CSCBL script enactment (see supporting data of finding XII in Table 4.8).

On the other hand, data supporting the findings in Table 4.9 show how 4SPPIces is appreciated by the practitioners as a useful tool assisting them in the design of CSCBL practices. Finding XIII evidences that 4SPPIces is seen as an instrument to: (1) support collaboration with technicians by fostering knowledge exchange, (2) reflect about the main elements of a collaborative activity combining spatial locations, (3) support the design of innovative activities integrating activities across locations, (4) supports designs focussed on the participants and (5) on the unexpected events that may occur during the enactment. Also the evidences behind finding XIV show that practitioners see this model as an instrument to improve unsuccessful activities. Finally, practitioners suggest to include an space for describing the general objective of the experience in the form provided by the tool.

It is worth noticing the relevance of the results obtained from this experiment for the evaluation of the model. On the one hand, the experience was carried out along three sessions of 3 hours each with a week between each. The participants had time to reflect about their different designs. Also, the profile of the participants is important. Non-technical users but with educational backgrounds and knowledge in media education.

6.4 Cross-case analysis in Q1

The objective of multicase Q1 is to make assertions about the quintain: "Does 4SPPIces support communication among technicians and practitioners when designing meaningful and innovative CSCBL scripts adapted to the needs of an actual educational context?".

Tables 4.11, 4.12 and 4.13 illustrate the findings of cases Q1-A, B and C, respectively, organized according to the importance for each theme. Table 4.10 provides an overview of how the different findings relate to each theme after the cross-analyzing the cases.

Does 4SPPIces support communication among technicians and practitioners when designing meaningful and innovative CSCBL scripts adapted to the needs of actual educational context?		
	(Q1-T1) Does 4SPPIces support communication among practitioners and technicians?	**(Q1-T2) Are the CSCBL scripts designed meaningful, innovative and adequate to the learning context?**
Case Study Q1-A	Findings: *no related findings*	Findings: I-(H), II-(H), III-(M), IV-(H)
Case Study Q1-B	Findings: V-(H), VI-(M), VII-(H)	Findings: VII-(H), VIII-(H), IX-(M), X-(H), XI-(M)
Case Study Q1-C	Findings: XII-(H), XIII-(H), XV-(M)	Findings: XII-(M), XIII-(M), XIV-(M)

Table 4.10: Summary of the findings of cases in multicase Q1 in relation to the two themes. We only show those findings rated with H or M utility.

Case Q1-A	**(Q1-T1) Does 4SPPIces support communication among practitioners and technicians?**	**(Q1-T2) Are the CSCBL scripts designed meaningful, innovative and adequate to the learning context?**
Finding I: focus on the meaningfulness of the a Jigsaw-based CSCBL script in terms of learning benefits related to the integration of formal and informal activities across spatial locations	**L**	**H** (A Jigsaw-based CSCBL script is perceived by students and teachers as a good means for combining formal with exploratory activities that facilitates a first contact with the campus, the services that will help during their engineering studies (Campus 2009)).
Finding II: focus on the meaningfulness of the a Jigsaw-based CSCBL script in terms of learning benefits related group work	**L**	**H** (Working in groups formed according to the students personal experience (log files from the exploration) is shown to be a successful mechanism for promoting collaboration and help the students to meet each other (Campus 2009))
Finding III focus on the motivational benefits of the Jigsaw-based CSCBL script	**L**	**M** (The inclusion of free exploratory experiments technologically supported in a formal sequence of activities fosters the students motivation on the studies, the University services and their interest on technology (Campus 2009))(Teachers consider that the activity is motivating)
Finding IV focus on the innovative aspects of the Jigsaw-based CSCBL script with respect to other introductory activities	**L**	**H** (Students highly appreciate the CSCBL script compared with their previous experiences in terms of innovation, use of supporting technology and discovery (Campus 2009))

Table 4.11: Findings of Case Q1-A organized according to their utility with regard to the information that they give about each of the themes of the cases study Q1: H = high utility; M = middling utility; L = low utility. *Adapted from Stake (1998)*

Case Q1-B	(Q1-T1) Does 4SPPIces support communication among practitioners and technicians?	(Q1-T2) Are the CSCBL scripts designed meaningful, innovative and adequate to the learning context?
Finding V: focus on the the usefulness of 4SPPIces for designing a CSCBL script narrative dealing with the limitations described by the practitioners	**H** (The narrative of the CSCBL scenario designed with practitioners, using 4SPPIces as the structuring communication framework, enables visiting more than one district of Barcelona, integrates structured work activities to promote collaboration and incorporates the use of ICT)	**L**
Finding VI focus on 4SPPIces for capturing the educational objectives of the practitioners the CSCBL script	**M** (Educational materials and activity contents capture the main aspects underlying the learning objectives of the activity)	**L**
Finding VII: on the 4SPPIces-based CSCBL script to cope with the limitations detected by the teachers in previous editions and the expected learning objectives	**H** (Teachers point out that the exploratory technology-enhanced activity allows learning about more districts of the city compared with previous experiences)	**H** (Teachers highlight that the activity reinforces students' autonomy as well as their technological and orientation skills) (Students stress as very positive the dynamism of the activity, their orientation skills acquisition and the advantages of learning *in situ*)
Finding VIII: on the effectiveness of the 4SPPIces-based CSCBL script for promoting collaboration and cooperation between students and the development of teamwork skills	**L**	**H** (Working in groups with a determined role-distribution supports students interaction by promoting discussions (critical thinking), facilitating decision making processes (communicative skills) and enhancing cooperation between group members.)(Working directly in contact with the environment enhances students interactions with people in the city making them to practice their communicative and social skills in situations they are not used to.)(Organizing the exploratory phase through a sequence of questions promotes debates that make students reflect and look for agreements (reflective and explorative learning))
Finding IX: on the effectiveness of the pretest district assignment policy and role distribution to structure collaboration	**L**	**M** (Students value structuring the collaborative activity with roles as very positive to learn how to collaborate)
Finding X: on the effectiveness of the 4SPPIces-based CSCBL script to motivate and promote the active participation of the students in an innovative way	**L**	**H** (Students use adjectives as innovative, different, interactive, dynamic, interesting and funny for describing the experience)(Students and teachers see the use of ICT as one of the innovative aspects compared with previous experiences)
Finding XI: on the learning benefits of combining and integrating explorative activities with activities in class	**L**	**M** (Teacher stress that these types of activities complement the contents worked in class at a more concrete level that they can analyze directly) (Observations from the presentations evidence that the students have been looking for information using other sources for complementing the ideas they gathered during the route or worked in the classroom)

Table 4.12: Findings of Case Q1-B organized according to their utility with regard to the information that they give about each of the themes of the cases study Q1: H = high utility; M = middling utility; L = low utility. *Adapted from Stake (1998)*

Case Q1-B	(Q1-T1) Does 4SPPIces support communication among practitioners and technicians?	(Q1-T2) Are the CSCBL scripts designed meaningful, innovative and adequate to the learning context?
Finding XII focus on the characteristics that make 4SPPIces-based designs different	**H** (4SPPIces-based designs are more well described and detailed in terms of students' and teachers' roles in each phase, materials employed in each activity and technology used for their support.) (4SPPIces-based designs explicit the constraints of the activity that cannot be varied during the enactment) (4SPPIces-based designs are better structured so as to be interpreted by a technicians for implementing the technological environment for supporting its enactment)	**M** (4SPPIces-based designs explicit the different locations where the activities take place and their characteristics and relevance for the activity. Te space becomes an important factor considered in the activity)
Finding XIII: focus on the usefulness aspects of the model	**H** (4SPPIces is seen by designers as a good mechanism for support collaboration with other communities such as technicians by fostering knowledge exchange) (4SPPIces supports the design of activities taking into consideration the unexpected situations that can occur during the enactment)	**M** (4SPPIces is seen by Designers as a good support to reflect about the main elements of an educational activity that is collaborative, that combines activities across spatial locations and that use technological means)(4SPPIces support the design of innovative designs combining activities across spatial locations) (4SPPIces supports the design of experiences focussed on the participants)
Finding XIV focus on the context in which the model can be applied	**L**	**M** (4SPPIces is seen as a means to think about alternatives for unsuccessful learning experiences)
Finding XV focus on aspects to be improved from the model	**M** (To add a section to explain the objective of the experience in few words)	**L**

Table 4.13: Findings of Case Q1-C organized according to their utility with regard to the information that they give about each of the themes of the cases study Q1: H = high utility; M = middling utility; L = low utility. *Adapted from Stake (1998), p.51*

6.4.1 Assertion Q1-1

Cases Q1-B and Q1-C are significant cases for evaluating the question regarding the utility of 4SPPIces as a means for supporting communication among practitioners and technicians. A shown in Table 4.2, this was highlighted by the expected utility of each case, since the functionings of these cases, extending and enhancing already proposed designs with 4SPPIces, require high intervention from practitioners. Case Q1-A, however, is not significant since the teachers involved in the design of the experience played both the role of practitioners and the role of technicians.

Therefore, findings from cases Q1-B and Q1-C leads to the assertion: *4SPPIces is a good assistance for practitioners and technicians to facilitate communication between stakeholders when designing CSCBL scripts for extending and enhancing existing practices.*

On the one hand, findings V and VII indicate that 4SPPIces offers a good support for analyzing an actual experiment and identifying its main limitations. The participatory design process followed with practitioners shows that the narrative of the resulting CSCBL script designed copes these limitations.

Also, finding VI denote that practitioners are happy with the materials and organization generated for the experiment because they capture the main aspects underlaying the expected learning objectives.

On the other hand, findings XII and XIII in case Q1-C show that, when using 4SPPIces for enhancing a design created without the model, practitioners describe the experiment in a more structured and systematic way. Particularly, they explicitly define students' and teachers' roles in the different activities and the materials and technological support employed in all the phases of the learning flow. Moreover, their designs also point out the constraints that cannot be violated during the activity enactment and think about alternatives to deal with the unexpected situations related with the use of technology. This structured information helps on interpreting the needs and objectives of the practitioners and facilitates the identification of the requirements for an operationalization solution potentially supporting the enactment of these designs.

Finally, the dialogues established with designers suggests that the objectives of the experiments should be also included as part of the definition of the model. Although these objectives are implicit in the learning flow description, finding XV of case Q1-B reveals that a more global definition of the educational objectives serving as an umbrella of the 4 factors would be of interest. It is worth notice, however, that this last finding is rated with a middling degree of importance because only 2 of the 5 participants that answered the final questionnaire after the 4SPPIces Seminar suggested this improvement.

Therefore, findings of case Q1-B complemented with results from case Q1-C indicate that 4SPPIces is a good means for: (1) organizing the information and the educational requirements facilitated by practitioners and (2) supporting technicians when explaining the possibilities offered by ICT for creating innovative experiences particularized to a learning context.

6.4.2 Assertion Q1-2

Findings related to Theme 2 in the multicase study Q1 leads to the assertion: *4SPPIces is useful as a support for designing meaningful and innovative CSCBL scripts or for extending already existing practices particularized for a learning context.*

First of all, findings associated to those cases that put into practice a CSCBL script (cases Q1-A and B) show that CSCBL scripts are meaningful in terms of learning benefits related with the educational objectives of the activity and with collaborative learning.

On the one hand, findings I and III in case Q1-A and VII in case Q1-B indicate that the expected learning objectives have been accomplished: both teachers and students perceive that they have learnt about the campus in one case and about the city in the other.

On the other hand, findings II in case Q1-A and VII and IX in case Q1-B show the collaborative learning benefits that the enactment of CSCBL scripts entail. Findings II and VII highlight how grouping policies based on students experiences is a good mechanism to promote collaboration. Moreover, when this group policy is accompanied by a concrete role distribution within group members and supported by an activity based on questions, like in case Q1-B, collaboration among group members is even more significant. Discussions and debates are promoted forcing the students to argue, reflect and look for agreements.

Second, findings IV in case Q1-A and X in case Q1-B show that both students and teachers highlight the usage of technology as one of the aspects that makes CSCBL scripts innovative compared with other similar activities. These innovative issues are specially important in Case Q1-B, in which the CSCBL script is proposed as an extension of a previous experiment and teachers can compare the benefits of both practices.

Findings XII and XIII in Case-C, complete these conclusions showing how 4SPPIces-based designs, compared with activities created with out the model, introduce activities occurring into a combination of spatial locations and supported by a variety of technologies. Furthermore, designers emphasize that 4SPPIces is a good means for creating innovative solutions for unsuccessful activities focussed on the participants, the technology and the space where the activities take place.

And third, findings I and III in case Q1-A and XI in case Q1-B show how 4SPPIces-based CSCBL script successfully integrates formal activities in classroom with informal exploratory activities beyond the classroom leading to encouraging and motivating experiences for the students. Both, the positive students and teachers perceptions about the experiments suggest that the interplay of formal and informal activities have been successfully achieved. Even more, teachers stress that these type of activities complement the contents worked in class by providing an opportunity to put knowledge into practice.

Therefore, all these findings indicate that 4SPPIces successfully support the design of meaningful and innovative CSCBL scripts that smoothly integrate formal and informal practices with good learning benefits in terms of collaboration that enable putting into practice knowledge achieved in the classroom.

7 The multicase study Q2

Three of the four experiments (Figure 4.9) are considered in the Multicase-Q2. As we did for the Multicase-Q1, this section describes each of the cases involved in the multicase and the main findings obtained through the issues and topics that guided the anlaysis.

7.1 Case study Q2-A: Discovering the Campus together 2009

The added value of this case is that we evaluate the 4SPPIces-based technological environment implemented for supporting the CSCBL script enacted in the experiment “Discovering the campus 2009”. One of the most relevant aspects that made the “Discovering the campus 2009” a successful experiment was the integration and coordination of the different phases of the script (i.e. grouping students or distributing activities occurring across spatial locations).

Figure 4.10 shows a general schema of the operationalization solution proposed for enacting the phases of CSCBL script as a unique integrated learning setting. The schema is organized according to the phases of the experiment:

1. *Discovering the campus:* NFC Mobile phones and NFC tags were the support for the first phase for those performing the “mobile” exploration. Software tools were developed for writing and reading the tags (see attached in the dissertation for CD ROM). Bluetooth technologies were used to collect the log files resulting from the exploratory activity. The stream of tags accessed by each student was stored into these log files. After the exploratory activity, students had to fill in a web-based questionnaire in Google Forms (Google, 2011). All the students were classified in different groups depending on the option selected for the exploration.

2. *Explaining the campus:* The expertise of the students that conducted the activity with the mobile phones was defined according to the number of tags of each area they visited during the exploration. Depending on the number of tags available in each building, the amount of tags accessed required for becoming an expert in that area was different (see Table 2 in the paper IV in the appendix B) with the description of the constraints for each building). However, in order to have a more balanced number of people per building, some of the students were assigned to the second more visited building and not to the first one. For those students who carried out the exploration following any other methods (visiting the web of the university or walking around the campus without technological support), their expertise was defined according to the results of the questionnaires. We analyzed

the question asking the students to list the buildings visited/accessed and that about recommending one building to their colleagues in order to define their expertise. Once the buildings were assigned, the students were distributed randomly in groups of 4 people with the same expertise and classified depending on the medium used for the exploration in: MOBILE (conducted the exploration with mobiles), OTHER (conducted the exploration via web or walking) and MIX (two from MOBILE and two from OTHER). The list of group assignments was delivered to the students via the Moodle learning management system. Students contacted their groups members mainly using e-mail.

For delivering the final presentations resulting from this phase, we employed the Moodle of the course. Moodle includes a functionality for delivering projects online. Only 9 students from the 241 listed from the beginning did not deliver the presentation.

3. *Reflect about the campus:* All student's presentations were uploaded by the teachers in five different public folders to the Moodle course platform. Students from the different groups had 5 days to access and review the presentations from their classmates. The final individual questionnaire was also done using Moodle questionnaires functionality. The individual final questionnaire was filled in a 25-minute practical session in the subject. The questionnaire had 25 questions, all of which were related to common aspects described by the students in their final works.

7.1.1 Findings case study Q2-A

The technological solution proposed for this experiment is focussed on the operationalization of the Space factor for appropriately integrating the activities at home, at the classroom and around the campus into a unique learning setting. Therefore, the main issue under evaluation in this case is the operationalization solution proposed to integrate the activities occurring across different spatial locations. Or, what is the same, *we analyze the implemented technological environment for supporting the CSCBL script enactment with regard to the functioning "Space-focussed operationalization".*

We address the evaluation of this issue focussing on the analysis of the successful aspects and limitations of the operationalization solution proposed

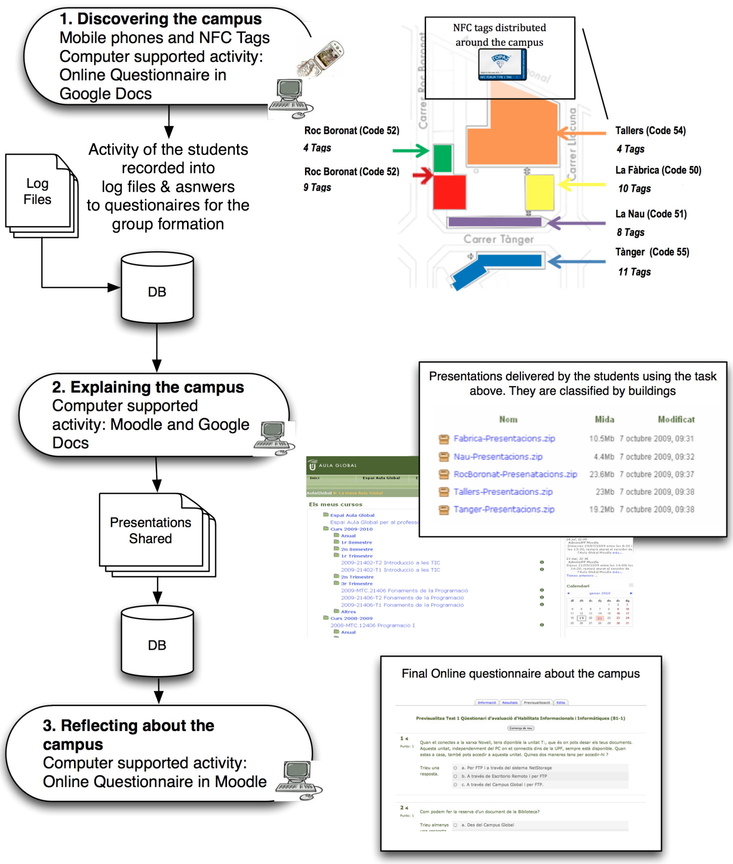

Figure 4.10: Operationalization solution implemented for enacting the CSCBL script of the experiment "Discovering the Campus 2009": A combination of mobile devices with an integrated NFC reader, NFC tags, a Moodle Platform and Google docs allows an integration of the different activities of the learning flow into a unique learning setting.

for the CSCBL script enactment for integrating activities at home, the classroom and around the campus. Therefore, the two topics guide the study of the issue behind this case:

- **Topic 1:** When providing a technological environment for operationalizing a CSCBL script the first issue that we seek to understand is whether it's been successfully adopted by the users: the teachers and the students. Also, and since one of the main characteristics of the CSCBL script enacted is that it integrates activities across spatial locations, the other issue to evaluate is whether the technological solution proposed successfully operationalizes this integration according to the learning objectives of the activity. Therefore, the topic under study are the successful aspects of the operationalization solution proposed for supporting students and teachers activities occurring at different spatial locations.

The information questions guiding this analysis are: (F3-1) Is it easy for the students and teacher to adopt the the combination of technology proposed for the experience?, (F3-2) Is the technological environment proposed a good solution for blending formal and informal activities and fostering collaboration?

The findings related to this topic are collected in Table 4.14.

- **Topic 2:** Finally, the other important aspect that we also intend to identify is the limitations of the operationalization solution proposed.

  For this particular topic, the main information question analyzed is: (F3-3) Which are the weak points of the operationalization solution?.

  The findings related to this topic are collected in Table 4.15.

The following subsection details the characteristic of the operationalization solution addressed for enacting the CSCBL script in the experiment "Discovering the campus" and the main findings organized according to the two topics and information questions.

Regarding the first topic, the evidences supporting finding I in Table 4.14 indicate that a S-focussed operationalization solution based on the kit mobile phones and NFC tags, a Moodle platform and Google docs are easily adopted by students. Besides, data supporting finding II evidence that using log files for capturing the activity of the students is a good mechanism for the integration of formal and informal activities across spatial locations fostering collaboration.

Findings III and IV in Table 4.15 evidence some limitations of the operationalization solution proposed. First, the functionalities for reading the NFC tags during the exploratory activity failed in some situations. Second, the data evidence the lack functionalities supporting teachers' organizational tasks such as grouping tasks, which were very time consuming.

Findings	Results	Selected supporting data
Finding I: on the teachers' and students' adoption of the kit mobile phones + NFC Tags, Moodle platform and Google docs as an S-focussed operationalization solution	The use of mobile devices enables the generation of informal activities that balance flexibility and guidance for the students.	- 81.40% of the 74 students participants answered that they found it useful using mobile phones for the exploration [Students Final Questionnaire] - A student comments about the use of mobile phones for the exploration"(I found it useful). You know the campus better because you can follow the mobile phone indications" [Students Exploration Questionnaire]
	Students easily managed the University Moodle platform	- "(The Moodle platform) helped me on contacting with the members of my group and looking for their e-mails (...) [Students Final Questionnaire]
Finding II: on the log files-based operationalization solution for integrating formal and informal activities across spatial locations fostering collaboration	Log files for storing the actions of the students during the exploratory activity are a good support for the integration of formal and informal activities occurring in different spaces.	- "The combination of informal and formal activities help students to get familiar with the university methodologies." [Teachers final Questionnaire] - "The activities are more significant to them (they experience the services of the university vs. they just hear about the services)" [Teachers final Questionnaire]
	Log files capturing the actions of the students in combination of online questionnaires is a good technological support for defining expert groups by fostering collaboration.	- A student comment about the group formation proposed "Working in groups has helped me a lot because we all liked the same campus area and, when you like something, you do it better and more motivated."

Table 4.14: Findings Case Q2-A: *Discovering the Campus Together 2009* Topic 1 - Successful aspects of the CSCBL script S-focussed operationalization. More data supporting this partial results in the CD-Rom attached with the thesis.

7.2 Case study Q2-B: Discovering BCN

This case study evaluates the operationalization solution implemented for supporting the enactment of the CSCBL script of the experiment "Discovering Barcelona". The main interest of this case is that it *analyzes a 4SPPIces-based operationalization system created with able of (1) integrating the CSCBL scripts activities across spatial locations and (2) providing the mechanisms for monitoring the participants' actions occurring simultaneously in these locations on runtime.*

Particularly, the CSCBL script enacted in this experiment implies the monitoring of the student's activity occurring at 6 different areas of the city simultaneously. At the same time, the technological solution should support the integration of this exploratory activity with the rest of the activities

Findings	Results	Selected supporting data
Finding III: focus on the usability of the kit mobile phones and NFC tags for supporting students tasks	The mobile device application could be improved by including the possibility of accessing the same tag with two different mobiles at the same time and making it more robust for reading the tags.	- Observations during the exploratory activity show that "Two mobile together accessing the tag at the same time do now work properly" [Teacher comments] - "Sometimes the it was hard to read the tag with the mobile phone" [Students exploration Questionnaire]
	The audio-contents should be improved by turning up the sound of the registrations.	- "The audio volume was to low" comments one student as an aspect to be improved [Student exploration Questionnaire]
	Students suggest other technologies such as PDAs for facilitating the access to content such as video or images.	- "It would be a very good idea to use PDAs instead of this Nokia phones because the screens are bigger" [Students final Questionnaire]
Finding IV: on the limitations of the S-focussed operationalization solution for supporting group teachers' orchestration tasks	Time consuming and demanding tasks in terms of group formation, logistics and preparing the materials for the experiment suggest the development of operationalization solutions for automatizing these tasks	- "(...) It is highly time consuming the design, planning and implementation of these activities (e. g., coordinating groups, distributing tasks/buildings, gathering students' outcomes, configuring and making the technology work, etc...)" [Teacher final Questionnaire]
		- "The most time demanding and difficult part of the activity was to organize the groups depending on the students' activity registered in the log files and the preferences answered in the questionnaires. since the preferences" [Teacher final Questionnaire]
		- "We did not used any tool for creating the groups. I would have been very useful to have an automatic system to analyze the logs and the response to the questionnaires to crete the groups." [Teacher final Questionnaire]

Table 4.15: Findings Case Q2-A: *Discovering the Campus Together 2009* Topic 2 - Weak points of the CSCBL script S-focussed operationalization. More data supporting this partial results in the CD-Rom attached with the thesis.

of the CSCBL script occurring at home and at the classroom.

Figure 4.11 shows the operationalization solution implemented for this case. This operationalization solution is based on the operationalization solutions presented in section 3.

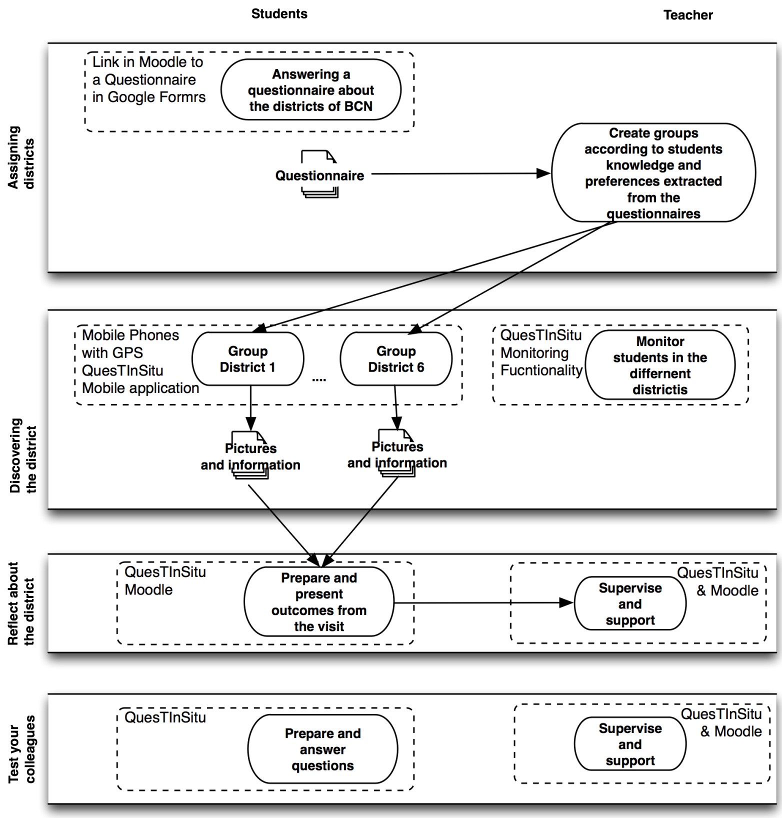

Figure 4.11: Operationalization solution implemented for enacting the CSCBL script of the experiment "Discovering Barcelona": A combination of mobile devices with GPS, a Moodle Platform and Google docs and the application QuesTInSitu allows an integration of the different activities of the learning flow into a unique learning setting.

7.2.1 Findings of the Case study Q2-B

The technological environment analyzed in this case focusses not only on operationalizing the Space factor, such as the previous case Q2-A, but also the Participants factor and their relationships. The students start the activity in a particular location and, depending on this location, s/he will be shown a set of questions or another. This requires an operationalization solution relating the P and S factors.

Therefore, the main issue under evaluation is the technological environment designed with 4SPPIces for supporting the CSCBL script enactment regard to the functioning “Space & Participants-focussed operationalization”. Or, in other words, *whether 4SPPIces help son identifying the operationalizing requirements for enacting a CSCBL script focussed o supporting the monitoring of the participants across spatial locations.*

We address the evaluation of this issue from two different perspectives, the design perspective and the enactment perspective. These perspectives set the basis for defining the two topics and associated information questions to guide the study of the issue behind this case:

- **Topic 1:** The first topic relates to the identification of the requirements of the technological environment for supporting the tasks defined by the CSCBL script; i.e., whether the technological environment designed could potentially support the functionalities related with the CSCBL scenario narrative defined.

  Only one information questions is associated to this focus: (D2-1) Does the technological environment proposed provide the functionalities required for supporting the tasks of the CSCBL script narrative designed?

  The findings related to this topic are collected in Table 4.16.

- **Topic 2:** The second topic relates to the capabilities of the collaborative technological environment designed as well as the activities proposed for supporting the students and teachers tasks during the CSCBL script enactment. This focus regards to the appropriateness of the combination of technologies and the suitability of the learning activities proposed for supporting teachers and students tasks during the script enactment. The strengths and limitations experimented by both, teachers and students, during the enactment are also considered in this point.

  The information questions guiding the evaluation are: (E2-1) Is the combination of the technologies proposed appropriate for supporting teachers and students tasks during the enactment? (E2-2) Are the role task distribution and district assignments policies satisfactory for learners and teachers? and (FE2-3) Which are the successful aspects, limitations and suggested improvements of the technological collaborative environment?

The findings related to this topic are collected in Table 4.17.

The mails, the documentation exchanged with the practitioners along the participatory design process as well as the reports of the different meetings show 4SPPIces as a good support for identifying the technological requirements for the activity enactment (finding V in Table 4.16). 4SPPices was used to organize and structure the educational requirements imposed by the practitioners and to understand the relations among the different factors required to be operationalized. Different technological possibilities were discussed with the practitioners to end up with a design covering all their needs.

With regard to topic 2, findings in Table 4.17 show the capabilities of the computational mechanisms proposed for supporting teachers and students during the activity enactment. Data supporting finding VI emphasize on the appropriateness of an operationalization based on mobile GPS devices combined with QuesTInSitu and Moodle for providing teachers with a support for monitoring the students along the different phases. Besides, this solution provides also a good mechanism to structure and coordinate the exploratory activity occurring into 6 different spatial locations simultaneously (evidences related with finding VII). Finally, some problems were detected with the GPS coverage during the visit to the districts, which should be taken into account for further developments. Also, teachers suggested adding and audiovisual mechanism to follow students at runtime (data supporting finding VIII).

7.3 Case study Q2-C: Discovering the campus 2010

The main interest of this case is that it analyzes an operationalization system proposed for dealing with the orchestration limitations found in the technological environment implemented for the CSCBL script of the experiment “Discovering the Campus 2009”. Particularly, 4SPPIces is employed for analyzing the problems of the CSCBL script enactment in the 2009 edition of the experiment to extract the requirements of a new operationalization solution dealing with these limitations (see section 3.2 for the details

Findings	Results	Selected supporting data
Finding V: on the usefulness of 4SPPIces as means for defining the technological requirements for supporting the teachers' and students' activities defined in the CSCBL script narrative	The technological environment provides the functionalities to support the students and teachers tasks defined in the CSCBL narrative	[Meetings, e-mails and Documentation exchanged with the practitioners during the design process] (See data on tables of paper V in the Appendix B)

Table 4.16: Findings Case Q2-B: *Discovering Barcelona* Topic 1 - Design of the technological environment to potentially support the activities defined by the CSCBL script narrative

of the learning flow and Table 4.15 for the limitations found in the 2009 edition). 4 limitations were detected:

1. Students' data analysis: Manually analyzing the log files was hard to carry out without errors. Also combining the preferences and the log file results for assigning the students expertise is complex and very time demanding.

2. Expert group management: Creating and managing the expert groups was very time demanding because of the instability due to drop outs that characterize the first weeks of the course and mixing students from the two lecturing sessions.

3. Activity workflow: Moodle does not facilitate the integration of the activities to create an orchestrated view of the learning flow.

4. Scalability: Without technological support, these activities are very costly to carry out for a large number of students. The data analysis becomes very complex.

From an analysis of these limitations limitations, we extracted three main requirements (R) that the new operationalization solution should fulfill:

- R1: A mechanism to automatically analyze data from the exploratory activity

- R2: A solution for automating the group formation according to their expertise

Findings	Partial Results	Selected supporting data
Finding VI: on the appropriateness of a S&P-focussed operationalization based on mobile and GPS devices combined with QuesTInSitu and Moodle platform for providing teachers with a support to follow students activity	The teachers successfully followed at runtime the students activity and their answers during the exploratory phase, which enable them to discuss about students progress.	-"I found very interesting (the monitoring system) because it enables seeing how the activity evolve and, at the same time, enhances the autonomy of the students" [Teachers route Questionnaire]
	Teachers qualify the monitoring functionality as one of the best functionalities in QuestInSitu and define it as very intuitive.	- Teachers value the level of intuitiveness of the monitoring functionality with the higher mark (5 over 5).
	Teachers value positively the whole tooling employed during the experience (Moodle, QuestInSitu and GPS Mobile Devices) and describe it as practical, functional, easy to understand, organized and clear.	- "The teacher say that they consider the tools practical, logical, concrete, comprehensive and functionals" [Observations taken during the exploratory activity]
Finding VII: on the appropriateness of a S&P-focussed operationalization based on mobile and GPS devices combined with QuesTInSitu and maps for structuring and guiding students' explorative activities	The map complemented the feedback during the exploratory phase.	- 33/34 (97%) students indicated that the feedback helps them to know how to continue in the activity and their progress on it. [Students Final Questionnaire]
	Students highlight that mobile devices and the automatic assessment and feedback system are easy to use, useful and a structured and clear way to know which tasks to perform at anytime.	- "Yes. I it (found using the mobile devices) useful because everything is guided and structured easily. Once you understand the sms, the feedback is very easy!" [Student route Questionnaire]
	Teachers highlight using the automatic assessment and feedback system with mobile devices as an interesting mechanism that helps on structuring the activity.	- (Teachers found as one of the most interesting aspects) "The way in which the questions were structured with the mobile devices" [Teachers final Questionnaire]
	Students using GPS during the whole exploratory phase found the device a very useful guide.	- 6 (out of 10) students using the GPS during the whole experience answered that they could have performed the activity without map.
	Students from the Sant Marti Group (mixing activities with and without GPS) prefer the activity when it is supported by GPS because it is more interesting, practical and faster.	- "Yes. It (to use the GPS Mobile) was a practical way of finding the way in the city" [Students route Questionnaire-MIX group]
	Students that did not use the GPS during the exploratory experience consider that the GPS was not necessary. However, they comment that it had been useful because they experienced some difficulties on finding some streets and interpreting the map.	- "I think that the GPS would have been useful because sometimes, when answering the questions and listening to the clues for the next question we were confused because we were not correctly located" [Students route Questionnaire - NoGPS]
Finding VIII: on the limitations and improvements of a S&P-focussed operationalization based on GPS devices for supporting students' exploratory activities and teachers' monitoring tasks	Students had some problems with the GPS coverage.	- "The GPS fails again and the students go directly to the next question. I seems that they are already familiar with the proceed and the use of the device" [Observations taken during the exploratory phase]
	Observations and teachers answers highlight that the monitoring system could be improved by adding system to visualize and talk to the students at runtime and the final mark of the test.	- "It would be very interesting, if its possible, to see a video of the students while they are performing the activity to follow them with an audio-visual system" [Teachers route questionnaire]

Table 4.17: Findings Case Q2-B: *Discovering Barcelona* Topic 2 - Capabilities of the operationalization solution proposed for supporting teachers' and students' tasks during the CSCBL script enactment

- R3: A mechanism to automate the connection between phases in the learning flow
- R4: A technological solution easy to replicate.

The case “Discovering the campus together 2010” analyzes a technological system proposed to fulfill these requirements for dealing with the limitations of the 2009 edition of the experiment. The operationalization solution is a Unit of Learning (UoL) compliant with IMS LD complemented with the Generic Service System (GSI) and a Kit of mobile devices with NFC tags.

The UoL structures the learning flow of the whole activity. GSI proposes a framework to include any kind of web-based tool in the context of IMS LD courses, making possible to adapt the flow depending on students behavior. GSI has been used to integrate Google Spreadsheets to administer students data and to automatically create the expert groups. the Kit Mobile devices with NFC tags are used in the same way that in the first edition of the experiment (2009) to explore the campus. Finally, the questionnaire in the last phase was designed compliant with the QTI specification.

Figure 4.12 shows a general schema of the operationalization solution proposed for enacting the phases of CSCBL script as a unique integrated learning setting according to the new requirements. The course flow is managed as follows:

- **Discovering the campus phase:** Two types of participants take part in the course: learners and teachers. Within the students, there are also two roles: A (performs first the exploration with mobile phones and after that the web) and B (first exploration via web and second exploration with mobile phones). These are the roles defined in the UoL. During the first act, learners visit the campus and acquire knowledge they will use in later activities. They perform the visit with a NFC mobile phone as in the first edition of the experiment (described in section 3.1). Once finished, they fill in a questionnaire to show their acquired knowledge of the campus.

  After the exploration with mobiles, all student logs are stored in the same folder of the teacher computer and are automatically analyzed with a script specially developed for the experiment. The log analysis produces a *csv* file with a summary of the events generated by each student: (1) the number of tags accessed per building and (2) the building expertise, which is the building with the maximum number of tags accessed. This summary is uploaded to the Spreadsheet with the students' questionnaire answers. The spreadsheet then contains all the data from the logs and questionnaires. With this information, the spreadsheets, which has been previously edited with a set of formulas with a particular criteria for creating the expert groups, distribute the students in expert groups. The criteria to group students considered data from questionnaires and log files.

Once the groups are formed, teachers can manipulate the final distribution if they do not agree and, if no more group changes are expected, marks the activity as finished. This action triggers data synchronization between IMS LD and the external spreadsheet. The course flow is then adapted to each student depending on which group the student has been related to.

- **Explain the campus phase:** Students receive the activity description that corresponds to their group, and they see no information about the other groups. They prepare the presentation together and upload into a form embedded into the UoL. Teacher can control when all the presentations are delivered.

- **Reflect about the campus phase:** Once all presentations have been delivered, the teacher makes all the presentations accessible for all the students. Students review all the presentations and access to the final assessment task.

  The final assessment is an QTI test2. Students access this test through a link in the UoL and login to the QTI server. The QTI test is composed of 5 questions: 3 common QTI questions (Multiple Choice, Yes/No and Multiple response) and 2 Google Maps-based QTI questions (Navarrete et al., In press). For these questions, students locate their answer in a Google Maps map.

7.3.1 Findings of the Case study Q2-C

To overcome with the limitations detected in the previous practice, the technological solution proposed for this experiment requires considering all the factors in 4SPPIces. First, the integration of the exploratory activity at the campus with the activities in the classroom (Space) need to be assured. Second, the management of the participants and distribution into expert groups need to be improved (Participants). Finally, the task distribution

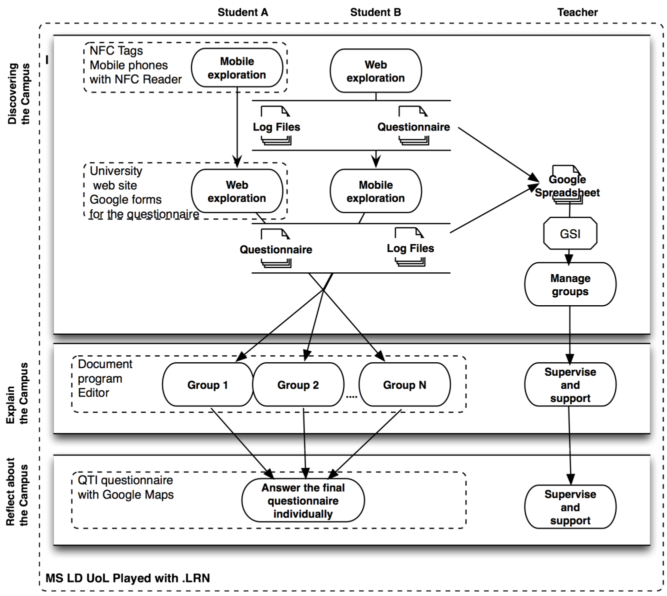

Figure 4.12: Operationalization solution implemented for enacting the CSCBL script of the experiment "Discovering the Campus 2010": A combination of mobile devices with an integrated NFC reader, NFC tags and a UoL codified in IMS LD + GSI system (with a Google Spreadsheet) + QTI, all interpreted by the .LRN system an integration of the different activities of the learning flow into a unique learning setting.

among students have to be adapted depending on the group they belong to (PM).

Therefore, the main issue under evaluation in this case is the 4SPPIces-based implemented technological environment for supporting the CSCBL script enactment with regard to the functioning "Space-Participants-Pedagogical-focussed operationalization". In other words, whether 4SPPIces help on identifying the operationalizing requirements for enacting a CSCBL script focussed on the integration of activities occurring across different spatial locations, on supporting the management of the participants and the adaptability of activity on runtime.

For the analysis of the issue under study we propose a set of topics focussed on understanding how the operationalization proposed fulfills the limitations detected in the previous section. 2 topics and associated information

Findings	Results	Selected supporting data
Finding IX: on the S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC with IMS LD+GSI+QTI as a scalable solution (R4)	The activity could be replicated 4 times with 4 different groups of students.	*Activity enactment in 4 different instances, one for each of the 4 sessions*
	Teachers comments show that they perceive each replication as a new activity independent from the previous activities carried out with other groups	- When a teacher is asked in an interview whether she felt her session independent from the rest she answers: "Independent. I didn't feel that my session was connected to another previous session" [Teacher Interview]
Finding X: on the S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC with IMS LD +GSI+QTI as a solution for efficiently integrating technologies and orchestrating collaborative learning flows combining formal and informal activities across spatial locations (R3)	Students perceive the whole experiment as a set of interrelated and complementary activites.	- Students say about the activities that "all are related" or "that some activities complement the others" [Students final questionnaire]
		- Students value with 2.05 the breaks between activities in a range from 1 to 5 (std. deviation 1.07 in a confidence interval mean $[1, 2.45]$)
	Teachers perceive that all the activities are well integrated and that the breaks between activities are natural and normal in teaching-learning situations.	-"I do not think that activities and technologies are perceived as discrete parts of an experience. The breaks are natural in any teaching/learning situation involving groups, and only served to strengthen the whole activity, because it allows for informal and social learning which was part of the goal. I felt that these breaks could have been more emphasized, so as to avoid confusion." [Teachers Questionnaire]
		- A teacher highlights that the time spent for the group formation is reasonable. However, she thinks that if it would have been taken longer it would "have required preparing an additional material for that slot of time". [Teacher Interview]
	Teachers do not perceive the system as a set of interconnected tools but as a unique and integrated system.	- "Look, I don't know whether it is a psychological factor, but using Google Spreadsheets made me feel comfortable because I'm used to Google tools" [Teacher Interview]

Table 4.18: Findings Case Q2-C: *Discovering the campus together 2010* Topic 1 - Operationalization solution to fulfill the requirements imposed by the limitations of previous edition (2009)

Findings	Results	Selected supporting data
Finding XI: on the S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC with IMS LD+GSI+QTI as a solution for efficiently organize the activity and supporting group formation and group management tasks	Observations and the interview with one teacher indicate that teachers knew what to do and how to follow the activity.	-“There were not a lot of students in the session, therefore we needed to manipulate the groups a bit to be able to have a balance. However, I think that the formula and suggestions offered were appropriate.” [Teachers Questionnaire]
	Teachers understood the group formation mechanism and found it helpful and appropriate to organize the students groups.	- “I thought that the automatization of groups is extremely helpful, however, in this session there were only 9 students which I think hindered its true abilities.” [Teachers Questionnaire]
		-“Having the log files processed and the answers to the questionnaires automatized and instantaneously in the spreadsheet is very useful. I could understand the students’ progress and know when they finish the activities” [Teachers Questionnaire]
		- Students value with a 3.82 in a range from $[1, 5]$ that the groups for the collaborative activity were well-formed
Finding XII: on the appropriateness and adoption of a S-P-PM-focussed operationalization based on the combination of kit mobile phones + NFC with IMS LD + GSI+QTI as a solution supporting and structuring students’ tasks	Students did not have problems on understanding how the system works and could follow the activity autonomously	- “I think that all the activity process was intuitive and easy to understand” [Students questionnaire]
		- “Students easily manage the mobile phones” [Observer]
Finding XIII: on the limitations and improvements of a S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC with IMS LD+GSI+QTI for supporting teachers tasks	Teachers highlight that the Questionnaire QTI should avoid submitting each of the answers separately and the mark integrated in the spreadsheet.	- “ (...) It is strange to click on *submit* every time you answer a question (...) ” [Teacher Interview]
		- With regard to the interface one teacher comments that “the visual information, how the windows are distributed...” could improve the usability of the system.
	Teachers comment that that using the spreadsheet is a little bit tricky and that they would have need a preparation before to be more comfortable with the system and its possibilities.	- “Having to juggle multiple spreadsheets to enter text and decide who went where was a bit tricky, and might cause error. Indeed I did not discover that one of the students was not assigned to a group until after they had started.” [Teachers Questionnaire]
		- “I found it difficult to complete some of the tasks of which I was supposed to complete only for a lack of proper training on how to complete them. I feel that if I had a course (or several) before the actual session, training me how to perform the tasks depending on the specific situations, I would have been able to complete them without problem.” [Teacher Questionnaire]
Finding XIV: on the improvements of a S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC for supporting students’ explorative activity	Students suggest improving the mobile experience by adding more interaction with the environment with Augmented Reality and similar technologies.	- “(I recommend) To include Augmented Reality functionalities” [Students Questionnaire]
	Students suggest extending the time of the exploratory experience with mobile devices and prepare it as a hunting activity or a gyncama	- “(I suggest) To make the mobile activity in groups such as a gymkhana” [Students Questionnaire]

Table 4.19: Findings Case Q2-C: *Discovering the campus together 2010* Topic 2 - Operationalization solution successful aspects and limitations on supporting students’ and teachers’ tasks

questions are proposed:

- **Topic 1:** This first topic focusses on analyzing whether the operationalization solution (the framework formed by IMS LD complemented with GSI and QTI plus the KIT Mobile and NFC tags) effectively support the enactment of the planned activities fulfilling the requirements imposed by the previous experiment.

  The information question related to this topic is: (F1-1) Does the CSCBL script solve the orchestration limitations problems detected in previous editions (group formation, adaptability, flexibility, integration and replication)?

  The findings related to this topic are collected in Table 4.18.

- **Topic 2:** The second topic focusses on analyzing successful aspects and limitations of the operationalization solution for supporting students' and teachers' tasks during the CSCBL script enactment.

  Three information questions are related to this topic: (F1-2) Does the CSCBL script support teachers tasks?, (F1-3) Does the CSCBL script support students tasks? and (F1-4) Which are the main problems detected with regard to the orchestration process and the technology employed for supporting it and how they could be improved?

  The findings related to this topic are collected in Table 4.19.

Firstly, the data supporting findings IX and X in Table 4.18 provides information about the first topic addressed in this case study. On the one hand, 4 different sessions were carried out in one day. This fact evidences the scalability of the operationalization solution based on a combination of kit mobile phones with NFC for operationalizing the S and P factors, and the triplet IMS LD with GSI and QTI for modeling the PM in relation with the P and S factors. Moreover, the comments of the teacher confirms that the session replications were successfully achieved. On the other hand, teachers and students observations behind finding X evidence that the operationalization proposed effectively integrates activities and tools.

Secondly, evidences underlying findings XI and XII in Table 4.19 show that both teachers and students easily adopted the computational solution proposed. Nevertheless, teachers remark some usability problems regarding the final questionnaire in QTI and the lack of intuitiveness of some steps during the process, such as the point in which the log files are transferred to the

Does the 4SPPIces-based operationalization solution successfully support the enactment of the CSCBL script?		
	(Q2-T1) Does the operationalization solution successfully support teachers' orchestration tasks during the enactment?	**(Q2-T2) Does the operationalization solution successfully support students' tasks during the enactment?**
Case Study Q2-A	Findings: II-(M), IV-(H)	Findings: I-(H),III-(H)
Case Study Q2-B	Findings: V-(M), VI-(H), VII-(H), VIII-(H)	Findings: V-(M), VII-(H), VIII-(M)
Case Study Q2-C	Findings: IX-(H), X-(H), XI-(H), XIII-(H)	Findings: X-(H), XII-(M), XIV-(M)

Table 4.20: Summary of the findings of cases in multicase Q2 in relation to the two themes. We only show those findings rated with *H* or *M* utility.

computer (finding XIII in Table 4.19). From the students side, we received suggestions for improving the interactive process with the NFC tags such as adding Augmented reality functionalities (finding XIV in Table 4.19).

7.4 Cross-case analysis in Q2

The objective of multicase Q2 is to make assertions about the quintain: "Does a 4SPPIces-based operationalization solution successfully support the enactment of a CSCBL script?".

Tables 4.21, 4.22 and 4.23 illustrate the findings of cases Q2-A, B and C, respectively, organized according to the importance for each theme. Table 4.20 provides an overview of how the different findings relate to each theme after the cross-analyzing the cases.

7.4.1 Assertion Q2-1

Findings I, II, IV in case Q2-A, V, VI, VII VIII in case Q2-B and IX, X, XI, XIII in case Q2-C give the information necessary to extract an assertion related with the T2-Q2 research question *Does the operationalization solution successfully support teachers' orchestration tasks during the enactment?*

The different operationalization solutions provided can be analyzed from different perspectives according to the most important teachers' task supported during the enactment: the monitoring of the students' activity and the learning flow management of activities.

First, from the perspective of the monitoring of the students' activity we distinguish between those activities occurring in a physical space from those occurring into a virtual space. Data behind findings II, VI and XI show that the proposed solutions successfully support the monitoring of the students' actions in activities beyond the classroom. Log files (findings II and XI) extracted from the kit mobile devices and NFC tags and online questionnaires in Google Forms, for example, are shown good means for capturing the activity of the students' across the campus. While finding VI shows how mobile devices with GPS complemented with a the tool QuesTInSitu effectively support the monitoring of the students activity on runtime. This latter solution, however, could be improved by providing an audiovisual system for visualizing and talking with the students on runtime (finding VIII).

To follow the students' activity in a virtual environment cases Q2-A and Q2-B propose using Moodle (findings I and VI), while case Q2-C propose using a UoL codified in IMS LD and complemented with GSI to register the students' activity during the whole learning flow (XI).

These two approaches links to the second point, which relates with the the perspective of the technological support provided for the management of the learning flow. We see that, as more factors with their relationships are considered in the operationalization solution, more automatized the orchestration is, which have direct implications in the teachers tasks. Findings II, I and VII show that in cases Q1-A and B, Moodle is the platform employed to structure the whole learning flow and to organize the activity distribution. Although both teachers and students easily appropriate this platform (findings I and VI) as an instrument supporting communication and collecting their outcomes from the experiment, some limitations with regard to the teacher orchestration tasks are detected.

Using platforms such as Moodle do not provide teachers with the mechanisms to facilitate the tasks distribution among groups, which makes this tasks very time demanding because they have to be done done manually (finding IV). Finding XI, shows that these limitations can be solved using a system for semi-automatically controlling the activity learning flow based on IMS LD combined with GSI. Teachers successfully followed the students performance and organized them in expert groups.

For the particular case of the exploring activities, finding VII suggest that operationalization solution based on GPS mobile devices in combination with a Web-based tool such as QuesTInSitu, which provides an automatic feedback for the students on runtime, helps on structuring the activity.

All cases propose successful solutions operationalizing the space factor based on mobile devices for solving the integration of formal and informal activities across spatial locations.

However, the support provided for the teacher during whole experiment enactment in each case is different. These differences rely on the operationalization degree of each solution or, what is the same, the way the Space factor is related with the Participants and the Pedagogical Method through the hIstory.

These divergences are clearly shown in cases Q1-A (S-focussed operationalization) and C (S-P-PM-focussed operationalization), which enact a CSCBL script with the same objectives and structure with a different operationalization system. Although both cases propose a Space-focussed operationalization system based on recovering the information about the students activity through the log files registered into NFC tags, case Q1-C provides teachers with a mechanism that automatically analyzes these log files an organizes the students in groups according to their experiences. At the same time, this group management is integrated as part of the IMS LD computationally representing the learning flow for also automating the students' tasks distribution according to the group they belong to (finding X).

Case Q2-B (S-P-focussed operationalization) proposes a mechanism that strongly relates S and P factors but does not provide any functionality to automatically integrate the exploratory activity with the next activities in the learning flow as case Q2-C does.

Moreover, another of the advantages of the operationalization solution provided by case Q2-C is that it allows replications of the activity in a short period of time (IX). While cases Q2-A and B demand lot of time for the activity preparation and during the activity enactment, the solution proposed in case Q2-C facilitates the CSCBL script replication (4 activities were carried out the same day). Even more, the activity that was enacted into two different sessions distributed along two different weeks in cases Q2-A and B were carried out in a 2-hours session in the case Q2-C. Hence, the adoption of these type of practices can be easier when providing a higher degree operationalization solution.

Therefore, findings in the multicase leads to the assertion: *4SPPIces supports the design of technological solutions with different degrees of oper-*

Case Q2-A	**(Q2-T1) Does the operationalization solution successfully support teachers' orchestration tasks during the enactment?**	**(Q2-T2) Does the operationalization solution successfully support students' tasks during the enactment?**
Finding I: on the teachers' and students' adoption of the kit mobile phones + NFC Tags, Moodle platform and Google docs as an S-focussed operationalization solution	**L**	**H** (The use of mobile devices enables the generation of informal activities that balance flexibility and guidance for the students) (Students easily managed the Universitys Moodle platform)
Finding II: on the log files-based operationalization solution for integrating formal and informal activities across spatial locations fostering collaboration	**M** (Log files for storing the actions of the students during the exploratory activities are a good support for the integration of formal and informal activities occurring in different spaces) (Log files capturing the actions of the students in combination of online questionnaires are a good technological support for defining expert groups by fostering collaboration)	**L**
Finding III: focus on the usability of the kit mobile phones and NFC tags for supporting students tasks	**L**	**H** (The mobile device application could be improved by including the possibility of accessing the same tag with two different mobiles at the same time and making it more robust for reading the tags) (The audio-contents should be improved by turning up the sound of the registrations) (Students suggest other technologies such as PDAs for facilitating the access to content such as video or images)
Finding IV: on the limitations of the S-focussed operationalization solution for supporting group teachers' orchestration tasks	**H** (Time consuming and demanding tasks in terms of group formation, logistics and preparing the materials for the experiment suggest the development of operationalization solutions for automatizing these tasks)	**L**

Table 4.21: Findings of Case Q2-A organized according to their utility with regard to the information that they give about each of the themes of the cases study Q1: H = high utility; M = middling utility; L = low utility. *Adapted from Stake (1998)*

ationalization (depending on the factors operationalized) that successfully support teachers' tasks during the CSCBL script enactment.

Case Q2-B	**(Q2-T1) Does the operationalization solution successfully support teachers' orchestration tasks during the enactment?**	**(Q2-T2) Does the operationalization solution successfully support students' tasks during the enactment?**
Finding V: on the usefulness of 4SPPIces as means for defining the technological requirements for supporting the teachers' and students' activities defined in the CSCBL script narrative	**M** (The technological environment provides the functionalities to support the students and teachers tasks defined in the CSCBL narrative)	**L**
Finding VI: on the appropriateness of a S&P-focussed operationalization based on mobile and GPS devices combined with QuesTInSitu and Moodle platform for providing teachers with a support to follow students activity	**H** (The teachers successfully followed at runtime the students activity and their answers during the exploratory phase, which enable them to discuss about students progress) (Teachers value positively the whole tooling employed during the experiment (Moodle, QuestInSitu and GPS Mobile Devices) and describe it as practical, functional, easy to understand, organized and clear and qualify the monitoring functionality as the best one)	**L**
Finding VII: on the appropriateness of a S&P-focussed operationalization based on mobile and GPS devices combined with QuesTInSitu and maps for structuring and guiding students' explorative activities	**H** (Teachers highlight using the automatic assessment and feedback system with mobile devices as an interesting mechanism that helps on structuring the activity)	**H** (Students highlight that mobile devices and the automatic assessment and feedback system (complemented with a map) are easy to use, useful and a structured and clear way to know which tasks to perform at anytime)(Students using GPS during the whole exploratory phase found the device a very useful guide) (Students from the Sant Marti Group (mixing activities with and without GPS) prefer the activity when it is supported by GPS because it is more interesting, practical and faster) (Students that did not use the GPS during the exploratory activity consider that the GPS was not necessary. However, they comment that it had been useful because they experienced some difficulties on finding some streets and interpreting the map)
Finding VIII: on the limitations and improvements of a S&P-focussed operationalization based on GPS devices for supporting students' exploratory activities and teachers' monitoring tasks	**M** (Observations and teachers answers highlight that the monitoring system could be improved by adding system to visualize and talk to the students at runtime and the final mark of the test)	**H** (Students had some problems with the GPS coverage)

Table 4.22: Findings of Case Q2-B organized according to their utility with regard to the information that they give about each of the themes of the cases study Q1: H = high utility; M = middling utility; L = low utility. *Adapted from Stake (1998)*

Case Q2-C	**(Q2-T1) Does the operationalization solution successfully support teachers' orchestration tasks during the enactment?**	**(Q2-T2) Does the operationalization solution successfully support students' tasks during the enactment?**
Finding IX: on the S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC with IMS LD+GSI+QTI as a scalable solution (R4)	**H** (The activity could be replicated 4 times with 4 different groups of students)(Teachers comments show that they perceive each replication as a new activity independent from the previous activities carried out with other groups)	**L**
Finding X: on the S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC with IMS LD +GSI+QTI as a solution for efficiently integrating technologies and orchestrating collaborative learning flows combining formal and informal activities across spatial locations (R3)	**H** (Teachers perceive that all the activities are well integrated and that the breaks between activities are natural and normal in teaching-learning situations) (Teachers do not perceive the system as a set of interconnected tools but as a unique and integrated system)	**H** (Students perceive the whole activity as a set of interrelated and complementary activities)
Finding XI: on the S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC with IMS LD+GSI+QTI as a solution for efficiently organize the activity and supporting group formation and group management tasks	**H** (Observations and the interview with one teacher indicate that teachers knew what to do and how to follow the activity) (Teachers understand the the group formation mechanism and found it helpful and appropriate to organize the students groups)	**L**
Finding XII: on the appropriateness and adoption of a S-P-PM-focussed operationalization based on the combination of kit mobile phones + NFC with IMS LD + GSI+QTI as a solution supporting and structuring students' tasks	**L**	**M** (Students did not have problems on understanding how the system works and could follow the activity autonomously)
Finding XIII: on the limitations and improvements of a S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC with IMS LD+GSI+QTI for supporting teachers tasks	**H** (Teachers highlight that the Questionnaire QTI should avoid submitting each of the answers separately and the mark integrated in the spreadsheet) (Teachers comment that that using the spreadsheet is a little bit tricky and that they would have need a preparation before to be more comfortable with the system and its possibilities)	**L**
Finding XIV: on the improvements of a S-P-PM-focussed operationalization based on the combination of kit mobile phones+NFC for supporting students' explorative activity	**L**	**M**(Students suggest improving the mobile experience by adding more interaction with the environment with Augmented Reality and similar technologies) (Students suggest extending the time of the exploratory experience with mobile devices and prepare it as a hunting activity or a gyncama)

Table 4.23: Findings of Case Q2-C organized according to their utility with regard to the information that they give about each of the themes of the cases study Q1: H = high utility; M = middling utility; L = low utility. *Adapted from Stake (1998)*

7.4.2 Assertion Q2-2

The combination of findings I and II of case Q2-A with findings VII and VIII in combination with findings X, XII and XIV of case Q2-B provide the evidences for the assertion: *4SPPIces-based operationalization solutions successfully support students tasks during the CSCBL script enactment.*

Findings I and VII indicate that using mobile phones in combination with other mechanisms such as NFC tags or geolocalized questions (with GPS devices) are a good operationalization solution for supporting exploratory students tasks during the CSCBL script enactment that balances flexibility and guidance.

However, when using GPS devices some limitations can be found with the GPS coverage (finding VIII). These limitations might hinder the appropriate enactment of the activity if any supplementary support (such as a map) is given to the students (finding VII). In addition, findings suggest that exploratory type of activities with NFC tags should be also improved by adding the possibility of reading the same tag with more than one device simultaneously or by including more "fancy" functionalities such as Augmented Reality (findings III and XIV).

These technological supports are also seen as a good way to integrate the learning flow of formal and informal activities occurring among spatial locations (findings I and VII). Moreover, when combined with a solution based on IMS LD and GSI, this integration is transparent (finding X) and easily adopted by the students (finding XII).

7.5 Holistic view of the two multicase studies

The assertions of the multicases are intimately interconnected since they both are rooted in the same research question. Therefore, only a holistic reflection about the assertions of each multicase study set the basis for answering the main research question under evaluation in this dissertation:*Is 4SPPIces useful for assisting technicians and practitioners in collaboratively designing meaningful and innovative CSCBL scripts and the technology operationalizing their enactment.* We review each of these assertions according to this main research question.

First, the cross-case analysis of multicase study Q1 culminates in the assertions Q1-1 and Q1-2, which give the clues to answer the main research question from the perspective of the design. Concretely, we can affirm that, based on the evidences of the cross analysis of cases Q1-A, B and C, *4SPPIces is a useful instrument for assisting technicians and practitioners in collaboratively design meaningful and innovative CSCBL scripts.*

Assertion Q1-1 is based on evidences showing that the descriptive potential of 4SPPIces facilitates designers providing a complete description of CSCBL scripts systematically organized according to the 4 factors of the model. This 4-factor based structured definition assist both designers and technicians to capture the complexity that CSCBL scripts entail and on identifying the relationships of the intervening factors and how to strength them for providing a better integration of the different activities leading to an enriched practice. At the same time, this systematic description facilitates technicians the identification of the requirements for an operationalization solution potentially supporting the script enactment.

The findings supporting assertion Q1-2 confirm that 4SPPIces supports the design of meaningful and innovative CSCBL scripts. The scripts are meaningful in terms of learning benefits related with the educational objectives pursued by the practitioners during the design. Also, the facets of the Pedagogical Method factor make teachers reflect about the concrete group organization leading to learning benefits related to collaborative work. Besides, explicitly introducing the Space as a factor to be considered during the design process, result on designs that propose combinations of activities across spatial locations supported by a variety of technologies that smoothly integrate formal and informal activities into the same learning setting.

Second, the cross-case analysis of multicase study Q2 lead us to Q2-1 and Q2-2 assertions for answering the main research question from the perspective of the operationalization. Particularly, we can state that, based on the cross analysis of cases Q2-A, B and C, *4SPPIces supports the design of different degree-operationalization solutions that successfully support teachers' and students tasks during the CSCBL script enactment.*

Findings supporting assertion Q2-1 indicate that solutions with higher operationalization degree support better the teachers' orchestration tasks. In concrete, the analysis of a set of concrete technological supports shows that: (1) mobile devices in combination of other tools are good means the integration of formal and informal activities across locations and on supporting the monitoring of the students and (2) that activities in the learning flow are easily managed by the teachers when providing semi-automatic tools facilitating the task distribution among groups and students.

Evidences on assertion Q2-2 show that 4SPPIces-based operationalization solutions successfully support students work. However, results also indicate that the space factor is specially constraining the final design of the activity when using devices dependent on the GPS coverage.

All these operationalization solutions are examples of how technology can be employed differently depending on the relationships established between the 4 factors of the model.

In conclusion, and according to the four assertions we can affirm that *4SPPIces provides a helpful conceptual instrument that assists technicians and practitioners in systematically describing the complexity of CSCBL scripts in an attempt to efficiently design technological environments for operationalizing their enactment.*

Nevertheless, it is worth notice that the results of this evaluation are based on the findings originated from an important work of data analysis and interpretation framed in specific contexts. For this reason, the conclusions extracted from this evaluation work cannot be fully generalized. These results can be very helpful as a basis for further work in the design of CSCBL scripts and of the technology for their support. The case studies here analyzed can give hints about how technicians and practitioners can collaborate in the design of CSCBL scripts and how to provide higher or lower operationalized solutions for supporting their enactment according to the educational needs.

8 Summary

This chapter has presented the evaluation addressed to answer the main research question in this dissertation: *Is 4SPPIces useful for assisting technicians and practitioners in collaboratively designing meaningful and innovative CSCBL scripts and the technology operationalizing their enactment.* We revise each of these assertions according to this main research question.

To address this research questions we have proposed an evaluation of two different perspectives based on two multicase studies Q1 and Q2. Each multicase study gives information regarding this main question from a particular perspective.

Multicase study Q1 evaluates 4SPPIces assistance for supporting communication between technicians and practitioners when designing a CSCBL sc-

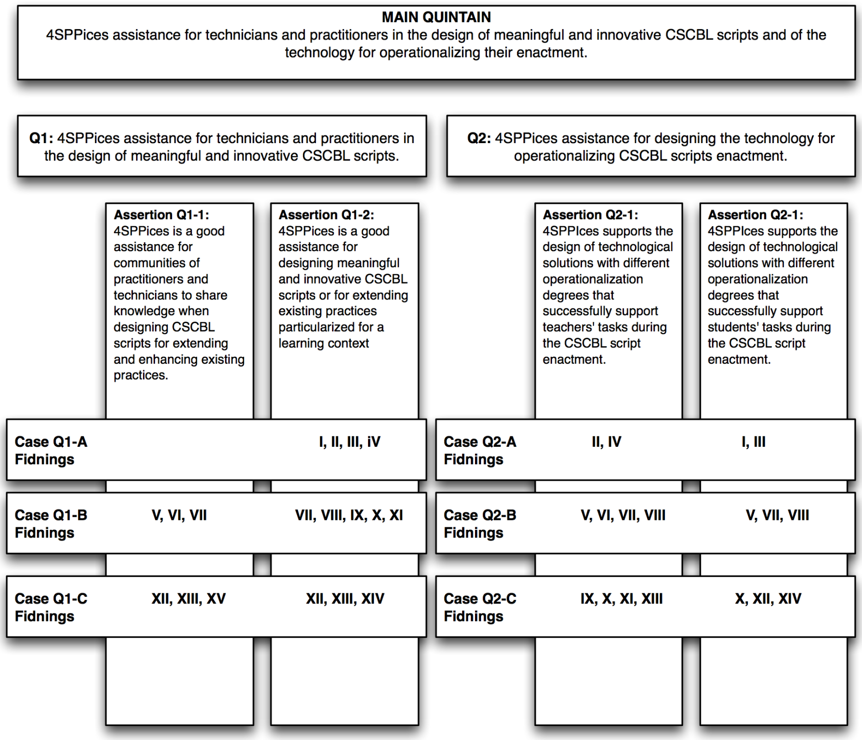

Figure 4.13: Summary of the results extracted from the cross-case analysis of each multicase as evidences supporting the assertions.

ript from scratch, when extending a current educational practice and when enhancing an education design.

Multicase study Q2 evaluates 4SPPIces assistance for designing the operationalization solutions for supporting CSCBL scripts. The evaluation of this last quintain is addressed through the analysis of the operationalization solutions proposed into three case studies that put into practice a CSCBL script into a real educational environment.

A cross-case analysis of the different findings of cases in both multicase Q1 and Q2 have led to a set of assertions about the model:

- 4SPPIces is a good assistance for communities of practitioners and technicians to share knowledge when designing CSCBL scripts for extending and enhancing existing practices.

- 4SPPIces is a good assistance for designing meaningful and innovative CSCBL scripts or for extending existing practices particularized to a learning context.
- 4SPPIces supports the design of technological solutions with different operationalization degrees that successfully support teachers' tasks during the CSCBL script enactment.
- 4SPPIces supports the design of technological solutions with different operationalization degrees that successfully support students' tasks during the CSCBL script enactment.

Also, from the evaluation we have learned lessons with regard to the operationalization solutions employed in each case. We show these lessons learned as a set of indications for further developments:

- For the operationalization of the Pedagogical Method factor modeling languages such as IMS LD have been shown good and useful solutions for providing an automatic or semi-automatic management of the learning flow. Also, LMS systems such as Moodle or .LRN platforms can be also employed although they require more intervention from the teacher side for particular orchestration tasks such as group management or task distribution.
- For the operationalization of the Space factor when it is manifested outer areas such as the campus or the city, mobile technologies have been shown an effective device to support and complement the orchestration tasks. Mobile technologies permit recovering the students' actions occurring into different spatial locations for adapting the learning flow accordingly.

  It has been also observed that, mobile devices with GPS are specially useful when the interest is to capture the activity of the students at runtime. However, GPS technologies are very dependent of the context and it should be previously studied if there is enough GPS coverage where the activity is planned to take place.

  In indoors activities or those activities which require the students to observe objects or locations very close to each other, using NFC tags or similar approaches such as QR codes have been shown a good alternative. Accompanied with a system for capturing the information of the tags accessed by the students with a log file, these types of technologies are very effective to provide the students with information about a concrete location/object and recover their actions later.

- For the operationalization of grouping management tasks in collaborative blended learning activities it has been shown as specially important to consider the relation of the factors P, PM and I. Systems considering the intrinsic constraints of the PM factor (through the grouping policies facet), the profile of the students in the P (profile facet) combined with a system for capturing the unexpected events related to these factors through the I is a good operationalization solution for these orchestration tasks. Other systems based on the same ideas but using different technological approaches can be explored.

Chapter 5

Conclusions

> The best way to predict the future is to invent it.
>
> *Alan Kay*

This thesis presents contributions in Computer Supported Collaborative Learning (CSCL). In particular, the activities and results of this thesis contribute to face the challenges associated with the design and enactment of scripted collaborative blended learning situations. This chapter presents a summary of the main contributions organized into three blocks: (1) modelling operationalized CSCL scripts for blended learning settings, (2) computational mechanisms facilitating the design and enactment of the computer-supported orchestration of collaborative blended activities and (3) novel educational experiments. Also, this chapter reviews the lessons learned about the successful aspects of using 4SPPIces as a mechanism for the design of CSCBL scripts and of the operationalization solutions proposed for supporting their enactment. Finally, the new research avenues derived from this dissertation, going from new usages of the model to an extension of the operationalization proposed are presented.

1 Summary of contributions

The main motivation of this thesis has been the new opportunities and challenges that the introduction of interactive and portable technologies entails for CSCL. In particular, we have focussed on how the possibility of combining formal and informal activities occurring at different spatial locations beyond the classroom affects the way collaborative activities can be designed and orchestrated (chapter 1).

We have provided a review of the literature in ubiquitous technologies, case studies in Technology Enhanced Learning (TEL) and CSCL research in the areas related to the specific challenges of the dissertation. This analysis of the literature has shown the lack of current theoretical and technological approaches to support the operationalization of collaborative activities in blended learning settings. Moreover, this review has led us to propose a set of definitions that offer a more accurate terminology for expressing the challenges and objectives addressed in the dissertation. Specifically, we have defined Collaborative Blended Learning (CBL) and Computer Supported Collaborative Blended Learning (CSCBL) scripts highlighting the complexity that combining and integrating activities across spatial locations entails (chapter 2).

The literature review has also permitted us to discern four factors that condition the design of computationally operationalized collaborative blended learning scripts (or CSCBL scripts): the Space (S), the Pedagogical method (PM), the Participants (P) and the hIstory (I) - SPPI. Up to now, the literature has studied these factors separately, with special emphasis on the pedagogical method and the participants. However, the complexity of these scripts requires a holistic and integrated view of all the factors. From this, we have proposed 4SPPIces as a model that integrates all these factors into a one unique representation.

To support the enactment of these practices, we have analyzed and described how third-party solutions can be adopted to operationalize the different factors of the model. This analysis have enabled us to identify a set of limitations for current computational mechanisms to address some aspects considered in the model. Subsequently, we have proposed a set of computational solutions offering new possibilities for the operationalization of these factors (chapter 3).

Finally, we have proposed 4 experiments that apply 4SPPIces to design innovative and meaningful CSCBL scripts. These experiments have been analyzed in a set of case studies. The cross-analysis of the findings obtained from each case study serves to evaluate the usefulness of the 4SPPIces model and of the selected operationalization solutions. Moreover, the results of these experiences also suggest new uses of ICT for supporting the orchestration of collaborative blended learning situations (chapter 4).

The contributions of this thesis can be organized into three main blocks:

1. Modelling operationalized CSCL scripts for blended learning settings

This block brings together those contributions regarding the modelling of CSCBL scripts.

Our definition of blended learning (BL) places emphasis on the idea of blending in a broad sense, i. e. blend of spaces, blend of formal and informal activities and blend of technological devices. Deriving from this definition, we propose the concept of **CSCBL script** as a particularization of CSCL scripts in which orchestrated sequences of formal and informal activities occurring across spatial locations are integrated and combined into one unique learning setting.

We also offer an organization of the current approaches in CSCL according to their operationalizing degree: (1) *Low degree* when the script orchestration is partially-technologically mediated and (2) *High degree* when the script orchestration is fully mediated by a technological system. This serves to identify and categorize the state of the art (and forthcoming proposals) regarding computational mechanisms that address the enactment of collaborative blended learning scripts.

The most remarkable contribution of this block is the proposal of the aforementioned model **4SPPIces** for supporting the design of these CSCBL scripts. This representation stresses the role of space and analyses in a more detailed, deep and interrelated way all the intervening factors from what has been proposed so far. By being specified, these factors aim at providing a systematic and structured instrument for assisting practitioners and technicians in participatorily design CSCBL scripts. Although these factors have already been considered in the literature, the novelty of 4SPPIces falls on combining them in a one unique representation. More specifically, this relies on the explicit definition of: (1) the space as a relevant factor that conditions the design of computationally operationalized blended learning scripts and (2) highlighting the role of the hIstory to explicitly model the relations between the other factors that affect the enactment of the scenario.

2. Computational mechanisms facilitating the design and enactment of orchestrated collaborative blended activities

These contributions emerge from the identification of a lack of computational mechanisms for addressing the operationalization of some of the aspects considered in the 4SPPIces model. Three main contributions can be highlighted with respect to this:

- The educational technology standard IMS LD has been shown to be an effective and useful solution for the operationalization of the Pedagogical Method factor. This type of operationalization solution enables the automatic or semi-automatic management of the activity sequences during the enactment of the collaborative blended learning script. However, this specification presents some flexibility limitations when modelling learning flows for blended settings. This dissertation contributes with two different approaches that propose using IMS LD to support an operationalization focussed on the adaptation of the Pedagogical Method factor.

- This thesis also contributes with a prototype that enables practitioners to flexibly manage groups of students according to the variability of the context with regard to the expected number of Participants. It particularly recommends considering the intrinsic and extrinsic constrains stipulated by the Pedagogical Method when interplaying with the Participants factors.

- This thesis also contributes with a profound study of the role of space when enacting activity flows. In particular, we propose: (1) a specification of the space factor to represent the different learning spaces that intervene in collaborative blended learning scripts through the formalization of the physical space components characteristics and their arrangement in areas, and (2) a web-based tool to allow practitioners to represent these learning spaces. This approach also incorporates a solution to include the specification of learning spaces as a part of flows modelled with IMS LD. Moreover, this proposal is an attempt to show how necessary it is to formalize the space as a new factor in the definition of learning flows that systematically acknowledge the different usages and methods that incorporate both new and traditional devices in educational settings. Formalizing enables storing, classifying and identifying common patterns about usages of ITIC according to the type of activity. This could be useful for proposing suggestions about the most suitable tool in relation to the characteristics of the activities and the spaces where they take place.

3. Novel educational experiments

Finally, this block groups the contributions related to the provision of novel and real-life educational practices that apply operationalized collaborative blended scripts. Specifically, four different experiments based on 4SPPIces-based CSCBL scripts. Three of these experiments analyze the impact of enacting these types of scripts into real educational contexts in terms of educational benefits and the orchestration support provided for teachers and students during the enactment.

Each experiment proposes solutions for supporting the CSCBL script enactment with a different operationalization degree. This differences allow us to understand which usages of technologies are more convenient for which learning situations and which type of support for both teachers and students they offer.

First, using modeling languages such as IMS LD for operationalizing the Pedagogical Method factor has been shown a successful solution for providing an automatic or semi-automatic management of the learning flow. However, to assure an integration of this factor with the Participants and the Space factors through the hIstory, this representation should be complemented with other tools such as the Generic System Integration or the Grouping Tool.

Second, the usage of GPS and NFC technologies have been shown effective to support and complement the orchestration tasks by capturing the actions of the Participants in relation to the Space and the Pedagogical Method. However, it is worth mentioning that the NFC type of technology is better for indoors activities or activities in which students need to observe elements of the space very close to each other.

Also, two of the experiences, “Discovering BCN” and “4SPPIces seminar”, shed light on how designers with non-technological skills can use 4SPPIces to design and enhance structured collaborative learning practices. The results show that by providing designers with the list of factors and facets included in the model they successfully describe a CSCBL script in a structured and detailed way.

Therefore, these experiments offer a new perspective on how ICT can be used to orchestrate collaborative blended learning situations and how 4SPPIces can be used to design and select these technologies.

2 Lessons learned

A key question addressed in this dissertation and related to the other contributions was: Is 4SPPIces a good means to assist practitioners and technicians in the design of meaningful CSCBL scripts and the technology operationalizing their enactment? In light of the outcomes presented we can answer *yes*. However, we should give a word of caution since the results of this dissertation must always be considered in terms of the context in which they have been evaluated. Hence, the answer is positive within a particular context that we try to make more explicit in what follows.

A cross-analysis of four experiences applying 4SPPIces as the instrument for designing CSCBL scripts shows that the proposed model is useful for promoting collaboration between practitioners and technicians. From the practitioners side, the descriptive potential of the model helps them to define what they have in mind in a concrete and structured manner. From the technicians point of view, these structured definitions help them to extract the requirements of the design and to suggest alternatives to the practitioners.

Until now the natural tendency of research in educational technology has been to propose solutions and mechanisms to support and facilitate what practitioners already do in their daily practices. But, what about educational designs that practitioners do not accomplish because they do not envisage them? Most practitioners do not know the potential of current technologies. And now, more than ever, technologists need to help them discover what these technologies offer. Maybe the way is not to change what they already do well but to show them the added value of the technology. Since education is becoming more and more technological every day, I think that, apart from bringing technicians and educators closer together, we need to begin encouraging teachers to think from more technological perspective. In this context, models such as 4SPPIces, which is specific enough to facilitate the design of a particular practice but general enough as to not constrain the creativity of the designers, can help practitioners when facing designs under a different perspective. In fact, the results of the experiment "Discovering Barcelona" show how using 4SPPIces in collaboration with teachers the activity was extended providing the students with the opportunity of visiting more than one neighborhood in one morning. Also, this experiment complemented with the findings related to the "4SPPIces seminar" show how 4SPPIces facilitates a systematic description of the CSCBL script that introduce activities occurring at different spatial locations.

The three evaluation experiments putting into practice the application of a CSCBL script into a real context, apart from being a contribution themselves, shed some light on how CSCBL scripts should be addressed at every stage from the design to the enactment.

The experiment that best demonstrates the whole process is "Discovering BCN". The CSCBL script has been designed in a participatory design process with the practitioners and the activity has been enacted with real students. The operationalization solution was proposed according to the teachers needs that came to light during the participatory design process. Furthermore, teachers adapted the experience in line with the type of technology available. The experiences Discovering the Campus 2009 and 2010, with a special emphasis on the operationalization solutions, complement the study by providing a deeper understanding of how ICT can be combined to support these collaborative blended learning experiences. Thus, the participatory design phase is key in enabling the communication between practitioners and designers and in giving practitioners the opportunity of discovering the opportunities offered by technology.

We have also learnt from the three experiments that, the more factors in the model are considered when defining the operationalization solution, the more support is granted to the teachers and the students. It is clear that, during the experiment Discovering the Campus 2010, which had the highest degree of operationalization, more support is given to the teachers during the enactment compared to the other experiments. This evidence that complete systems developed taking into account the operationalization of all the factors in an integrated manner are the most successful approach to follow for facilitating the orchestration tasks in CBL activities.

Finally, this thesis has evidenced the importance of introducing the Space and the hIstory as essential factors in conditioning the design of CBL experiences. On the one hand, the space defined through the characteristics of the elements that compose it is something that needs be considered when describing and designing activities in blended learning settings. The affordances of the different technological devices that compose the space need to be considered as potentially conditioning the participants interactions. As we have shown in the synthetic experiment related with the space factor, the characteristics of the location where the activity takes place strongly affects the way collaboration is produced and, therefore, orchestrated.

On the other hand, the hIstory factor is crucial for maintaining the coherence throughout the activity. In such as complex situations like CSCBL scripts, the hIstory is the factor that allows taking into account those issues arising from the relationships between factors and which cannot be observed from the study of the factors in the model as atomic units.

3 Future perspectives

Apart from the aforementioned contributions and conclusions, this essay has also identified some new lines of research.

- A lot of work has been done on the evaluation of real educational experiences enacting CSCBL scripts into real educational context. The results of this evaluation work shed light on which are the novel factors that intervene in the design of effective and innovative collaborative blended learning experiences and also on the aspects to be considered in operationalizing their enactment. Guidelines in the form of templates or patterns that gather the successful aspects from both the educational and technological perspectives in CBL and CSCBL scripts should be proposed for supporting practitioners and technicians in the design of future similar experiences. Therefore, a future line would be ***to extract patterns or guidelines of the CSCBL experiences to facilitate the enactment of similar experiences***.

- This work has also evidenced some of the deficiencies in current technology to support these types of CBL experiences. In particular, it has been shown that the space and the characteristics of the technology are affect the way in which collaboration is produced and orchestrated. ***More research has to be done to introduce the space factor as a new element in the design of CBL experiences***. One of the approaches proposed in this dissertation is to extend current modelling languages employed for representing learning flows such as IMS LD (IMS Global Learning Consortium, 2003) for including the specification of the physical space where activities should take place.

  The formalization of the space factor proposed opens up new opportunities to study the relationship established between the affordance of the different space elements and the learning events that they support (reflection, exploration, debate, experimentation). In this way, it may be possible to relate particular sets of technological usages to a particular space affordance to assist practitioners in finding the most appropriate space for supporting a particular activity.

- ***To study alternatives for operationalizing CBL scripts is also a new research avenue in the field of CSCL***. The operationalization solutions proposed open a new line of research for exploring how other ICT can be combined to support these types of practices. Therefore, to look for alternative solutions for operationalizing the different factors of the model and their relationships is something to be addressed in further developments.

- ***Using 4SPPIces as an organization framework for suggesting technological solutions to support the operationalization of the factors intervening in particular practices***. There is not a unique and perfect technology fitting each situation, but models such as 4SPPIces can help on identifying the main requirements that this technology have to accomplish. According to these requirements, designers can select the most appropriate technology also taking into consideration other aspects out of the scope of the model such as which the technology available for each situation is.

  This notion is compatible with the idea of providing suggestions about the technologies that best fits a particular situation according to the requirements. In fact, the four factor structure proposed by 4SPPIces provides a good organization framework which if combined with semantic approach, in the line of the proposal of Vega Gorgojo et al. (2010) for the selection of CSCL tools or Chacón et al. (June 2011) for the selection of CLFPs, will allow the suggestion of technological solutions to support the operationalization of the factors intervening in particular practices. Moreover, the technological solutions implemented by the three experiences carried out as part of this research work set the basis for providing combinations of devices and software tools that can also be included as part of this kind of "recommender" system.

- Another future line is ***to include 4SPPIces as part of existing CSCL authoring tools***. Tools such as WebCollage (Villasclaras-Fernández et al., 2009) propose a solution for designing collaborative CSCL scripts that conforms to the IMS LD standard using CLFP as a reference. We can benefit from these tools for supporting the design of CSCBL scripts by adopting CLFP as the structure for the PM and adding new components to define the rest of the factors in the model such as the Space and the hIstory. The combination of the web-based version of the tool Collage (Hernández-Leo et al., 2006) with the approach for flexibly managing groups of students in blended learning settings (Pérez-Sanagustín et al., in press,N) while complemented with the web-based tool proposed for representing learning spaces is another possible approach to be explored (Pérez-Sanagustín et al., September 2010).

Recently, the concept of ubiquitous learning has been gaining relevance in Technology Enhanced Learning. Ubiquitous learning emerged as a concept associated to the use of handhelds and mobile devices for supporting learning anywhere and anytime. "Ubiquitous learning implies a vision of learning which is connected across all the stages on which we play out our lives. Learning occurs not just in classrooms, but in the home, the workplace, the playground, the library, museum, and nature center, and in our daily interactions with other" (Bruce, May 2008). Recent approaches have started focussing on exploring the importance of how, when and with whom learning takes place (Jorrín-Abellán and Stake, 2009). In accordance with this last notion, ubiquitous learning can be seen as learning across spaces and across stages of life. In such a context, it is important not only to be aware of the technologies and physical places where learning occurs but also the connections and transactions between these places.

CBL and CSCBL scripts share similarities with the notion of ubiquitous learning but differ in some aspects. CBL and CSCBL scripts also consider activities occurring beyond the classroom such as museums but suggest these activities to be part of a formal learning flow. Accordingly, CBL and CSCBL scripts can be defined as a particular type of ubiquitous learning experience with the peculiarity that they integrate activities occurring in and beyond the classroom into one unique formal learning setting. In this sense, this research work, which has identified the factors conditioning the design of CBL practices, sets the basis for indicating those factors involved in other ubiquitous practices.

Besides, the operationalization solutions for supporting the enactment of CBL scripts can also inspire in how the connections between objects and links between spaces in collaborative ubiquitous learning settings should be produced. The experiments carried out as part of this dissertation show how the actions of students taking place in a particular space such as the campus or the city can be captured with technologies such as RFID or GPS and then processed to transform and condition the next activity in class. These approaches provide a means to link spaces that can be taken as a reference for future orchestrated ubiquitous learning developments.

In fact, the “Discovering the campus together” 2009 and 2010 experiments constitute the main scenario of the Spanish Learn3 project (TIN2008-05163), in which the UPF collaborates with the University Carlos III de Madrid and together set the basis for a new Spanish project that addresses the investigation of new orchestrated ubiquitous learning settings.

Appendixes

Appendix **A**

Evaluation Data of the Case Study "4SPPIces Seminar"

This appendix includes the reference to the tool employed in the "4SPPIces Seminar" experiment and the support data regarding its evaluation. The data are organized according to the topics and information questions forming the conceptual structure of this case. The raw data is available in the attached CD-ROM.

4SPPIces Tool and Support data

The tool provided for the experiment "4SPPIces Seminar" can be accessed at http://193.145.50.226/4SPPIces/. You can register, create your own CSCBL and share it with the users already registered into the platform. Figure A shows an image of the interface shown to the users at the home page.

Designer	Designs created without 4SPPIces	Designs created with 4SPPIces
1	Designer1-LdShake1.pdf-"Redacción"	
	Designer1-LdShake2.pdf-"Arte&conocimiento"	Designer1-4SPPIces2.pdf-"Conocer por la arte"
2	Designer2-LdShake1.pdf-"Sé un artista de vanguardia"	Designer2-4SPPIces1.pdf-"Vanguardismo"
	Designer2-LdShake2.pdf-"Discapacidad no es igual a incapacidad"	
3	Designer3-LdShake1.pdf-"Aprendizaje y Estrategias"	
4	Designer4-LdShake1.pdf-"Producció radial a distancia"	
5	Designer5-LdShake1.pdf-NoName	
6	Designer6-LdShake1.pdf-"Aprox.al Caso B" Designer6-LdShake2.pdf-"Aprox.al Caso B (2)"	
7	Designer7-LdShake1.pdf-NoName	
8		Designer8-4SPPIces1.pdf-"Sentidos"
9	Designer8&9-4SPPIces.pdf-"Jaqueline, Taller de radio en verano"	
10	Designer10-4SPPIces1.pdf-Etnias	

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Table A.1: All the designs created with and without the model during the seminar. We have maintained the names proposed by the designers. Some of them have spelling and gramatical mistakes because designer 1 was Brazilian.

Factor	**Without 4SPPIces: Designer1-LdShake2.pdf- "Arte&conocimiento"**	**With 4SPPIces:Designer1-4SPPIces2.pdf- "Conocer por la arte"**
Objective	Sharing knowledge about culture through the village artistic expressions	Sharing knowledge about culture through the village artistic expressions
PM	-Structure of the learning flow into 6 different phases.	-Structure of the learning flow into the 6 original phases but phase 6 changes. Phase 6 (evaluation) organized following a combination of the CLFP "Pyramid" and "Brainstorm" and adding a survey for a self-evaluation.
	-Concrete explanation of the objectives of each phase and of the students' and teachers' tasks.	-Explanation of the objectives of each phase and of the students' and teachers' roles. In Phase 3, there are different roles to be distributed among the group members (some take pictures, others go to the museum and other look for information about the art pieces).
	-Phases 1 and 5 specifies which are the supporting materials and the outcomes expected from the students.	-All phases explicit the supporting materials to be employed during the activity.
	-Phases 2, 3, 4 and 6 explicit the technological support for the activity.	-All phases explicit the technological support for the activity.
		-Definition of grouping policies: in groups according to their profile and assigned to a particular group.
P	-Num participants: *n.d.* -Profile:Primary school students -Profile-group formation dependencies: *n.d.*	-Num participants: 20 -Profile: Information from the students' blog. -Profile-group formation dependencies: by the artistic expression that students select to study and what they want to produce at the end of the activity
	-Location: *n.d.*	-Location: defined for each phase (1. classroom, 2. home or a classroom with computers, 3.home, community and museums, 4. virtual space (web blog) and classroom, 5. room and other school areas, 6. room and virtual environment
S	Tools specified for phases: 2 (internet), 3(museums, internet and cameras), 4 and 5 (web blog). *Information extracted from the explanation of the activity*	Tools specified in all phases: 1(computer with internet and projector), 2(at home with a personal computer with internet), 3(home, community and museums, mobile devices), 4(home, personal computer with internet), 5(computer with drawing software), 6(online questionnaire).
I	*n. d.*	-Events PM: The order of the activities should be maintained but the materials facilitated can vary -Events P: The number of participants should be maintained. -Events S: Places where the activities take place can vary but the order (and objectives) cannot be varied.
Diffs.	- The original design specifies and describes the tasks of teachers and students and the materials employed in each phase, however, the incomes and outcomes of the activity in each phase is not explicit. Not all the activities use a technological support. - No grouping policies specified although makes group activities. - No description of the location where the activities take place. No emphasis on the usage of a third place for the activity. - Vague definitions about the tools employed in each phase.	- All the phases, teachers' and students' roles as well as the materials employed in each phase are systematically described. All the activities use a technological support. - Group policies and group distribution specified. - All the locations are specified and the activity is improved by using a mobile device for the activities outside the classroom. - Concrete descriptions about the tools employed and its usage in each phase. More tools included in the activity. - Description of the locations where the activity take place and their relation with the activity. Emphasis on the importance of mixing locations into the same learning flow.

Table A.2: Comparison of the pair of designs by designer-1: *Designer1-LdShake2.pdf-"Arte&conocimiento"* and *Designer1-4SPPIces2.pdf-"Conocer por la arte"*.*n.d.* stands for *non defined*

Factor	**Without 4SPPIces: Designer2-LdShake1.pdf-"Sé un artista de vanguardia"**	**With 4SPPIces: Designer2-4SPPIces1.pdf-"Vanguardismo"**
Objective	Learning about the main expressions and characteristics of the Vanguard Movement	Learning about the main expressions and characteristics of the Vanguard Movement
PM	-Structure of the learning flow into 6 different phases -Explanation of the objectives of each phase and a general overview of the students' and teachers' tasks. -All phases detail the supporting materials employed. -All phases explicit the technological support for the activity. -Explicit definition of the group formation policy: according to the piece or art assigned in phase 2 (6 groups of 5 people)	-Structure of the learning flow into the 6 original phases but phase 6 changes. Phase 6 (evaluation) organized following a combination of the CLFP "Pyramid" and "Brainstorm" and adding a survey for a self-evaluation. -Explanation of the objectives of each phase and a concrete explanation of the students and teachers roles in each of the phases. Detailed explanation about the monitoring tasks of the teacher through a web blog. -All phases detail the supporting materials employed. -All phases explicit the technological support for the activity. -Explicit definition of the group formation policy: according to the piece or art assigned in phase 2 (6 groups of 5 people). Specification that in each group there should be 2 members knowing how to use a web blog.
P	-Num participants: *n.d.* -Profile:Secondary school students -Profile-group formation dependencies: *n.d.* -Location: *n.d.*	-Num participants: 30 -Profile: Name, age, expectations about the subject, knowledge about the subject, favorite artist, knowledge in creating blogs -Profile-group formation dependencies: by the artistic knowledge and their knowledge about creating a blog. -Location: defined for each phase: classroom for phases 1, 2, 4 and 6, home for a virtual visit to a museum, looking for information and creating the Artblog and a museum for looking for information in phase 3
S	Tools specified for each phase: 1(blog), 2(blog), 3(virtual museum, Google app.), 4("Drawing" from google docs, one per group), 5(Artblog and Google docs, one per group) and 6(Artblog, *not specified but can be extracted from the activity description*)	*Tools specified in the PM factor equivalent to the original design.* Usage: Projector and computers with internet access. For the first activity with googledocs, it should be one computer per student or, if its not possible, sharing a computer per pairs. Arrangement: all students should be located in an area of good visibility to see the projector. Good illumination and ventilation Mobility: we could use mobile phones for detecting the paths followed by the students in the museum
I	*n. d.*	-Events PM: The order of the activities should be maintained because it has sense as a learning flow. -Events P: *n. d.* -Events S: It could be avoided the use of Google apps for the "Drawing activity", but it will always be required internet connection and computers.
Diffs.	- No information given about the materials employed in each phase. - No constraints specified for the group formation. - No constraints specified for the activity enactment. - No definition about the spatial locations arrangement and characteristics	- The same information than in the original design but more information given about the data flow across phases by specifying what users use and which are the outcomes in each phase. - Constraints given for the group formation process. - Constraints specified for the activity enactment. - Details about the spatial locations arrangement and tools usage given.

Table A.3: Comparison of the pair of designs by designer-2: *Designer2-LdShake1.pdf-"Sé un artista de vanguardia"* and *Designer2-4SPPIces1.pdf-"Vanguardismo"*. *n.d.* stands for *non defined*

Figure A.1: Image of the home page when a user access to the 4SPPIces tool.

Appendix **B**

Collection of selected Papers

Paper I

Pérez-Sanagustín, M.; Hernández-Leo, D.; Nieves, R.; Blat, J. *Representing the spaces when planning learning flows.* In: Proceedings of the 5th European Conference on Technology Enhanced Learning, Barcelona: 2010, p. 276-291

Abstract Collaboration scripts formulate flows of orchestrated groups and learning activities. When these scripts are computationally supported they are called Computer-Supported Collaborative Learning scripts. Several modeling languages have been proposed to computationally represent the scripts so that they can be interpreted by learning environments. In this paper we address how the definition of these scripts can be influenced by the impact of the space characteristics, including the electronic and non-electronic devices available to support the learning activities. The use of portable and electronic devices is increasing the importance of the role of educational spaces, which become an agent able to shape users interactions and, therefore, the way collaboration and learning is produced. This paper introduces a model that enables the specification of the space as a conditioning factor in the design and enactment of scripting processes. Two real scenarios and a web-based prototype application for the design of learning spaces illustrate the value of the proposed model.

Representing the spaces when planning learning flows

Mar Pérez-Sanagustín, Davinia Hernández-Leo, Raúl Nieves and Josep Blat

ICT Department, Universitat Pompeu Fabra, C/Roc Boronat 138, 08018 Barcelona, Spain
{mar.perez, davinia.hernandez, raul.nieves, josep.blat}@upf.edu.com

Abstract. Collaboration scripts formulate flows of orchestrated groups and learning activities. When these scripts are computationally supported they are called Computer-Supported Collaborative Learning scripts. Several modeling languages have been proposed to computationally represent the scripts so that they can be interpreted by learning environments. In this paper we address how the definition of these scripts can be influenced by the impact of the space characteristics, including the electronic and non-electronic devices available to support the learning activities. The use of portable and electronic devices is increasing the importance of the role of educational spaces, which become an agent able to shape users' interactions and, therefore, the way collaboration and learning is produced. This paper introduces a model that enables the specification of the space as a conditioning factor in the design and enactment of scripting processes. Two real scenarios and a web-based prototype application for the design of learning spaces illustrate the value of the proposed model.

Keywords: CSCL, space model, scripting processes

1 Introduction

Orchestration is the term used in the Computer Supported Collaborative Learning (CSCL) field to define the process of organizing a flow of interrelated activities and group hierarchies for stimulating group interactions that potentially produce fruitful learning [4]. Scripts are proposed in this context as a way to guide and support these orchestration processes [5]. When these interactions are technologically mediated these scripts are called Computer Supported Collaborative Learning Scripts (or CSCL scripts). CSCL scripts can be automatically interpreted by learning environments. This automation facilitates the orchestration processes by computationally guiding students along the sequence of activities (indicating groups, resources and tools needed to conduct the activities) and, therefore, reducing the coordination efforts of teachers and students [17].

Different approaches and tools have been developed for technologically supporting CSCL scripts [8, 9, 10, 12, 18, 19, 20]. However, in the last few years, the infusion of portable and interactive devices has opened up new opportunities for collaborative learning that these approaches are not able to capture. The anywhere and everywhere capabilities of these technologies put the space as a central factor that can shape users' interactions by enabling or inhibiting learning [3, 7, 21, 23]. Whether the elements of the learning environment are portable or not, electronic or not, sharable or not conditions the way students are distributed over the space and how they interact by affecting not only the orchestration processes but also the way in which the learning flow is defined. In this context, space and its elements become essential factors that should be considered during the whole cycle of the scripting process: the edition, the instantiation and the enactment. New formalization efforts for integrating the space as a factor in the scripting process definition are required.

This paper presents a conceptual model of the space. This model defines the space elements that condition the design and enactment of a CSCL script design process when applied to blended learning contexts (where online, technology supported, and face to face (f2f) activities are combined in a given space [19]). The objective is to enable the design of a complete, abstract and portable description of the main space elements to support the integration of the space as part of a scripting process definition. Therefore, the aim of this paper is twofold: (1) to describe and discuss the main elements of the space model we developed and (2) to present an example of two real learning settings in which a system based on the model would help in the design of the space involved in the collaborative script applied.

This paper is structured as follows. Section 2 discusses the main aspects of the literature on learning spaces and educational technology that motivate this work. In section 3, the conceptual model of the space is presented by defining the requirements it should fulfill and by describing its main elements. Section 4 presents two real learning scenarios in which the space plays a crucial role for the script definition. In the same section, an application prototype based on the ideas of the model is used to represent the spaces intervening in both experiences. Finally, both representations serve as a basis for discussing the requirements that the model overcomes. In the end, section 5 presents the conclusions and future work lines derived from the proposal.

2 Motivation

This work has been mainly influenced by contributions in two fields: research on learning spaces and studies in educational technology aiming at computationally supporting the organization of collaborative learning flows. This section presents the main concepts of these fields that inspired the model definition.

2.1 The influence of space in learning

Research on learning spaces studies highlight the influence of the physical space in learning practices. The physical space is considered a changing agent that has an impact on learning: it affects how one learns and how one teaches. Space can shape users' interactions and activate collaborative learning [3, 7]. Whether physical or virtual, the space becomes a determining contextual factor in blended learning scenarios by enabling or inhibiting learning [23]. Diana Oblinger states in her book "Learning Spaces", "*a particular space can bring people together; it can encourage exploration, collaboration, and discussion. Or, space can carry an unspoken message of silence and disconnectedness*" [22].

Since the first schools appeared, the space influences the teaching methods and the way we learn. However, the introduction of information technologies (IT) in education brings new possibilities to educations that are transforming learning experiences [22, 23]. In this context, the space becomes still more important and relevant in the learning environments and an essential factor altering the learning design processes. Computational artifacts have moved from being conceived as a means of distance communication to be an element embedded in the educational setting that can increase the possibilities of f2f experiences [26]. To understand how the integration of technology in learning environments can benefit learning it is necessary to understand the relationship between the space, the technological devices and the learning activities that can be carried out. Temple says, " (…) *Technological change is said to be affecting the nature of learning itself, as well as the ways in which it takes place* (…)" [27]. For example, Dix et al. consider or support the idea that "*devices are situated and embedded within a space and their interaction is mediated through this space*" [1].

A study by Milne [21] proposes six categories organized into three clusters for classifying learning technologies as a first step to understanding how they relate to the physical space design. The first cluster is called **Virtual technologies** and refers to technologies not tied to particular physical hardware. In this group we find the first two categories: (1) technologies to support **online presence**, either through real-time interaction or asynchronous personal repositories (Skype, Flickr...) and (2) **online resources** that provide access to resources that are public, not personal, in nature; for example, databases or digital libraries. The third, fourth and fifth categories are clustered into those technologies that include a specific physical instantiation and are named **Installed appliances**: (3) **media representations systems** or devices that allow playback of media of different formats (DVD player or slide-to-video unit), (4) **remote interaction systems** such as web cameras or videoconferencing systems that allow real-time interaction and (5) **room-scale peripherals** referring to those devices for supporting group interacting such as interactive displays or room schedule displays. And the third cluster stands for **Mobile devices** and corresponds to (6) **Personal information and communication devices** such as PDAs, smart phones, Table PCs or iPods. We make use of this categorization to define in our model the different types of elements that can be found in a learning space and affect learning practices.

Besides, other researchers highlight the importance of the affordance of technology as something that influences the way in which educational strategies are carried out in educational settings [16, 26]. Affordance is defined by Kirschner as "*the perceived properties of a thing in reference to a user that influences how it is used*". Hence, in a learning context it is crucial not only to understand what the potential of the technology embedded into the learning setting is but also how people use it for supporting collaboration.

2.2 Technology for structuring learning flows

Some researchers in educational technology have put their efforts into studying ways to computationally represent learning flows for facilitating orchestration tasks. In particular, CSCL scripts are seen as a mechanism for reducing the coordination efforts of teachers and students when orchestrating a collaborative activity [17]. One of the best-established modeling languages used for representing learning flows is IMS Learning Design (IMS LD) [13, 19]. This specification supports the use of a wide range of pedagogies in online learning. IMS LD specifies what activities have to be performed by learners and teachers to attain the learning objectives. With IMS LD, the formal design of a teaching-learning process is modeled through what is called a Unit of Learning (UoL). A UoL can be distributed and interpreted with runtime systems conforming to this specification. In a UoL electronic resources and tools can be modeled within a learning flow using the IMS LD *environment* element. *Environments* contain references to the *learning objects* (resources) and *services* (tools such as chat or forums) needed to carry out a particular activity. However, *environments* are only devoted to specify the supporting resources and tools within a virtual space but they are not meant to model physical elements of the learning setting.

Some specialized tools for collaborative learning have been specially designed based on IMS LD specification. Collage, for example, is an authoring tool which helps users when creating their own collaborative Learning Designs in IMS LD using existing patterns, called Collaborative Learning Flow Patterns (CLFP). These patterns represent the broadly accepted techniques used to structure the flow of types of learning activities involved in collaborative learning situations [12].

Other approaches have been developed for computationally supporting collaborative learning flows. In another paper by Miao et al. (2005), a CSCL scripting language and a conceptual framework for this modeling language is presented. They perform an analysis of the IMS LD specification and outline its main limitations for CSCL scripting. Finally, they propose a new specification that is able to capture the main elements of CL practices [20]. A study by Kobbe et al. (2007) proposes a generic framework for the specification of collaboration scripts. It provides a list of components necessary for describing a script that is independent of its particular implementation in a computer-supported learning environment, addressing concerns from both research and practices [17]. In the same line, Harrer and Hoppe created a modeling language for collaborative scripts called MoCoLADe (Model for Collaborative Learning Activity Design) [8]. This language was developed as a visual language for the edition of collaborative learning scenarios and integrated as a plugin into another application called FreeStyler. Since this visual editing tool cannot be integrated into any other learning engine to be interpreted, the proposal incorporates the option of exporting graphical models into IMS-LD documents. In this way, they can be interpreted and reused by LD players or editors. All these approaches propose good solutions for capturing the necessities for computationally represent CSCL scripts. Nonetheless, these solutions lack consideration of the physical space as a factor conditioning the edition and enactment of a script.

Summarizing, technology enhances current learning spaces by transforming, extending and offering new possibilities for collaborative learning practices. To reflect on the affordances of the technology-enhanced spaces and their limitations whilst designing a collaborative experience means reflecting on the new opportunities that technology offers for generating innovative learning practices. New approaches categorizing and specifying space elements conditioning learners' interactions and affecting teaching and learning design processes, compatible with the current learning specifications are required for supporting designers and practitioners in a reflective process for conceiving innovative learning scenarios. Furthermore, we contend that, a conceptual model specifying and categorizing the space components might be a first approach towards a deeper understanding of how technology-enhanced spaces offer new learning opportunities which would not be possible without technology. Therefore, we need a model sufficiently expressive to facilitate teachers and designers modeling, managing and graphically representing any learning space according to their particular educational needs. Furthermore, we need this model to be interoperable and compatible with existing specifications for facilitating the spaces' reuse.

3 Modeling the space

This section introduces a conceptual model of the space following a schema similar to the structure adopted by [18] when presenting IMS LD. Firstly, we present the requirements that this model aims to fulfill according to the needs specified in the previous section and secondly, we introduce each of the elements that compose it.

3.1 Objectives of the space model

The objective of the space conceptual model is to provide a framework of elements that can describe any physical learning space in a formal way. More specifically, the space model and its compliant implementations aim to meet the following requirements:

- R1. Completeness: This conceptual model must be able to describe any type of physical learning space. The model should be also able to describe the usage of the elements composing the physical space and their arrangement.
- R2. Graphical: All the components defined in the model should be able to be graphically represented.
- R2. Flexibility: The components defined in the model should be flexibly managed and defined. These elements should be able to be moved and located in different areas according to the learning necessities and their usage defined. In addition, the designer should be able to accommodate the different components according to the needs of the actual learning space context.
- R3. Personalization: The model must be able to provide different abstract visualizations for the different users involved in the experience according to the interactions they can perform with the different components.
- R4. Interoperability: The space model must support interoperability with other specifications.
- R5. Compatibility: The space model should be compatible with other existing specifications.
- R6. Reusability: The space model should allow isolating the components of the space and the space itself to be used in other learning situations and other contexts.

3.2 The space conceptual model

Figure 1 expresses the conceptual space model as a set of UML classes and a definition of the vocabulary used. This UML representation provides a view of the overall conceptual model in an abstract way for understanding the main components and their relations [25].

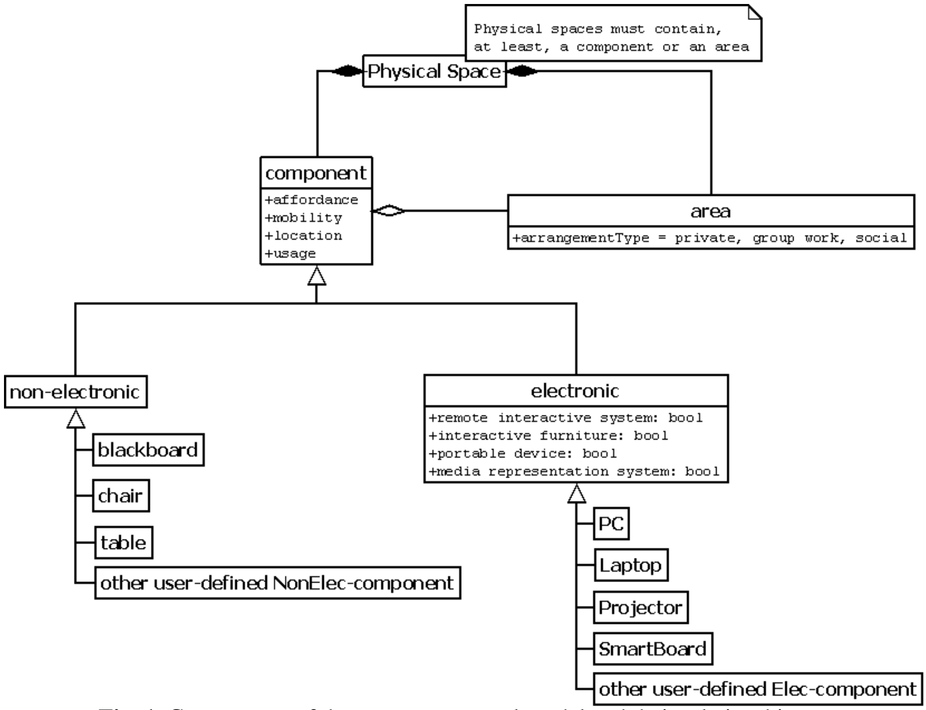

Fig. 1. Components of the space conceptual model and their relationship.

Physical spaces are defined by a set of components that users can be physically in contact with, touch and manipulate. Chairs or pencils are examples of physical components. Physical space can also be composed of areas (e.g. a section of a classroom). These spaces cannot exist if there is not an area or a component associated with it. It is possible to model a physical space without components but it has to include at least one area (e.g. in a drama lesson, the teacher separates the classroom into an area for acting and another one for the audience, which is necessary for orchestrating the practice). In the same way, a physical space can be defined without areas but then, it has to include at least one component (e.g. for having an online meeting, a conference room has to be equipped by, at least, a PC or a laptop with internet connection).

Areas are sections of the physical space composed by a set of physical components and associated to a particular type of task determined by the learning designer. This relationship between areas and the physical space is expressed in the UML representation as a composition. An area cannot exist if it is not associated to an existing physical space and, if the space is deleted, the areas that it contains are also deleted. An area is the *place* where the actions occur and where the interactions between students with the components have an educational meaning. Depending on the arrangement of the components belonging to an area, their nature and their affordance some interactions are triggered. Depending on the interactions elicited by this arrangement the areas can be divided into: *private*, *group work* or *social* areas.

– *Private working area*: A type of area reserved for individual or private task. The components composing this type of areas should have been defined with an individual usage.
– *Group work area*: A type of area reserved for working in groups. The components of these types of areas should have a collective usage or provide facilities supporting communication, collaboration or coordination purposes.
– *Social area*: A type of area conceived as a *place* for socialization. The components in this area are focused on supporting the students in sharing their experiences. The main difference with respect to the *work area* has to do with the affordances of the tools that

they include and the purpose of the activity. In a social area, it is not necessary to include technology for supporting a particular type of collaboration or learning objective, whereas in a work group area, technology must be used as a mechanism for scaffolding collaboration.

The components are the more atomic elements of the space with independent meaning. **Components** of the physical space are classified depending on their nature into two main groups: *electronic* and *non-electronic*. All components have a set of characteristics defined as attributes that can modify the way in which an activity is carried out. Each component is defined by its *affordance* that indicates whether the component is used by a group of persons (collective), only one person (individual) or both. A component is also characterized by its *mobility* (if it can be easily moved or not). A PC, for example, is more difficult to move than a laptop, which can condition the way in which the space is arranged for a particular activity. A component is also defined by its *usage*, which is determined by the learning practitioner or the necessities of the learning activity being carried out (if it will be used for a brainstorming activity, or negotiation, or document sharing or information visualization...). In some cases, components can have *location* attributes that define their position in the space (X, Y, Z). This location attribute is especially interesting for those activities that make use of portable devices such as PDAs or mobile phones.

Non-electronic components are the type of components that are typically found in learning or working areas and are neither electronic nor interactive. The model defines the three more typical elements found in a learning scenario: *blackboards*, *chairs* and *tables*. It is also specified a component to be defined by the learning designer depending on the learning activity. For example, in a science lab, there would be defined tests tubes or microscopes.

Electronic components are defined as components with electronic properties that allow the user to interact individually with it or with other students. These types of components have been especially designed for allowing the users individual interactions with the same component and as a medium for triggering interactions among groups of users. The model fixes as common components found in a learning environment a *PC*, a *laptop*, a *projector* and a *smart board*. Other *non-defined* electronic objects such as a tabletop or a TV can be included by the practitioner depending on the learning context. Electronic components can be described according to their nature:

- *Remote interactive systems*: these systems are focused on providing the user with a system for establishing remote connections with users in other spaces (e.g. webcam).
- *Interactive furniture*: understood as the classical elements, typically found in an educational environment, which are technologically enhanced by extending their interactive properties. This type of furniture is specially created for reacting to the users' actions and triggering interactions related with some learning aspects (e.g., noise sensitive table [6]). Interactive in this context refers to the properties of the furniture to react differently according to the user actions by changing their behavior.
- *Portable devices:* electronic components that can be easily transported. These types of objects can be seen as elements with characteristics in between remote interactive systems and interactive furniture (e.g., mobile phones).
- *Media representation systems*: devices that allow media representation (e.g., projectors).

Some devices can be described using a combination of the previous attributes. For example, a PC allows remote interactions and is also a media representation system for a little group of students. The way in which a collaborative activity is carried out undoubtedly has an impact depending on whether the devices are used for supporting online presence or users' interactions and the usage proposed by the practitioner.

4 Considering the space in two collaborative learning situations

This section is divided into three subsections. The first subsection presents two real learning situations already carried out in which the space where they took place was relevant for the application of a Jigsaw-based script. The second subsection introduces a web-based application developed according to the space model and shows its use to represent the two spaces taking part in both scenarios. At the same time, this prototype aims at being a first approach for allowing the user to define a representation of learning spaces integrated into a scripting design process. Finally, the third subsection discusses how the two scenarios and their representations provide a first evaluation effort to understand whether the aspects defined by the model enable the modeling of two different spaces' characteristics and satisfy the targeted requirements.

4.1 Two real learning situations: the same activity but in two different spaces

Each year, the authors of this paper take part as teachers in an e-Learning seminar at the Autonomous University of Barcelona. One of the activities prepared for this seminar consists in making the students reflect about the future of educational technologies. With this purpose, the teachers propose the reading of the "Horizon Report" [14, 15] of the corresponding year. Since this document is divided in three parts (1 year or less, 2 to 3 years and 4 to 5 years), teachers organize a Jigsaw activity for collaborative working on the different sections of the paper [2, 11]. The activity is divided into three different phases: (1) an individual activity in which each student reads one of the parts randomly assigned by the teacher, (2) an expert group phase in which students having read the same part prepare a poster with the main ideas of this part and (3) a jigsaw group phase in which experts in different parts are joined together to explain the poster to the rest of the group members.

The first academic year that this experience was carried out, the activity took place in a room including two different areas: an area with three rows of tables with PCs facing a blackboard and with a screen projector, and a second area with three separated round tables for working in groups. Due to the arrangement of the space, the teachers organized the second and third parts of the activity in the following manner. Students accessed and read their assigned report parts from the PCs but for the expert group phase, each group was allocated to one of the tables situated in the work group area and worked together on their poster. For the jigsaw group phase, students rotated through the different tables listening to the explanation of their colleagues using posters. In each rotation one of the owners of the poster had to stay at their table to explain it to the students coming to the table.

The second academic year, the activity took place in another classroom. The room was composed of a set of aligned tables with PCs in rows facing the blackboard with a projector without any appropriate place for working in groups. In this case, the teachers decided to assign one of the rows of tables to each expert group for the poster preparation. However, due to the difficulty for the students moving from one table to another the jigsaw activity was modified. Each of the expert groups presented their poster in front of the whole collective class, without forming jigsaw groups and rotating from one poster to another. One of the groups decided to prepare a presentation (instead of a poster) and presented it using the projector. This turned out to be a good idea because the posters of the other two expert groups were difficult to read from the tables. In this situation the differentiation between electronic and non-electronic component is important, for example, having an electronic portable projector totally changed the arrangement of the students in the classroom and the possibilities of presenting their work and the classroom organization. Students were located in front of the projector, which has to be located in a unique place in the classroom (ie. with a plug in source and a screen).

These two situations show how the enactment of an activity with the same learning flow is modified because of the space characteristics in which it takes place. In the first situation, the arrangement of the space elements permits the movement of the students around the class facilitating the interaction between the different expert groups. On the contrary, the classroom arrangement of the second situation constrains the students' movements limiting the classmates' interactions and then, forcing the learning flow to be changed. Moreover, if the teachers had considered the arrangement of the classroom when designing the activity they may have planned in the second situation to ask students to create the posters with the PC instead of on paper so that they could be shown on the projector.

4.2 Supporting the space design

The web-based application prototype has been developed according to the space model defined in section 3. The prototype provides the user with a graphical interface in which the different elements and components are directly manipulated.

Figure 2 shows an overview of the main functionalities. In the center, there is a blank sheet where the user can design graphically the learning spaces involved in the activity. In an upper menu there are represented, as an example, the three activities of the learning flow: individual, expert groups and jigsaw groups. The user can generate one representation of the activity spaces for each of the phases in the learning flow.

On the right hand of the interface the user can choose to represent a physical space. Notice that, in the same phase there can be involved different spaces at the same time. The space type is represented as a dark gray rectangle or a square in the central sheet of the interface. Clicking on the space, the user can define the number of areas forming the space and select whether the area is for private or group work or an area with socialization purposes. The user can drag and drop components to the space. The components are classified into electronic and non–electronic typologies. For each component included in the space, the user can specify its usage; add a title for describing the object and select whether it is going to serve as a collective or individual support. In the case of being a physical component, the user could select which of the areas defined in the space (if the areas have been defined) it belongs to.

Figure 3 and 4 represents the classroom where the activity was carried out in the first situation for the first and second phases, respectively. In the first phase, students occupied the left hand side of the classroom for reading individually their section of the Horizon Report. The same space was used for the expert and jigsaw phases in the learning flow. On the right-hand of the space we can distinguish the three areas defined as *work group*. Each area contains a set of chairs and a table defined as a collective support and assigned to a particular group in its *usage* (1 year or less, 2-3 years and 4-5 years – sections of the "Horizon Report"). Although the classroom includes a projector, its usage is not been defined because it is not used as support for this experience.

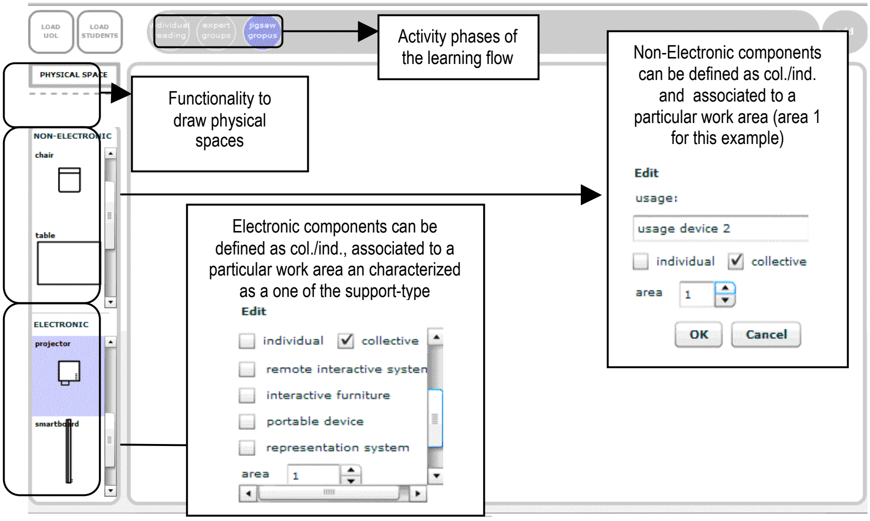

Fig. 2. General interface of the web-based prototype including the functionalities needed to represent the elements and their characteristics defined by the space model.

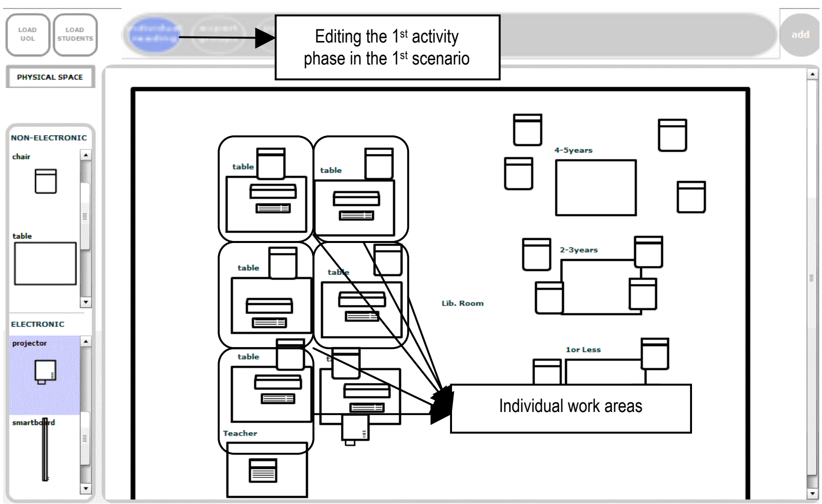

Fig. 3. Representation of the space for the learning flow in the first phase of the first learning situation.

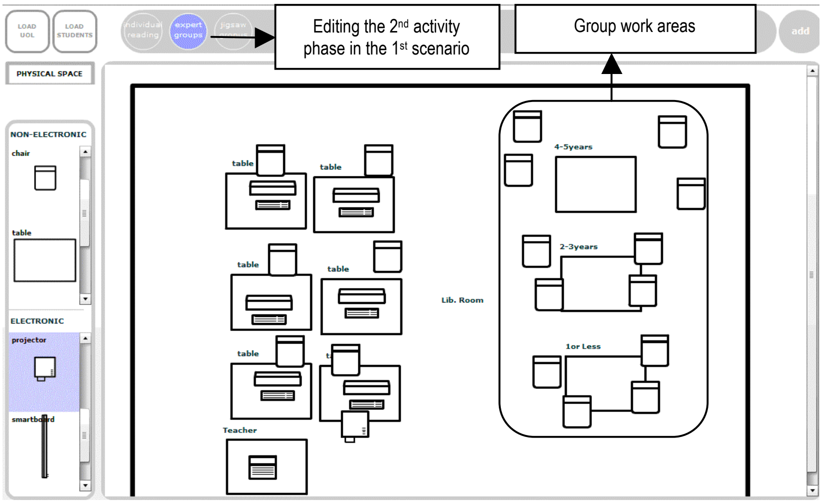

Fig. 4. Representation of the space for the learning flow in the second phase of the first learning situation.

Figure 5 represents the classroom for the second situation. In this case, the space is divided into four areas. Three work group areas corresponding to the three expert groups defined for the activity. These areas are composed of a set of aligned tables with computers defined as *work group*. The tables are also defined as a collective support. The forth area corresponds to the place in front of the projector used for the poster presentation and this is what differentiates this situation from the previous one. This area includes the laptop of the teacher and the projector. In this case, both elements are characterized as *representation system* support because it served one of the groups for presenting their work.

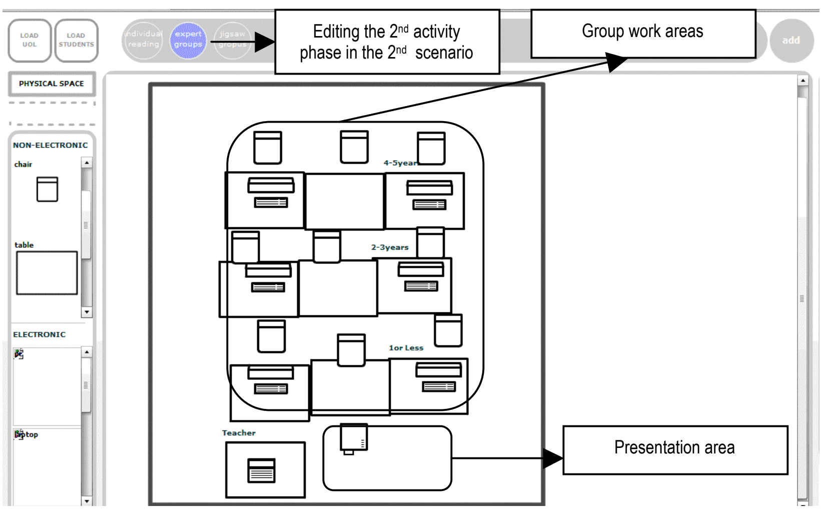

Fig. 5. Representation of the space for learning flow in the second learning situation

In both cases, for the first individual activity, students accessed a Learning Management System (LMS) to download the corresponding part of the Horizon Report. The LMS system could be seen as a virtual space that complements the physical space. However, the representation of these virtual spaces is out of the scope of this work because they are already considered by existing specifications for the description of activity flows, such as IMS LD.

4.3 Discussion

The analysis of the resulting space representations for the two experiences presented above provides a first evaluation of the space model. This analysis is structured in this subsection around the requirements for the model formulated in section 2.

With regard to the completeness requirement, we have shown that the model provides the elements and attributes needed to define the main characteristics of two real learning situations. On one hand, defining the usage of the components in the space allows for particularizing their learning purpose according to each situation. On the other hand, the definition of the space components arrangement enables modeling the particularities of two different spaces that make use of similar devices.

All the components have been graphically represented in the web-based application prototype presented. Although many different representations can be built from the elements in the model, this implementation is a first approach for showing that they are abstract enough and representative so as to be graphically represented. Future designs would help gain a deeper analysis of this requirement.

The two examples show that the model proposed is flexible enough for managing and particularizing the characteristics of the different components. On one hand, the components are characterized by a *usage* defined by the teacher, which makes it possible to particularize how a component is employed in a concrete learning scenario. On the other hand, the components have *location* attributes that enable the user to accommodate them according to the learning needs and characteristics of the actual situation. Moreover, the spaces designed for a phase of the learning flow can be reused for another phase (e.g. phases 2 and 3 of the two situations).

The "Load UOL" bottom in the prototype interface shown in Fig. 4 is planned to enable importing IMS LD units determining the flow of activities (in the examples the phases of the Jigsaw) and the virtual spaces supporting the activities. The physical spaces design with our tool would complement the design of the unit of learning. This approach could be also implemented with other related specifications thus facilitating interoperability and compatibility. The space specification will be included as a new resource type to be referenced in the *environment* element of the IMS LD specification.

The tool currently being prototyped is devoted to teachers but a viewer of classroom configurations for students is also going to be developed. This viewer would show students the spaces personalized according to their roles and the associated activities. It is clear that further efforts in the development of tools and their implementation in educational situations are necessary in order to provide more evidence showing the full potential of the model in terms of their targeted requisites.

Although the two experiences analyzed describe a type of activity that is normally carried out in a "traditional" classroom (using the projector and the different classroom areas), the space is shown as a relevant factor influencing the final learning design. Besides, it is worth noticing that if the devices intervening in the design also include an interactive table and a Smart Board, the influence of the space in the learning design is expected to be even stronger.

5 Conclusions and future work

The Space Model presented in this paper is a first effort towards the formalization of the learning spaces to support its integration as a part of scripting design processes. The aim is to provide a complete and flexible model for graphically representing and personalizing any learning space compatible and interoperable with other specifications. Because of its recent development, it is still too early to provide evidence and strong conclusions about the effects of using the model. However, this first approach raises several questions and aspects that could be pursued in future work.

Firstly, to what extent does the space model serve for representing the characteristics of real educational scenarios? This paper has presented a preliminary evaluation of the model by analyzing its potential for representing two different real learning spaces. However, other experiences involving the use of interactive devices such as touch screens or Smart Boards are planned for the next courses to understand the capabilities of the space model to express the diversity of spaces involved in different learning scenarios.

Another line of work is the binding or computational representation of the space model so that it can be integrated in units of learning packages and interpreted by learning environments (players). Currently, we are preparing an XSD document of the space model from which we could extract XML representations of learning spaces. In parallel, we are also implementing a web-based application to validate these XML files according to the model. The idea is to use the web-based prototype presented in this manuscript to obtain an XML file representing the space that could be validated automatically by the web-based application. As mentioned above, we are also working on the integration of this space definition into a Unit of Learning represented with the IMS LD specification. In relation to this point, we have already included in the current version of the web-based prototype, a section for representing the students in class and organizing them in relation to the space and other constraints imposed by the learning flow, as proposed in [24].

From a more theoretical point of view, we are currently carrying out a study on the relationship established between the affordance of the different space elements and the learning events that they support (reflection, exploration, debate, experimentation…). In that way, it may be possible to relate particular sets of technological usages to a particular space affordance for helping practitioners in finding the most appropriate space for supporting particular learning objectives.

Finally, this work aims at reflecting on how important it is to consider the space as a factor conditioning the learning experiences of the future, in which the use of interactive devices such as a tabletop or mobile devices will be natural. This paper is also an attempt to show how necessary the space formalization efforts are to systematically understand the different usages and methods that include traditional and new devices in educational settings. We contend that this model deserves further research in order to understand what the implications in learning and teaching processes are.

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Paper II

de-la-Fuente-Valentín, L.; Pérez-Sanagustín, M.; Santos, P.; Hernández-Leo, D.; Pardo, A; Blat, J.; Delgado-Kloos, C. *System orchestration support for a flow of blended collaborative activities.* In: Proceedings of the 2nd International Conference on Intelligent Networking and Collaborative Systems. Thessaloniki: 2010.

Abstract The introduction of portable devices in education opens up new possibilities for Computer Supported Collaborative Learning (CSCL) by providing advanced learning scenarios with activities in different spatial locations. However, organizing and structuring collaborative learning flows in these innovative scenarios represents also a workload for practitioners, which hinder the adoption of these technologies. As a step forward to alleviate this workload, this paper analyzes the limitations and bottlenecks detected in an actual collaborative blended learning experience carried out in a previous study and proposes a technological solution for solving them. The resulting solution is presented as a concept proof consisting of a Unit of Learning suitable to be instantiated with IMS Learning Design and complemented by a Generic Service Integration system. The paper also discusses to which extent the proposed solution covers the limitations detected in the previous study and how useful could be for reducing the orchestration effort in future experiences.

System orchestration support for a flow of blended collaborative activities

Luis de-la-Fuente-Valentín, Mar Pérez-Sanagustín, Patricia Santos, Davinia Hernández-Leo, Abelardo Pardo, Carlos Delgado Kloos, Josep Blat
Telematics Engineering Department, Carlos III University of Madrid, Madrid, Spain
{lfuente, abel, cdk}@it.uc3m.es
Department of Information and Communication Technologies, Universitat Pompeu Fabra, Barcelona, Spain
{mar.perez, patricia.santos, davinia.hernandez, josep.blat}@upf.edu

Abstract— **The introduction of portable devices in education opens up new possibilities for Computer Supported Collaborative Learning (CSCL) by providing advanced learning scenarios with activities in different spatial locations. However, organizing and structuring collaborative learning flows in these innovative scenarios represents also a workload for practitioners, which hinder the adoption of these technologies. As a step forward to alleviate this workload, this paper analyzes the limitations and bottlenecks detected in an actual collaborative blended learning experience carried out in a previous study and proposes a technological solution for solving them. The resulting solution is presented as a concept proof consisting of a Unit of Learning suitable to be instantiated with IMS Learning Design and complemented by a Generic Service Integration system. The paper also discusses to which extent the proposed solution covers the limitations detected in the previous study and how useful could be for reducing the orchestration effort in future experiences.**

Keywords- IMS Learning Design; blended learning; CSCL; GSI; service integration

INTRODUCTION

Portable devices have impacted multiple aspects of our everyday life. In education, the potential of this technology is seen by researchers and practitioners as a chance for expanding current educational scenarios and exploring innovative learning methodologies [26]. Particularly in the area of Computer Supported Collaborative Learning (CSCL), the introduction of portable devices opens a new debate about how this discipline is going to evolve [10].

Significant research effort has been devoted to introduce portable devices in learning experiences and to understand how they might enhance current educational settings. Some works benefit from the mobile and content delivery capabilities of this technology to generate learning settings enabling learners to work and collaborate in different spatial locations beyond the class. For example, Facer et al. [2] propose a mobile gaming experience in which children are invited to understand the animal behavior in a savanna in direct physical interaction with this space. The findings of this study show that this innovative experience increased the self-motivation of children. Another work by Ruchter et al. describes an experience using mobile computers as a guide for supporting environmental learning [1]. The results show that using these computers as mobile guides can lead to an increase in knowledge about the natural environment and an increase in students' motivation to engage in the educational environmental activities. Both studies propose activities in which students interact with course material with their hand held devices in different spatial locations and introduce a new concept of learning in which activities are no longer limited to the classroom space.

A study by Park et al. states that "mobile learning activities could provide a better learning experience by establishing the conditions for optimal flow" [4]. This idea relates with the CSCL concept of *orchestration*. Orchestration is defined as the process of structuring learning flows for achieving potential effective learning outcomes [11], and the path followed by course participants during the whole activity enactment is called *learning flow*. According to Roschelle and Pea "learning content's performance is optimized when it is orchestrated with a pedagogical sense" [10]. One of the proposals to organize and computationally support these learning flows are the so called "scripts" [3, 12, 13]. CSCL scripts manage resources and deliverables, define roles and phases and enable specific interaction in order to guide collaborative processes for producing situations of effective learning [14] by facilitating and reducing the coordination efforts of teacher and students [6, 5, 16]. However, when these scripts combine activities supported by portable devices with activities taking place in different spatial locations, the orchestration process becomes more complex. In such type of scenarios it becomes particularly challenging tracking students' progress [4]. This hinders the establishment of the relations within activities and makes the management of the collaborative learning flow more difficult. As a consequence, the orchestration of collaborative learning flows in such scenarios translates into an increase in the teaching staff workload.

The results of a previous work carried out by the authors of this paper in a real educational context evidence this workload [8]. The work presents a case study of a collaborative blended learning experience that combines mobile based activities with in-class sessions. Despite the encouraging results, the enactment of these types of learning settings imposes a significant workload on the teaching staff. As a consequence, one of the conclusions of the study proposes automating some aspects of the experience enactment for future editions of the course. The work presented in this paper is based on the above-mentioned previous experience. The goal is to present the proof of concept of a technological setting that automates some of the orchestration tasks of this experience. As a consequence, the teaching staff effort is expected to be reduced thus facilitating the replication of the experience with a reasonable cost in future editions. With this aim, we created a scripted learning flow implemented in a Unit of Learning (henceforth simply UoL) for orchestrating the activities and automating management duties. The UoL is compliant with IMS Learning Design (IMS LD) [7] and extended with Generic Service Integration (GSI) [9]. As a conclusion, we discuss to which extend these technologies can overcome with the limitations detected and how useful might be in similar situations.

The rest of the paper is organized as follows: Section II describes the scenario from the previous experience and exposes its main limitations. Section III describes the system architecture prototype built as a proof of concept to automate the orchestration process of this scenario. Finally, Section IV discusses how the proposed scripted flow is envisaged to solve the limitations detected in the previous study and help reducing teaching staff workload on similar experiences.

LIMITATIONS ON THE ORCHESTRATION OF A REAL EDUCATIONAL EXPERIENCE

This section is divided into two parts. First, the learning experience carried out in a previous work by the authors of this paper at the Universitat Pompeu Fabra (Barcelona, Spain) is presented. In the second part, the experience is analyzed by re-using the data of the study and the qualitative results obtained. As a result, we identify the main limitations regarding the orchestration process.

Scenario: meeting the campus together

The CSCL experience was carried out with 74 first -year ICT engineering students enrolled in a mandatory course called Introduction to Information and Communication Technologies. The aim of the course is to give a global vision of the University and its resources, and an introduction to the professional world of ICT industry. The CSCL activity started the first day of the 2009-2010 academic years and continued during the next two weeks. The scenario was organized in three different phases following the learning flow defined by the Jigsaw Collaborative Learning Flow Pattern (CLFP) [22, 23].

The first phase consisted in an individual exploration of the campus. We named this phase “Discovering the Campus”. To support this activity 46 NFC tags were distributed around the 5 campus's buildings. These tags contained information about the place in which they were located. Students were equipped with NOKIA (N6131, N6212) mobile phones which included an embedded RFID reader for accessing the information stored in the tags. Students had 30 minutes to freely explore the campus. All the information regarding the sequence of tags accessed by each student was stored into a log file. After the visit, students had to fill in a Google Forms questionnaire indicating which buildings had visited and which seemed to them the most interesting.

The second phase was called “Explain the campus”. In this phase, students were grouped in “Building's Expert groups”. Each expert group was associated to one of the 5 campus buildings and had 4 or 5 members randomly chosen from the students with similar building expertise level. To define the students' building expertise the teachers considered two sources of information: (1) the log files obtained during the exploration and (2) the answers to the Google Form questionnaire. The activity for these teams was to create a presentation explaining the main characteristics of the building assigned and upload it to the Moodle Platform of the University (henceforth Moodle).

Finally, the third phase was called “Reflect about the campus”. For this activity, the teachers uploaded all the presentations from the previous phase to Moodle. Students had to access and review all the presentations and answer an individual test including questions about the whole campus. This last activity was carried out in a 25 minutes session in a classroom with PCs.

Orchestration tasks and limitations detected

All the orchestration processes of the case study were carried out by two teachers and one researcher. The activity was technologically supported (NFC tags, mobile phones, Moodle) but there was no system that automatically integrated the whole process. This translated into some of the orchestrations tasks being done *by hand*. It follows a detailed explanation of teacher tasks in each phase. The focus of this paper is on those orchestration aspects that were more demanding and time consuming. A detailed description of the activity design and preparation tasks can be found in [8].

The task for the teachers in the first phase was to store the log files once the students finish the visit of the campus. Due to the number of students and the number of available devices, some of the students had to share a device for the visit. To identify which data log belonged to which student, teachers annotated the time when a device was given to a student or pair of students. This information was used later to make the correspondence between the log files and the students and produce a log file for each of the students participating in the experience. The files were uploaded to a computer via Bluetooth connection.

In the second phase, teachers had to form the building's expert groups. As explained before, the expertise was measured taking into account the number of tags per building visited by each student and the preferences indicated in the questionnaire. This was the most complex and time consuming task. One of the teachers of the course stated: *“Once the whole activity was set-up, I think it was more a matter of complexity than of difficulty. The logistics was the more demanding issue: creating groups, informing students about the groups, orchestrating their tasks depending on the groups, managing and analyzing their outcomes in order to propose them the following tasks, managing their outcomes in order to facilitate the assessment of their learning, etc*”. A set of limitations in the orchestration process were detected in this phase. First, the teachers manually analyzed all the log files created during the visit. Due to the number of students (74) this part was very time consuming and the process had to be reviewed three times by the two different teachers and a researcher to avoid errors. This task required 3 hours. Second, in the analysis of the preference questionnaire, the recommended building was considered the preferred one. This was carried out approximately in 4 hours. Students were divided into two groups for the regular lecturing sessions. For the described experience, students from both groups were randomly mixed. Combining people from these groups also posed some problems. On one hand, students could not contact easily their class mates because they did not meet face to face in the classroom. On the other hand, because the activity took place during the first two weeks of the course, there were students dropping out the course before the final presentation so some groups had to be rearranged. All these group adjustment were carried on by the teaching staff using e-mail for communication.

In the third phase, the task of the teachers consisted of uploading the students' presentations to a public repository in Moodle and make students complete the final test. The teacher organized the presentations per building and created one folder for each group in the public repository. The test was uploaded to the platform and the teachers had to control that all students had answered the test. This activity was carried out in a session with PCs.

Finally, the teachers organized the workflow using Moodle. They used the platform to inform students of the steps for the next activities, and e-mail to inform when the description of a new activity was available. However, other activities in the course were also carried out in parallel during this period (and published in Moodle) and students had problems to have a unified view of the scenario.

Another aspect to highlight is the scalability of the activity. 421 students were enrolled in the course. However, due to the complexity in the activity orchestration, only a group of 74 students performed the mobile-based activity. The rest of students visited the university on their own.

In summary, the evaluation of the case study detected the following limitations:

1) Students' data analysis: Manually analyzing the log files was hard to carry out without errors. Also combining the preferences and the log file results for assigning the students expertise is complex and very time demanding.
2) Expert group management: Creating and managing the expert groups was very time demanding because of the instability due to drop outs that characterize the first weeks of the course and mixing students from the two lecturing sessions.
3) Activity workflow: Moodle does not facilitate the integration of the activities to create an orchestrated view of the learning flow.
4) Scalability: Without technological support, these activities are very costly to carry out for a large number of students. The data analysis becomes very complex.

Proposed Scripted Orchestration

This section presents the technological solution developed as an approach for dealing with the limitations highlighted in Section 0. The proposal is to use a computational script as the orchestration mechanism for automating the most demanding tasks. The result is a Unit of Learning (UoL) (compliant with IMS LD and complemented with GSI) that structures the learning flow of the scenario described in Section II.A. Additionally, the proposed UoL (with minor changes) could be used for supporting analogous learning flows. The presented solution is a proof of concept to show that teaching staff workload can be significantly reduced in any learning situation which combines collaborative activities in different spatial locations supported by portable devices.

Course flow management technologies

One of the best-established modeling languages used to computationally represent learning flows is the specification IMS Learning Design [7]. It provides a framework to design and deploy a wide range of pedagogical models, which includes collaborative and blended learning. IMS LD is constructed upon the metaphor of the theatrical play: different actors play different roles. Each *role* is assigned to a set of *learning activities* that may occur in sequence or in parallel, depending on whether they are organized in *acts* or *structures*. Each activity takes place in a given *environment*, which consists of a set of *learning objects* and/or *services*. The concept of role allows complex collaborative learning models to be expressed by IMS LD [18], while the existence of *properties* and *conditions* makes possible the design of strategies based on adaptive content [19].

Natively-defined services are limited to e-mail facilities, conference, monitor and index. In practice, available services are not able to support complex blended learning flows, where different tools are used in different scenarios. Generic Service Integration (GSI) [9] proposes a framework to include any kind of web-based tool in the context of IMS LD courses, making possible to adapt the flow depending on students' behavior on the included tool. For the purpose of the work presented in this paper, GSI has been used to integrate specialized data management tools as part of the learning flow. We have used an on-line web spreadsheet provided by Google[1] to administer students' data and to automatically create groups.

The integration of Google Spreadsheets in a UoL can be summarized as follows [9]: students access a questionnaire (an HTML form) through a hyperlink located in the *environment* of an activity; on the other hand, teachers own a spreadsheet populated by student's responses, where each row contains data from a single student. Teachers can manipulate the spreadsheet arbitrarily so that they produce a value suitable to be mapped to an IMS LD property. Then, IMS LD retrieves the data contained in the spreadsheet and the appropriate properties are updated.

The inclusion of spreadsheets in IMS LD courses serves a double purpose. First, it provides support for assessment, the absence of which is one of the weaknesses of the specification. Assessment is made possible by including HTML questionnaires and using the responses to adapt the course flow. Second, it offers a well-known method to manipulate data, substituting the complex calculate element

1 http://spreadsheets.google.com

in IMS LD, which hinders the creation of mathematical formulas based of questionnaire responses.

Course flow details

The script was designed to support five working groups, whose number of members was set to five. As a result, 25 is the number of learners considered in the design of the learning script. The number of teachers is not restricted. We will refer to all teaching staff members as simply *the teacher*.

The course follows a blended learning approach: students receive the information through the computer; some of the activities are done on-line and the remaining ones are offline. An overview of the course flow is show in Figure 1.

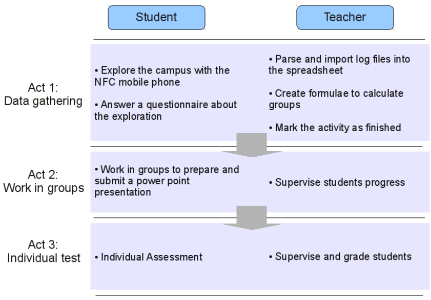

Figure 1. IMS LD Mapping of the original flow.

First phase: Discovering the campus

Two types of participants take part in the course: learners and teachers. These are the *roles* defined in the UoL. Although the learners are divided into groups, there still is a single role for all of them. This is because roles are populated at the beginning of the course, and therefore at design time there is not enough information about the number of required groups. This division is performed in a later step using *local properties*.

During the first act, learners visit the campus and acquire knowledge they will use in later activities. They perform the visit with a NFC mobile phone as described in section III. Once finished, they fill in a questionnaire to show their acquired knowledge of the campus.

Both, the answers to the questionnaire and the mobile activity logs, are stored in a Google Spreadsheet. The former requires no human intervention to do so, but the latter follows a different path shown in Figure 2. When a student finishes the activity, s/he is requested to use the resulting log file as the value of a file property. All student logs are stored in the same folder and are easy to manipulate. Furthermore, because files are related to their owners, it is also possible to easily identify which log belongs to which student. The regular structure of the log files allows automatic parsing. A script specially developed for the case performs the log analysis and produces a *csv* file with a summary of the events generated by each student. This summary contains, for each student: (1) the number of tags accessed per building and (2) the building expertise, which is the building with the maximum number of tags accessed. This summary can then be uploaded into a Google spreadsheet. The processes to generate this summary and uploaded it to the spreadsheet is done by the teacher and take place when all the students have finished their corresponding activities.

The spreadsheet then contains all the data from the logs and questionnaires. At this point, the teacher manipulates the data so that the output of the activity is finally produced. The calculated output is a number (from 1 to 5) assigned to each student representing the building's expert group. All values are calculated by the spreadsheet, which has been previously modified with the proper criteria. The formulas in the spreadsheet require numeric values, and as a consequence the original questionnaire was modified to include closed response questions to process results automatically. The questionnaire includes three types of questions: (1) a multiple choice option in which the students select the building they have visited, (2) a true-false question related to each building and (3) a Likert-scale question to evaluate each building. The use of closed response questions solves two problems: first, offers the possibility of automatically computing the students' preferences. Second, provides the teacher with an easy mechanism to evaluate the students' knowledge about the campus.

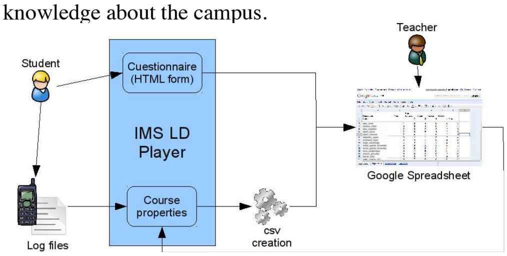

Figure 2 Data flow for group assignment automation

The criteria to group students considered data from questionnaires and log files. However, the absence of one of these sources was also supported. This fact provides a degree of flexibility to the course flow. For instance, students who could not perform the activity "Discovering the campus" will find their corresponding group in the next phase. This requirement is also supported by enabling the teacher to overwrite the groups assigned by the spreadsheet formulas.

Once the grouping phase has finished and no more group changes are expected, the teacher marks the activity as finished. This action triggers data synchronization between IMS LD and the external spreadsheet. When IMS LD properties obtain their value, conditions are evaluated and the course flow is adapted appropriately. There are two types of properties whose value is assigned:

- Each student has a property called *group*. The value is a number (from 1 to 5) that says in which groups the student has been placed.
- Each group has a property called *members*, which contains the team member names. This value is used to increase student awareness.

Second phase: Explain the campus

The second phase of the course flow has been modeled as an IMS LD act: all course participants start at the same time. The act adapts its contents depending on which group the student has been related to. There are three issues to be solved by the course flow:

1) Which tasks corresponds to each student?
2) How do students know who their partners are?
3) How do students submit their presentation?

To solve the first question, the course flow has been modeled with five different activities, one per building's experts group. The visibility of these activities is controlled by property values, so that only one of them will be shown to each student. In practice, students receive the activity description that corresponds to their group, and they see no information about the other groups. Each activity description shows the *members* property of the group. Therefore, students are aware of who are their teammates.

The presentation submission has been modeled as a local property whose value is set when students upload a file through a form included in the activity description.

Third phase: Reflect about the campus

In this phase, the delivery of the previously submitted presentations requires no intervention from the teaching staff: file properties are directly accessible from the statement. Thus, students may review all the presentations and access to the final assessment task.

The final assessment is an IMS Question & Test Interoperability (QTI) test[2]. Students access this test through a link in the UoL and login to the QTI server. The QTI test is composed of 5 questions: 3 common QTI questions (Multiple Choice, Yes/No and Multiple response) and 2 Google Maps-based QTI questions [25]. For these questions, students locate their answer in a Google Maps map.

DISCUSSION

Students data extracted from the empirical study presented in section 0 were used to simulate the enactment of the scripted orchestration proposed in section 0. This section analyzes whether the solution solves the limitations observed from the experience: the expert assignments process, the expert groups management, the activity workflow and the scalability. A simulation was performed with a set of data consisting of 74 log files. Since the questionnaires were modified to fit in the proposed orchestration, the simulation did not use data from the empirical study. Figure 3 shows the results of the analysis of the 74 log files.

Both the module for automating log files analysis and the numeric questionnaires solved the main limitations of the students' data analysis. On one hand, this solution may strongly decrease the time spent by the teacher in analyzing all the log files. On the other hand, this automatic approach might support the teacher in the assignment of students' expertise by diminishing the number of errors when doing this process manually. Moreover, this approach also provides the teacher with the possibility of modifying the automatic building assignment. Therefore, it offers a flexible semi-automatic system for analyzing log files and managing the students' building assignments effectively.

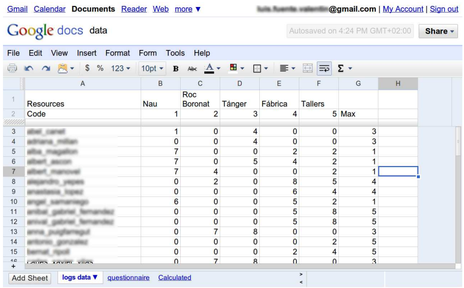

Figure 3: Student activity data imported from the analysis of the 74 log files.

The proposed semi-automatic solution relates the numeric lists obtained from the analysis of the log files and the answers to the questionnaire. The resulting values are used to generate a ranking of students per building that is shown to the teacher in a spreadsheet. The building assignment is done following the order established in the rankings lists and associating a number from 1 to 5 to each student. This semi-automatic group formation solution facilitates the teacher's grouping tasks alleviating the time investment. At the same time, this approach provides the user with a flexible mechanism to easily adapt the groups to the actual context of the activity.

The workflow is captured and delivered using IMS LD. The activity tree and activity content, is adapted for each student who receives, at the end of the course, a complete view of the learning flow.

The scripted course flow presented in this paper has been designed to support 25 students. In the course flow, manual interventions of teaching staff are: (1) Copy log files to the folder where they will be parsed; (2) Import the resulting *csv* file to the spreadsheet; (3) Insert a set of spreadsheet formulas to calculate grouping criteria; (4) Mark acts as finished when corresponds. From these actions, (3) is the only one requiring significant time. However, its completion is required only once regardless of the number of course replications. As a result, the learning script can be instantiated several times, with a low impact in teachers' workload allowing scalability.

CONCLUSIONS

This paper has presented a proof of concept of a technological solution that supports the automatic enactment of experiences requiring the orchestration of a complex collaborative learning flow, supported by different computing devices, involving different spatial locations and with a large number of students. The motivating example has been drawn from a real experience that presented promising results in terms of students' motivation and achieved learning but imposing a severe workload on the teaching staff.

The proposed orchestration was captured into a UoL codified with IMS LD and GSI. The use of GSI to integrate services in the context of the UoL allowed the learning flow to coordinate the use of different technologies such as NFC,

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Google Spreadsheets and QTI. In the designed course, a semi-automatic process of data acquisition and group formation complements the group-dependent scripted delivery of the learning material. The enactment simulation with the proposed script showed that this solution would provide significant reduction of teaching staff workload. The major limitations of the previous experience disappear with the semi-automatic orchestration of the learning flow. As a conclusion, the presented solution sheds some light on how technology can facilitate the orchestration process of complex and innovative collaborative learning using portable technology such as smart phones.

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Paper III

Pérez-Sanagustín, M.; Hernández-Leo, D.; Santos, P.; Sayago, S.; Griffiths, D.; Blat, J. *Dialogic learning and interactive groups: an IMS LD template integrated in runtime systems.* International Journal of Emerging Technologies in Learning, 2008; 3: 38-45.

Abstract Dialogic learning and interactive groups have proved to be a useful educational methodological approach in lifelong learning with adults. The principles of this approach stress the importance of dialogue and equal participation in every stage of the learning process including the design of the training activities. This paper adopts these principles as the basis for a configurable template that can be integrated in runtime systems. The template is formulated as a meta-UoL which can be interpreted by IMS Learning Design players. This template serves as a guide to flexibly select and edit the activities at runtime (on the fly). The meta-UoL has been used successfully by two significant practitioners so as to create a real-life example, with positive and encouraging results.

Dialogic learning and interactive groups: an IMS LD template integrated in runtime systems

M. Pérez-Sanagustín[1], D. Hernández-Leo[1], P. Santos[1], S. Sayago[1], D. Griffiths[2], J. Blat[1]

1 Universitat Pompeu Fabra/ Information and Communication Technologies Department, Barcelona, Spain

2 University of Bolton/The Institute for Educational Cybernetics, Bolton, UK

Abstract— **Dialogic learning and interactive groups have proved to be a useful educational methodological approach in lifelong learning with adults. The principles of this approach stress the importance of dialogue and equal participation in every stage of the learning process – including the design of the training activities. This paper adopts these principles as the basis for a configurable template that can be integrated in runtime systems. The template is formulated as a meta-UoL which can be interpreted by IMS Learning Design players. This template serves as a guide to flexibly select and edit the activities at runtime (on the fly). The meta-UoL has been used successfully by two significant practitioners so as to create a real-life example, with positive and encouraging results.**

Index Terms— **authoring, enactment, IMS LD, lifelong learning, pedagogical model, template, flexibility.**

I. Introduction

Some of the main problems of lifelong competence development are related to the enormous diversity among lifelong adult learners. This diversity encompasses a large number of factors such as age, gender and culture but also aspects such as needs and interests. The complexity of this context is also emphasized by the fact that lifelong learners have already accumulated experience in informal learning settings, typically associated to real-life situations, which can hinder the implementation of more formal or traditional learning strategies. This is the rationale behind the research on pedagogical models that is being conducted within the European TENCompetence project. In this project a pedagogical model is considered to be a representation of a pedagogical activity using the IMS Learning Design (IMS LD) specification [1], which can be used for authoring and delivering learning activities [2]. This representation does not need to be a full ready-to-run Unit of Learning (UoL).

In this paper we adopt the methodologies used in Agora as a significant basis for approaching TENCompetence pedagogical models. Agora is an association within the La Verneda School for adult education [3]. Their main objectives are to address social exclusion by providing opportunities for people to train and to update their skills beyond formal education. This is, to provide a space for life-long learning development in which the learners define their own education in relation to their own learning needs.

Agora relies on the principles of democratic participation as a basis for creating of a space for lifelong learning. Every participant has the opportunity to contribute in a myriad of decision spaces. In this way, the methodology they use in their training activities is based on dialogic learning and interactive groups [4]. Dialogic learning is defined as “the learning that results from the interactions produced by an egalitarian dialogue among participants” [19, p 91]. There are no hierarchies within participants and everybody can participate in the definition of the learning process. A well-tried and known way of implement Dialogic learning’s principles in practical real contexts is making use of interactive groups [19, p.93]. These are heterogeneous groups of persons with different academic levels and experiences that “work together” and “find out” together in a “logical” way guided and coordinated by the trainer [20 and references in there].

Therefore, in the context of adult education knowledge is the result of the convergence of the interactions and experiences’ exchanged through dialogue [18, 21].In this context, the traditional instructional design guidelines are too rigid since motivation and participation of learners become the gist of the learning process. Consequently, it is necessary to use also in the new design methodologies to tackle the flexibility requirements and also to generate the organizational structures for supporting them [18, p.125]. Flexibility here is not only a desire but it is also the base and the central requisite for the construction of a space for egalitarian dialogue and democratic participation. To propose a technical approach as a solution for this particular educational context is the main rationale behind this research.

We address this problem by adopting the ideas of dialogic learning and interactive groups and integrating them in an IMS LD configurable template (using a terminology according to the framework proposed in [12]) that can be directly integrated in runtime systems. The template is computationally represented in the form of what we call a meta-UoL. This is a fully-fledged UoL offering abstract information derived from other more concrete UoLs. This template incorporates a set of dialogical learning methodological activities that the participants can choose, complete and refine according to the needs of their particular situation. So that participants will end up with a defined UoL adapted to it.

For participative educational methodologies new requirements appear that cannot be supported by the existing approaches. The activities should not be detailed in advance and all the participants should collaborate in the edition process during the execution of the UoL. These situations demands a different approach to the current IMS LD implementations in which authoring tools are not integrated in runtime systems and where UoLs need to be planned in advance [6, 16].

Nowadays, most of the existing systems treat separately the edition from the enactment phase. Some examples for the edition phase are Reload [8] or Collage [9]. The reference IMS LD engine for the enactment is Coppercore [10]. Coppercore has been integrated in several IMS LD compliant players such as SleD [15], but these players do not integrate authoring functionalities. However, some studies underline the necessity of developing systems that allow the adaptation of learning designs to the actual context on the fly [6, 7]. Recently, a related research has proposed a mechanism for the introduction of small variations in the original UoL at runtime [11]. It codifies the changes through a set of notifications that are interpreted in the enactment phase. Nevertheless, the roles are previously defined in the edition phase. Thus, this system still considers the separation between the two different phases.

In this context, there are mainly two different situations in which flexibility, in terms of the actual running, is required. First, unexpected situations can occur which would require a UoL to be modified on the fly [6, 7, 11]. Second, it may also be required that the participants should be able to participate in the (on-going) dialogic design of the UoLs. It demands a system that breaks down the frontiers within the enactment and the edition phase and the distinctions between user roles.

Therefore, the aim of this paper is twofold: to define a pedagogical template based on the principles of dialogic learning and the interactive groups, and to formalize the template in an IMS LD interoperable format so that it can be integrated and directly refined (authored) in runtime systems. An additional important contribution of this research is to study which are the possibilities of using the IMS LD specification [14] in such a flexible context. And, moreover, analyze its efficiency when integrating the edition with the enactment phase.

The rest of the paper is structured as follows. The section II deals with the formulation and implementation of the pedagogical template. Section III illustrates the template integrated in the SLeD system [15] through a realistic use case and the result of using the proposals with two significant potential users. Finally, Section IV concludes this paper indicating the future work planned to enhance this approach.

II. Template based on dialogic learning and the interactive groups

The formulation of the template is accomplished in three phases. First, its design requires a description of the learning context and of the problems detected. Second, a detailed analysis of the dialogic learning and interactive groups methodological approaches. Third, it should be technically implemented according to the IMS LD specification so that it can be interpreted by compliant systems.

A. Learning context

In educational contexts such as in la Verneda School, the dialogical learning has been proved to be an efficient technique to promote the self-confidence of the learners and to involve them into the learning process [5, 18 p. 124, 19 p. 93, 21, 22]. However, one of the problems when carrying out the theoretical principles of the methodology in a real context is to find the appropriate activities that fit with them. It requires lot of practice and experience.

The template we proposed in this paper is an attempt for guiding the Agora's coordinator –especially novice- in the edition of UoLs before and during the training session. These UoLs provide a collection of learning processes that can be shared and reused among trainers as a mean for interchanging experiences as well as for facilitating their familiarization with the methodology.

Since the template is accessible for all the participants during the session it is a means for supporting the collaboration and let people decide collectively about the learning design [4 p. 3]. It is also a mechanism for supporting the communication and community building beyond face-to-face possibilities, even at home. Moreover, as it provides an integrated view of the whole session, it also helps the coordinator to avoid repetitive explanations. At the same time, is a way for the learner to freely follow the activity, which enhances their self-confidence and self-evaluation competences.

Therefore, we consider the use of a template as a good solution mainly for two reasons. First, it has proven to be a good approach not only for the reuse of learning designs but also for guiding users in structuring their learning activities [13, 9]. Second, its configurable nature allows users (learners and trainers/coordinators) to refine the learning design according to the necessities of the actual learning context [5, 18, 19].

B. Design of the template

The design of the template was the result of an iterative process with different phases. Three learning designers followed a top-down and bottom-up approaches considering the theoretical principles of dialogic learning and the Agora coordinators' accumulated experience. That is, they applied a methodology based on theory and practice.

Flecha (2000) [4, p.1] defines seven principles as a guide for implementing dialogic learning:

- Egalitarian dialogue: there are no hierarchies among participants and all the opinions have the same value.
- Cultural intelligence: the group of abilities developed along people's life to carry out operations in their everyday activities.
- Transformation: learning is a transformation process that affects the environment of the learner in many different aspects.
- Instrumental dimension: dialogic learning includes instrumental learning planned and scheduled by the participants. It enhances the ability of reflection to reach consensus.
- Creating meaning: the meaning created through interpersonal interaction.
- Solidarity: knowledge is built together and everyone learns from everyone.
- Equality of differences: exploiting the differences between people for enriching the learning process.

In the first phase on the definition process, the researchers studied individually the principles of dialogic learning. After that, they did a brainstorming session in which they came up with a list of activities that represent the ideas that arise from the methodology. For example, the principle of solidarity is strongly related to concepts such as collaborating or negotiating. In a second phase, they build a new activity list taking as a reference the actions usually performed in Agora's sessions. The third phase consisted on making a comparative analysis of the two lists and of generating a final one. The list should contain a number of activities enough rich to represent the organizational structures required for the learning context but short enough to be usable. In the last phase, the characteristics of each activity were defined: "who" the person in the session that decides the characteristics of the activity (the trainer or the learner) could be and "which" the input and the output artifacts treated on it were. At this point, it was decided to suppress the distinction between trainer and learner and consider only the role of participant, since any person can equally take part of the learning design process. Finally it was decided which was the tool that better supported each activity. For this last issue, it was decided to suggest web 2.0 tools because of their popularity, usability and availability, and also for their participatory nature [23]. All these aspects would be part of the configurable elements of the template.

Finally, only seven activities compose the first approach of the template. For each activity, the user is able to take the different types of design decisions as defined in the template, namely: *if an activity type appears and when*, *the activity description* (task), *the tool support*, *supporting resources* (supporting the activity), and the *output resources* (resulting from the activity). This initial approach is modified and readapted taking into consideration the suggestions of the users (modifications in section II.B).

The template described here is only an attempt for supporting dialogic learning and interactive groups in the particular context of Agora. Although other approaches could be defined, the evaluation experiences showed that the Agora's trainers success in mapping the activities in the template with those that they usually perform in their sessions.

C. *Implementation of the template*

In this paper we provide a prototype of a template resulting from first iterative design process that will serve as a guide for future implementations. The current version of the template[1] considers up to four possible different phases formalized as IMS LD *acts*. Within each phase, the user can select the activity type out of the seven types shown in Table I. Once selected, the edition of the chosen activity is enabled. Both the selection activity and each of the possible "edition activities" are modelled as *supporting activities*. See in Fig. 1 the code that implements a support-activity for the definition of the negotiation.

```
<support-activity identifier="define-activity-negotiation-3"
isvisible="true">
  <title>define-activity-negotiation-3</title>
  <activity-description>
    <title>Define the negotiation activity (3)</title>
    <item identifier="item-negotiation-3"
    identifierref="resource-negotiation-3"
    isvisible="true" />
  </activity-description>
</support-activity>
```

Figure 1 XML code for the definition of the negotiation activity that is codified in a *support-activity*.

When the user finishes the edition by having described the activity (Table I), the actual *learning activity* is available and has the characteristics previously configured. Each design decision is codified with *local properties*. Fig. 2 shows two of the five properties (the description and the supporting tools) of the negotiation activity selected. When the properties of the activity are set to true by pressing OK the activity is completely defined.

[1] Available online at http://www.tecn.upf.es/~daviniah/metaUoL.zip

Table I TYPE OF ACTIVITIES AND THEIR ASSOCIATED DECISIONS

TYPE OF ACTIVITY AND BRIEF EXPLANATION	DESIGN DECISIONS (Indications on supporting tools, input resources and output artifacts. Additional decisions are visibility, order and description of the activitieS)
NEGOTIATING In dialogical learning, people decide collectively, through discussion, the aims and contents of their activities.	Tool support: indicate the tool or tools to support the activity, suggestions are: Doodle or Forum to discuss about a topic […] Input resources: upload a comment or file to support the negotiation activity. Output artifacts: add a briefly description about the expected result of the process (statistics of the votes, the final decision).
DIALOGUING Interactive groups promote solidarity, dialogue between equals, reinforcing the communicative action and expressing implicit knowledge and the abilities.	Tool support: select means of communications based on the equally of learners and coordinators whose comments are not classified as better or worse but appreciated as different […] Input resources: for example a list of discussion points […] Output artifacts: description about the expected result […]
SHARING People help each other in their process of learning; people who know a specific content reinforce it by explaining it to their colleagues.	Tool support: provide spaces of relation and exchange among the learners themselves and between learners and trainers. Suggestions are: Blogger […], SlideShare […], Flickr or Youtube […]. Input resources: motivate the sharing with a resource […] Output artifacts: description about the expected result […]
DISCOVERING To foster integration in society and reflections, introduce readings related to culture (classic readings, articles, etc.)	Tool support: suggestions are Wikipedia […] or Google Reader which allows to sort and classify your readings. Input resources: upload also a text or whatever you would like to be discovered. Output artifacts: description about the expected result […]
CREATING COLLABORATIVELY Everyone has cultural intelligence. Dialogic creativity implies the confirmation of learning collectively generated by participants' contributions.	Tool support: select tools that enable everybody to contribute. Each person is different, therefore, irretrievable if not taken into account. Suggestions of tools are Wikispaces or Googledocs […] Intput resources: […] Output artifacts: […]
SELF-ASSESSMENT One way to foster people gain the autonomy and self-confidence necessary to learn is by offering self-assessment activities […]	Tool support: suggestions are for example questionnaires tools such as those supporting IMS QTI […] Input resources: for example a list of tasks with deadlines or a test with its correct answers […] Output artifacts: […]
ASSESSMENT (BY OTHERS) Participants can assess any result (such as documents) from their other colleagues and contribute with feedback, so they will help each other.	Tool support: a suggestion is to use a Blog where a student can upload a work and later the others can add their suggestions […] Input resources: […] Output artifacts: […]

Finally, the effects of showing and hiding the corresponding activities are achieved with *conditions* (Fig. 3).

```
<if>
  <is>
      <property-ref ref="LP-activity-negotiation-1-fixed" />
      <property-value>false</property-value>
  </is>
</if>

<then>
  <hide>
      <learning-activity-ref ref="activity-negotiation-1" />
  </hide>
</then>
```

Figure 2 Conditions are used for showing and hiding the corresponding activities as a result of the user's selection.

III. USAGE SCENARIOS

This section illustrates a realistic use case example and the results of interviews with two target users.

A. Use case

To facilitate the understanding of the template potential usage we describe a typical situation with a realistic use case. It happens in the context of a ICT (Information and Communication Technologies) session for elder people in La Verneda school. All the participants in the session have a computer with access to the same template. The process followed when using the template is always the same: 1) Selecting "activity type", 2) Defining/configuring the activity and 3) Performing the activity (Figure 3).

1. The trainer proposes three different alternatives to work on in this session by selecting the "dialoguing" activity type of the template (*1.1*). He describes it as an activity in which learners have to discuss about the different options and propose different mechanisms to arrive to a consensus (*1.2*). Once defined, the participants perform the activity (*1.2*).
2. Then, one participant proposes to vote the different possibilities (*2.1*). The trainer agrees with the proposal and let him to refine the "negotiating" activity in the template (*2.2*). The learner defines it and suggests a web 2.0 tool to do it. Then, all the participants vote and the winner option consists on use the browser to search information on Internet (*2.3*).
3. The trainer selects the "discovering" activity from the template (*3.1*). But, in this case, he asks different participants for refining each field in the activity description (*3.2*). The result is a "discovering" activity that consists on search information about their town using Google and Yahoo!. All participants realize the activity (*3.3*).
4. To conclude the session, the trainer proposes to put in common the results of the different groups selecting (*4.1*) and defining (*4.2*) an "assessment" activity type on the template (to be done by participants, *4.3*).

B. Using the template in Sled

The template is formalized as a meta-UoL that can be interpreted by any IMS LD compliant system. This section illustrates its integration in the SLeD [15] player that works under the Coppercore engine [10] (see Fig.5 for an overview of the whole cycle). We use two experiences performed by the two Agora's members in charge of coordinating and conducting training sessions related to lifelong learning of adults in information technologies. This medium-term effort is consistent with the need for rigorous evaluation studies in the field of IMS LD. Although the IMS-LD specification has been released relatively recently, the appearance of mature enough software tools (including players like SLeD) should facilitate deeper evaluation studies in the near future regarding proposals like the ones presented in this paper.

The users participating in the evaluation are representative in the context under study because of their expertise in the use of the dialogic learning and interactive groups methodology and in the application of technological support in their educational activities. They propose for the evaluation test two tasks that are usually problematic for the learners: to write a document and to search on Internet.

Following the guidance provided by the meta-UoL, the Agora's members created the examples in such a way that they represent the activities and the decisions that they normally perform in their training sessions.

The first user proposed to the participants to write a document and save it in a folder. The main objective was to let participants realize that they can become autonomous users in performing this type of tasks (*cultural intelligence* and *meaning creation* in dialogic learning methodology). With this purpose, he chose the *self-assessment* activity and configures it according to his needs. In the second activity he wanted to increase the level of difficulty and edited a task that consists of *creating collaboratively* a document about the towns where they were born (Fig.5). Finally, he defined a *negotiation* activity in which the participants decide what they want to do in the next session. To support this activity, he recommended the use of the Doodle Web 2.0 [17] tool as suggested by the UoL (Fig. 6). These two last activities are typical when using the interactive group methodology. Since, he did not need a forth activity in the UoL, he set the design of the UoL as finished (Fig. 7).

The second user started by proposing an activity of *dialoguing* for letting the participants talk about the topic to work on in the class. She attached a file with a guide for preparing a learning activity and she asked the participants to provide a file with their ideas. After this, she proposed the participants to use different Internet browsers so that they search for resources to complete their learning design proposal. For this she selected the *creating collaboratively* activity and propose a list of searchers as supporting tools. As a final result of the class, she asked the participants to provide a document with the result of the searches performed.

After these trials we performed a short questionnaire about the usefulness of the tool and the feedback was overall positive. Some of their comments were "*If I had had this tool when I started participating in Agora, it would have helped me more,*" "*I was used to traditional academic formation and in Agora I saw that the teacher is not a teacher!*" or "*It would have been also useful for me to see the lesson plans by other Agora trainers*". We asked also about the type of activities proposed and the answers where "*The list of activities is very complete and contains the type of actions that we usually do*". Moreover, they remark the fact that the groups are normally very heterogeneous and that it is good to have a long list of activities for choosing the most adequate. They propose to add a data base functionality for searching examples by type of group or activity.

They also stressed the need for flexibility in this type of contexts, "*There are many situations in which I need to improvise. Tools might not work properly; students do not have a keen interest in the topic or have specific needs, so I sometimes need to reschedule groups and activities to adapt to the circumstances*". Furthermore, they provided feedback regarding the vocabulary employed in the template and suggested changing some words to enhance their comprehensibility. For example, input resources and output artifacts should be changed by "*supporting resources*" and "*resulting products*", respectively; or the activities' name as "*creating collaboratively*" by "*create with your colleges*" or "negotiation" by some word "*less related to the business vocabulary*". They also found useful to have the possibility of including more than one resource in each activity.

All these suggestions have been considered and included as central aspects for the future work.

IV. Conclusion and Future Work

In this paper we propose a new approach to IMS LD authoring that can be integrated in runtime systems. This approach is based on a template formulated as an IMS LD compliant meta-UoL which can be interpreted by IMS LD players. The meta-UoL relies on the principles of dialogic learning and interactive groups and is an attempt for guiding the user in the implementation of this methodology. All participants (trainer and learners) has access to the same template and can edit it "on the fly" according to their needs [4, 5, 20, 18, 19]. The template offers also some hints or indications that may be useful to the user when refining the template (Table I). All participants of the session, trainer and learners, have the same rights of modifying the template either a priori or during the learning process. Two Agora's members have used the template successfully to create real-life examples, with encouraging results. It represents the first proposal that integrates authoring with enactment in the context of the IMS LD specification for this type of learning practices.

Future work includes more evaluation tests in order to analyze a wider use of the proposal with learners and find out other requirements that arise from the large authentic contexts. There is also considered to revise the template according to the evaluation results and extend it with more phases and further flexible possibilities, such as enabling the modification of the activity order and their configuration once they have been edited, and adding group-based functionalities for a better support of collaborative activities. In this line, we are also currently working on an approach for saving the users' design decisions with sharing and reusing purposes following the ideas in [12]. Moreover, we expect to provide the practitioners with activity proposals adapted to their contextual situation for facilitating the groups' management.

We also plan to enrich the template by integrating in the same player a questionnaire editor and interpreter based on the IMS QTI specification. Finally, regarding to the suggestions of the Web 2.0 tools, we plan to integrate a list of tools in the template using some of the solutions that are being developed in the TenCompetence Project. We expect to collect and analyze the uses of the tools in actual contexts. With the results, we aim to provide a general framework for a better understanding of these technologies usage in lifelong learning educational context.

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AUTHORS

M. Pérez-Sanagustín is with the Universitat Pompeu Fabra, Information and Communication Technologies Department Estació de França, Passeig de Circumval.lació 8, 08003, Barcelona, Spain (e-mail: mar.perez@upf.edu)

D. Hernández-Leo is with the Universitat Pompeu Fabra, Information and Communication Technologies Department Estació de França, Passeig de Circumval.lació 8, 08003, Barcelona, Spain (e-mail: davinia.hernandez@upf.edu)

P. Santos is with the Universitat Pompeu Fabra, Information and Communication Technologies Department Estació de França, Passeig de Circumval.lació 8, 08003, Barcelona, Spain (e-mail: patricia.santos@upf.edu)

S. Sayago is with the Universitat Pompeu Fabra, Information and Communication Technologies Department Estació de França, Passeig de Circumval.lació 8, 08003, Barcelona, Spain (e-mail: sergio.sayago@upf.edu)

J. Blat is with the Universitat Pompeu Fabra, Information and Communication Technologies Department Estació de França, Passeig de Circumval.lació 8, 08003, Barcelona, Spain (e-mail: josep.blat@upf.edu)

D. Griffiths is the Reader in eLearning at CETIS, The University of Bolton. (e-mail: D.E.Griffiths@bolton.ac.uk)

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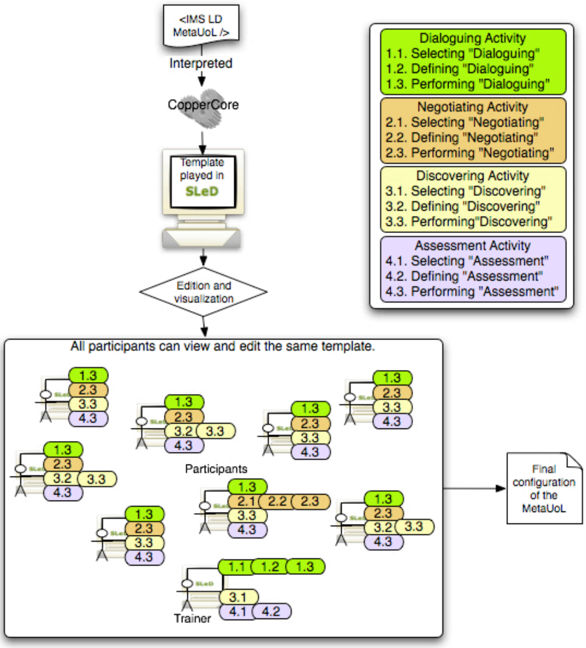

Figure 3 Complete cycle of the configuration of the meta-UoL

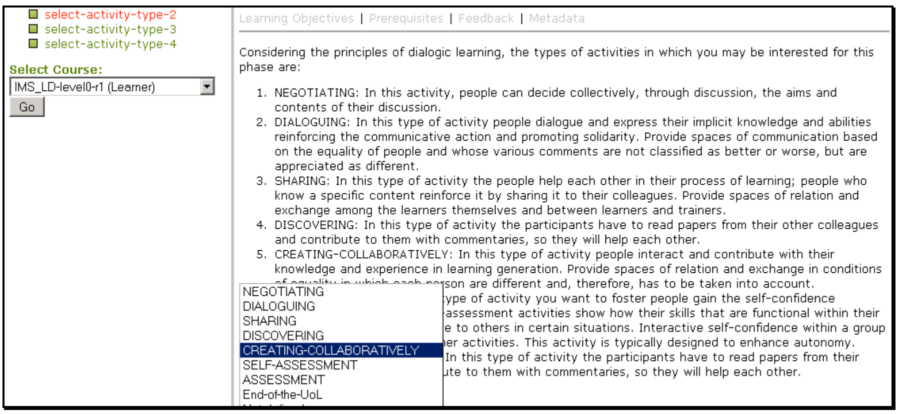

Figure 4 The user selects the creating collaboratively activity as the first one of the learning design.

Figure 5 The user selects the activity negotiation as the third one. He proposes the recommended tool Doodle as the supporting tool.

Figure 6 View of the UoL resulting from the design process

Paper IV

Pérez-Sanagustín, M.; Ramirez-Gonzalez, G.; Hernández-Leo, D.;Muñoz-Organero, M.; Santos, P.; Blat, J.; Delgado Kloos, C. *Discovering the Campus Together: a mobile and computer-based learning experience.* Journal of Network and Computer Applications (*in press*).

Abstract One of the difficulties that first year undergraduate students have to face is the adaptation to the new educational environment: the university. This paper presents a case study that proposes a computer-assisted collaborative experience for helping students in the transition from the High school to the university by facilitating their first contact with the campus, its services and the university community, methodologies and activities. The experience combines individual and collaborative technological supported activities occurring in and outside the classroom and structured according to the Jigsaw Collaborative Learning Flow Pattern. A particular technological environment that combines portable technologies and network and computer applications is developed for this study as a means for supporting and facilitating the orchestration of the activity flow into a unique integrated learning setting. The result is what we called a Computer-Supported Collaborative Blended Learning (CSCBL) scenario. The case study is carried out with first year engineering students, and its findings suggest that this type of CSCBL activities significantly improves their interest in the studies and the understanding about the campus and services offered. At the same time, the network and computational environment employed in the case can serve as an inspiration of how to exploit the potential of interactive and portable technologies in other similar actual educational situations which facilitate collaborative learning. This paper introduces the goals and context of the case study, describes how technology was employed for supporting the learning scenario, the evaluation methods applied and the main findings obtained.

Discovering the campus together: a mobile and computer-based learning experience

Mar Pérez-Sanagustín[1*], Gustavo Ramirez-Gonzalez[2,3], Davinia Hernández-Leo[1], Mario Muñoz-Organero[2], Patricia Santos[1], Josep Blat[1] and Carlos Delgado Kloos[2]

[1]*Universitat Pompeu Fabra, Roc Boronat 138 08018 Barcelona, SPAIN (e-mail: {mar.perez@, davinia.hernandez@, patricia.santos@, josep.blat@}upf.edu).*

[2]*Universidad Carlos III de Madrid, Av. Universidad, 30, 28911 Leganés (Madrid), SPAIN (e-mail: {gramirez, munozm, cdk}@it.uc3m.es).*

[3]*Universidad del Cauca, Campus Tulcán, Popayán, COLOMBIA (e-mail: gramirez@unicauca.edu.co).*

** Corresponding autor: Mar Pérez-Sanagustín (mar.perez@upf.edu, mdelmar.ps@gmail.com)*

Abstract One of the difficulties that first year undergraduate students face is to adapt to the new educational environment, the university. This paper presents a case study that proposes a computer-assisted collaborative experience to help students in the transition from the high school to the university by facilitating their first contact with the campus, its services and the university community, methodologies and activities. The experience combines individual and collaborative activities in and outside the classroom structured following the Jigsaw Collaborative Learning Flow Pattern. A specific environment combining portable technologies with network and computer applications has been developed to support and facilitate the orchestration of the activity flow into a single integrated learning setting. The result is a Computer-Supported Collaborative Blended Learning scenario enacted with fresh university engineering students within the subject *Introduction to Information and Communications Technologies*. Findings suggest that the scenario significantly improves students' interest in the studies and their understanding about the campus and services offered. Moreover, the environment developed is an innovative approach to successfully support teachers' and students' tasks during the scenario enactment. This paper introduces the goals and context of the case study, describes how technology was employed to support the learning scenario, the evaluation methods applied and the main findings obtained.
Keywords Collaborative Learning and Applications; Computer Supported Collaborative Blended Learning; Collaborative Learning Flow Pattern; Mobile and ubiquitous computing; NFC, Innovative Collaborative Scenarios

1. Introduction

One of the aspects that make first year students drop out or persist in engineering majors is the way they face the transition from High School to University. Psychological studies discuss the importance of emotional and social competency during this transition (Parker et al, 2004), and West (1991) claims that the more integrated a student is in the social activities of a campus environment, the more likely s/he is to persist in the University.

But emotional and social competencies are not the only difficulties. Students have to overcome practical problems of the academic environment such as locating the classrooms, the secretary or the library services. When arriving to the University for the first time, students do not even know the services and resources offered by the institution, and how to exploit them (Anderson-Rowland et al, 2004), and even some of them only get used in the final years.

Furthermore, new degrees compliant with the European Higher Education Area (EHEA, 2010) have been introduced in the Spanish Universities, including Polytechnics, in the last two years. The EHEA system is competence oriented. Learning strategies beyond the traditional ones of going through the engineering degree contents are introduced to work on the specific and transversal skills necessary to become a good professional. One of the strongest points included in the engineering curriculum is the development of collaborative work skills as engineers are professionals that work typically in groups and collaborate for developing large projects (Martínez-Monés et al, 2005). Learning how to interact with colleagues is essential for their future career.

Finally, fresh engineering students often show motivational problems during the first year. Experts consider that the main raison is their poor knowledge of their future professional world and highlight the need of bringing the students closer to practicing engineers. Haag and Collofello (2008) recommend: "*To shed a positive light on engineering, advisors, faculty, and teaching assistants can show applications of the coursework so the students can connect what they are studying to the 'real world"*.

New approaches are needed to help fresh students to deal with these difficulties and facilitate their transition to the University in the three aspects mentioned: (1) introducing them to the campus and services, (2) making them familiar with the EHEA methodologies and collaborative work skills, and (3) fostering their interest towards technology and the engineering profession. Different studies develop technological solutions that partially address these three issues. Sticklen et al (2009) propose replacing lecture sessions with web-based, voice-over slide presentations punctuated with full screen demonstrations and interactive quizzes to improve students' attitude towards engineering. Mueller (2004) discusses an e-mentoring system to connect students to practicing engineers or scientists that increases students' confidence in succeeding on their studies and their wish to pursue their career. Courter & Anderson (2009) propose including interviews with practicing engineers as part of the first-year student curriculum and show how this improves students' motivation and understanding of engineering practice.

These solutions partially cover some of the three issues of our context. However, explaining the university services, information that can be found on the web, is not enough for a first contact with the campus and the university community members and activities. It is also necessary to facilitate and support students' direct experiences with the services distributed around the campus to foster students' motivation and interest in the new environment. Currently, many researchers investigate the potential of mobile and interactive technologies to improve communication among students and provide more contextualized learning experiences in different spaces beyond the classroom (Cook et al, 2006; Cook et al, 2008; Roschelle & Pea, 2002). Projects such as *Savannah* (Facer et al, 2004), *MyArtSpace* (Sharples et al, 2007) or the work by Schwabe & Goth (2005) show that interactive experiences involving an active exploration of the environment improve the students' motivation. Thus, we propose a learning setting that integrates activities in the classroom and around the campus, that require the students' active participation to foster their motivation and that helps them to discover the campus, their new course mates and a first contact with the university methodologies.

To tackle these needs in an integrated manner, this paper presents a case study enacting an innovative Computer Supported Collaborative Blended Learning (CSCBL) scenario, carried out with first year engineering students at the Pompeu Fabra University. The scenario is structured according to the Jigsaw Collaborative Learning Flow Pattern (CLFP). A CLFP aims at capturing the essence of well-known techniques for structuring a flow of learning activities to potentially produce effective learning from collaborative situations (Hernández-Leo et al, 2005). With this CLFP we intend to: (1) foster collaboration to help students meet each other, and (2) integrate the set of activities into a coherent learning flow. We encourage the active participation of the students and facilitate their first contact with the environment through a set of formal and informal activities happening in different spatial locations around the campus. We developed a technological environment combining different network and computer applications to ensure the integration of all these activities and ease their orchestration. The experience consists of three phases organized sequentially. The first one takes advantage of mobile phones and NFC/RFID (Near Field Communication/ Radio Frequency Identification) technologies to support an exploratory informal activity around the campus; in the second phase the students use computers to collaboratively work on a formal presentation about their first phase experience, and, the third phase is an online Web questionnaire to reflect about the whole activity.

The results from the experience offer conclusions on the role of technologies to enable rich blended learning educational activities and derive educational benefits. This case study illustrates the suitability of generating innovative blended scenarios with significant learning benefits by orchestrating a combination of formal (in classroom) and informal (in the campus) learning activities through a CLFP and the appropriate technology, and we seek to stress the value of conducting this type of CSCBL experiences to enhance students' motivation towards technology and introduce them the services helpful in their studies. Moreover, we report how technologies and collaborative learning techniques complement each other to generate innovative collaborative computing experiences that facilitate students working and learning together. It is another example of the type of applications coming out from the emergent use of computing to support collaborative experiences.

The next section introduces the educational context in which the case study was carried out highlighting its main requirements. Then, the implementation of the CSCBL scenario and the supporting technological environment developed are detailed. The following section summarizes the main evaluation outcomes of the case study by presenting the evaluation issues, the methodology employed and the main findings. Finally, the conclusions and a discussion of the future research lines are presented.

2. Description of the case study context and the CSCBL scenario

2.1. Educational context

The case study takes place in a subject called Introduction to Information and Communication Technologies Introduction (ICTI) of the new curriculum of the Pompeu Fabra University (UPF) three ICT engineering degrees (Computing, Telematics and Audiovisual Systems), which is compulsory for all the first year students, 241 aged between 18 and 25 years. The subject aims at giving a global vision of the University and its resources and an introduction to the professional world of the ICT industry to facilitate the students' integration in their studies; it also includes an activity to introduce students to the campus and its services.

The new curriculum includes methodologies using technology to support group work or oral and written communication competences development. UPF uses Moodle (Dougiamas et al, accessed 2010; Moodle 2010) as the platform to manage the content and communication needs. This case study promotes the above-mentioned skills through a collaborative learning scenario based on the Jigsaw CLFP (explained later) applied to a blended learning context. The activity helps students to become familiar with the University campus, to learn about the services offered and to meet other course mates. By including technology as a support, the experience also aims at being a motivation driver for the first-year students, who see how innovative technology can be employed into real contexts.

2.2. The CSCBL scenario: Jigsaw CLFP applied to a blended learning scenario

The Jigsaw CLFP organizes a complex learning flow for a context in which several small groups face the study of a lot of information for the resolution of the same problem (Hernández-Leo et al, 2009). The activity flow is structured into three phases: i) an individual or initial group studies a particular sub-problem, ii) students involved in the same sub-problem are grouped in *Expert groups* for exchanging ideas, and iii) students are grouped in *Jigsaw groups* formed by one expert in each sub-problem to solve the whole problem. This pattern promotes mainly three educational benefits: positive interdependence, discussion and individual accountability. Although there are studies that have applied this script in different contexts (Aronson et al, 2002; Hernández-Leo et al, 2007) any of them applied the pattern to a blended learning context. This section presents how we benefit from the Jigsaw CLFP structure, mobile technology and other computing tools to capture the actions occurring in exploratory informal activities and use that information for designing the groups of people for next activities in the workflow.

The experience designed is divided into the three phases of the Jigsaw CLFP:

1. "Discovering the Communication-Poblenou Campus" (adaptation of the individual phase): Students freely explore a selection of the campus' buildings in order to get familiar with the different places and services that it offers. As a result of this phase, all the students are asked in a mandatory online questionnaire about the different areas visited during the exploration, their preferred buildings and main services.
2. "Explaining the campus" (adaptation of the expert groups phase): Students are distributed by the teachers in groups of 5 or 4 people and assigned to one of the campus' areas according to their expertise in the different buildings. Each group delivers a presentation about the area assigned and uploads it into the Moodle platform. The teachers upload all the presentations into a public repository so that all the students have access to them.
3. "Reflect about the campus" (adaptation of the *Jigsaw groups* phase): Due to the lack of hours for making oral presentations and the huge number of students registered to course, this activity is transformed into an individual activity. Each student reviews the presentations about the different buildings performed by their colleagues and answers an individual questionnaire containing 20 questions about the whole campus.

3. Implementation of the scenario

One of the most relevant aspects for assuring a successful collaborative experience relies on the orchestration of the different phases (grouping students or distributing activities) (Dillenbourg, 2008; Dillenbourg & Fischer, 2007). A step-by-step explanation of the workflow focusing on teachers' and students' actions, an overview of the technologies used and the outcomes produced will help on a deep understanding of the CSCBL experience. A summary of the whole scenario detailing the data and outcomes used for an integrated orchestration of the activity is collected in Table 4. At the end of this section, the technical details of the technologies employed and developed for supporting and facilitating this orchestration are explained.

3.1. Implementation of Phase 1: Discovering the Campus

For the exploration, students had three different options: (1) to access the University Web Page (UPF Webpage, 2010), (2) to walk around and read the information posters about the campus and ask veteran students or (3) to participate in an exploratory activity using mobile phones. One out of the three possibilities was mandatory and the students were free to choose one, two or the three of them.

The third choice was prepared specially for the ICTI course. A set of 46 interactive tags containing information about the five main buildings of the campus were prepared and distributed along the different areas of the campus by two teachers. The teachers prepared and recorded the contents of the tags before the experience. The contents included audios (mp3 format) explaining characteristics of the buildings and the services that they offered, images (jpg format) and videos (3gp format) related to the area where the tags were located (contents produced can be accessed via the Web created for the experience (Meeting the Campus 2009 Website, 2010)). All the tags were glued over a yellow card for facilitating their visibility and attached to the walls of the campus according to their content (see Figure 1). Students had 20-30 minutes to freely explore the different areas discovering the information hidden in the interactive tags using a mobile phone. The history of the sequence of tags accessed by each student was stored in a log file in each of the mobile phones. Technical details about the tags and mobile phones employed the log files and the processes for writing and reading the tags are explained later.

After the exploratory activity, students had to answer a web-based questionnaire in Google Docs (Google Docs, 2010). 241 students (74 chose the mobile experience and 167 other of the two options) answered this questionnaire. From the answers to the questionnaire, all the students were classified in different groups depending on the option selected for the exploration. Table 1 shows the final students' distribution.

{Insert here: *Figure1. Students interacting with the 46 NFC Tags distributed around the campus. The tags are glued in a yellow card to make them more visible. Students access the information hidden in the tags with mobiles that integrate NFC reader and that were facilitated for the experience.* }

{Insert here: *Table 1 Number of students that answer the questionnaires classified by the type of exploration performed*}

3.2. Implementation of Phase 2: Explaining the campus

The grouping and assignments in this phase required the adaptation of the concept of *expert group* of the *Jigsaw* CLFP. Typically, in the *Jigsaw* CLFP the expertise is defined by the topic or concept of study assigned to the student in the first phase. However, in the first phase of the activity the students were free to explore the campus on their own and were not assigned to any particular area. The expertise was defined by the particular actions performed by each of the students in the first phase. That is, the places, buildings and areas that each of the students visited (for those that performed the exploration with the mobile devices or the walk) or accessed (for those who preferred the web) determined the expertise that the student had in that area. In that way, the personal experience of each student in an informal activity was incorporated as a constraining factor that modified the activity.

The expertise of the students that performed the activity with the mobile phones (experimental group or EG) was defined according to the number of tags of each area they visited during the exploration. Depending on the number of tags available in each building the amount of tags accessed required for becoming an expert in that area was different (see Table 2 with the description of the constraints for each building). However, in order to have a more equilibrated number of persons per building, some of the students were assigned to the second more visited building and not to the first one. For those students that did the exploration following any other methods from Table 1 (control group or CG) their expertise was defined according to the results of the questionnaires. In particular, we analyzed two questions: 1) the question asking the students to list the buildings visited/accessed and 2) the question asking to recommend one building to their colleagues.

{Insert here: *Table 2 Number of tags available per building and minimum number of tags required for becoming an expert in each of the buildings*}

Once the buildings were assigned, the students were distributed randomly in groups of 4 people with the same expertise and classified depending on the medium used for the exploration in: MOBILE (performed the exploration with mobiles), OTHER (performed the exploration via web or walking) and MIX (two from MOBILE and two from OTHER). The list of group assignments was delivered to the students via the Moodle learning management system. Students contacted their groups' members mainly using e-mail. Students uploaded their final presentations one week later via Moodle. Table 3 shows the actual distribution of students in groups including only those students that finally delivered the presentation (only 9 students from the 241 listed from the beginning did not deliver the presentation).

{Insert here: *Table 3 Number of students for each of the group types defined*}

3.3. Implementation of Phase 3: Reflect about the campus

The presentations delivered were uploaded by the teachers to the Moodle course platform. Students from the different groups had 5 days to access and review the presentations from their mates. The individual final questionnaire was performed in a 25 minutes class practical session. The questionnaire contained 25 questions related to common aspects described by the students in their final works.

{Insert here*: Table 4. Workflow and outcomes of the CSCBL scenario*}

3.4. Technical details of the technological environment

Figure 2 shows a general schema of the technological environment supporting the experience as a unique integrated learning setting. The schema is organized according to the phases of the experience. NFC Mobile phones and NFC tags were the support for the campus exploration. Software tools were developed for writing and reading the tags. Bluetooth technologies were used to collect the log files resulting form the exploratory activity. Finally, Moodle and Google Docs were the web-based software tools employed for editing and answering the questionnaires and for uploading and sharing the final works. In the following subsections we describe the details of all these technologies and software tools adopted and developed for the experience.

{Insert here: *Figure 2. Technological environment. A combination of mobile devices with an integrated NFC reader, NFC tags, a Moodle Platform and Google Docs allows an integration of the different activities of the learning flow into a unique learning setting.*}

3.4.1. Architecture of the NFC Mobile phones

The mobile phones employed for the experience are from NOKIA (N6131, N6212) which include an embedded RFID/NFC reader (Manish & Shahram, 2005; Sweeney, 2005). These mobile phones offer a J2ME API with NFC functionalities. Figure 3 shows the NFC Mobile phones architecture.

{Insert here: *Figure 3. Detailed architecture of the NFC mobile phones employed for the experience.*}

These mobile phones encapsulate the data to exchange following a NDEF (NFC Data Exchange Format) format, which follows the specification NFC Record Type Definition (RTD) (N. Forum, 2007). The information exchanged can be a text or a URI, according with the NFC Text RTD (N. Forum, 2006) and the NFC URI RTD (N. Forum, 2006) specification, respectively. The information exchanged with the tags is determined by the NFC Forum Type 1 Tag (N. Forum, 2010) specification which, at the same time, is based on the ISO/IEC 14443A specification. The basic communication with the tag follows the NFC Logical Link (LLCP and IS/IEC 18092:2004 protocol (N. Forum, 2009), which implements the NFCIP-1 for the point-to-point communication. The handover implements the structure and sequence of interactions that enable two NFC-enabled devices to establish a connection using other wireless communication technologies, such as WiFi or Bluetooth.

The more important API used is the JSR 257. This API manages the data flow from the modem NFC for communicating with the NFC Record Handler. The rest of the APIs (Bluetooth and MAPI) are employed for connecting with the computer and multimedia management.

3.4.2. NFC tags and software developed

The contents were recorded by the teachers in the NFC tags and stored in local in the mobile phones. Each tag operates on the Near Field Communication (NFC Forum, 2007) standard, the tags used are TOPAZ tags provided by Innovision (Innovision Research & Technology, 2010). For writing, storing, reading and communicating with the NFC tags, a suit of J2ME application as well as a Java PC server were specially developed for the experience (download these applications at Meeting the Campus 2009 Website (2010)). In the following, we describe each of these applications.

- **NFC Player:** Application used by the students for reading the content of a tag (Figure 4). When the application is executed shows the message "Touch the Object". Then, if the user touches a NFC tag, the path where the content is stored into the Mobile phone appears in the screen. When pressing *select*, the audio, video or image is reproduced. Always, when a tag is touched, the activity register is updated with the information of the tag and the time in which it was accessed.

{Insert here: *Figure 4. NFC Player application usage.*}

- **ReadOnlyBD:** This application shows the activity register of each mobile (which was related to one student in this case). When executed, the applications shows on the screen the list of objects that have been accessed (visualized by the students) with the date and the time of this access (Figure 5). During the experience teachers used this application to test whether the information about the route of each student was correctly recorded.

{Insert here: *Figure 5. ReadOnlyBD application usage.*}

- **ReadWriteTags:** This application was employed by the teachers to record all the information about the campus in the tags. To write the information on a tag, the user has to select "Write" and manually inserts the path corresponding to the content location in the mobile phone. For the experience, all the contents were stored in local in the same path of the mobile phones. Once the information is written, the teacher has to touch the tag and wait until the application indicates that the information has been successfully recorded. If the tag has been correctly updated, the word END will be shown (Figure 6). The user can test whether the path is stored in the tag selecting "Read" and touching the tag. Tags can be rewritten as many times as the user wishes. However, for the activity, the tags were recorded before the experience and maintained the same until the end of the experience.

{Insert here: *Figure 6. ReadWriteTags application usage – "Write" functionality.*}

- **send2server**: Teachers used this application to send the activity registration of the students' activity stored in the mobile (the log files) once they finished the exploratory activity to the central computer via Bluetooth. When the application is executed, the mobile phone connects and sends the log files automatically to the computer. This application works together with the application BT Bridge explained below.

  To connect the mobile phones with the teachers' computer and extract the information of the log files, an application called BT Bridge based on Bluecove Project (Bluecove, 2010) was developed. This application works under Windows and requires having previously installed in the computer a Bluetooth system. When BT Bridge is executed a pop up window indicates to the user that the connection is being processed.

  Once the connection is successfully established, the activity stored in the mobile phone is automatically downloaded to the computer into the path previously indicated by the user. The information about the activity is a log file with the name of the tag that was used to identify the student. Figure 7 shows an example of these log files. Each log file is then analyzed by the teachers to classify the students in expert groups as explained in the previous section.

{Insert here: *Figure 7. BT Bridge application usage – Log file generated and stored in the computer after the exploratory activity. There is one log file associated to each of the students participating in the activity.*}

3.4.4 Web based tools

Moodle is a Learning Management System for producing Internet-based courses and web sites. Moodle can be installed in any system with PHP and a SQL type database and runs over any operating system (Moodle, 2010). The University provides Moodle as the institutional learning management system to every subject, including ICTI. For the experience, teachers created an activity project for the students to upload the final presentations and share them with their colleagues. Also the questionnaire of the final phase "Reflecting about the campus" and the final marks were delivered through this platform.

Google Docs is a web-based application by Google for creating, sharing and collaboratively editing word files, presentations, spreadsheets and forms (Google Docs, 2010). The service is supported on Firefox, Internet Explorer, Safari and Chrome browsers running in any type of operating system. Google Docs supports the ISO standard OpenDocument format and other proprietary formats (.doc, xsl...). For the experience, Google Docs was employed by the teachers for preparing the post-exploratory questionnaire. The spreadsheet with the responses generated was used for recovering all the information about the students' knowledge about the campus after the exploration.

Both, Moodle and Google Docs, are cloud computing software applications, which facilitates a ubiquitous access by the students avoiding problems such as software incompatibility issues.

4. Evaluation of the Case Study

The main goal of the case study is to get evidence on the effectiveness of adopting a CLFP through the use of mobile and other technologies to create an effective CSCBL experience to help students in their transition to the University. The evaluation focuses on three main topics arising from this general aim. The first one has to do with the meaningfulness of the CSCBL activity generated; i.e. whether the application of a CLFP for orchestrating informal and formal activities facilitates the students in a first contact with the campus services and the university community members, methodologies and activities. The second one is related to the motivational benefits of the activity proposed and its educational innovation with respect to more classical introductory experiences. Finally, the third topic intends to identify the main successful aspects and the limitations experimented by teachers and students during the orchestration of the CSCBL experience. This issue may help on highlighting the strengths and detecting the weaknesses of the whole scenario and the technical environment for further improvements.

4.1. Evaluation Methodology

All the data is aggregated and analytically compared using a mixed evaluation method (Martínez-Monés, 2002; Frechtling & Sharp, 1997). This method combines quantitative techniques and sources, such as closed questions or event log files generated automatically by the mobile phones, with qualitative techniques, such as open questions and observations. All this information is analyzed and triangulated (Gahan & Hannibal, 1998; Guba, 1981). The triangulation consists in analyzing each conclusion from a different perspective in order to have several confirmations supported by both qualitative and quantitative data. The aim is not to demonstrate a hypothesis but to detect general tendencies in the issues aforementioned in this particular learning context.

Table 5 shows all the data sources that were used to evaluate the case study according to the mixed method. Students' perceptions about the exploratory experience with the mobile devices were collected in a paper-based questionnaire delivered immediately after the exploration. This data was also completed with observations gathered by four different observers that followed the students during the visit through the campus and with the data extracted from the exploration video recordings. Quantitative ratings, qualitative comments and opinions about the visit around the campus (physically or virtually) were collected from a mandatory web-based questionnaire completed after the exploration. Quantitative and qualitative results about the knowledge acquired were obtained from two sources: (1) the score average of the presentations (two different teachers evaluated each presentation), (2) the automatic scoring of the mandatory individual Moodle web-questionnaire about the campus and (3) comments gathered from teachers' and students' questionnaires and observations. Finally, data regarding the orchestration of the activity were obtained from quantitative ratings and open explanations provided by the two teachers of the course in a web-based questionnaire.

{Insert here: *Table 5 Data sources for the evaluation of the case study, and labels used in the text to quote them.*}

5. Results and Discussion

Table 6 shows an overview of the main conclusions of the research. During the analysis, we will refer as Experimental Groups (EG) to those students that performed the activity with mobiles, whereas we will refer as Control Group (CG) to those that did not.

{Insert here: *Table 6 Main conclusions offered by the research carried out along the case study.*}

The analysis of the first focus of study should indicate whether the resulting CSCBL scenario is effective for the students to meet the campus, its services and other their course mates. The first finding in Table 6 shows that **using mobile technologies in a CLFP-based blended learning scenario is a good approach for supporting the integration of formal and informal**

exploratory activities into a unique learning setting that facilitates the students discovering the campus.

Students from the experimental group obtained better presentations score than those from the control group (upper image in Figure 8). Also the Kruskal-Wallis Test applied to the samples of exploration with mobile phones, walking and via web shows that the means sample really differs between groups ($p<0.001$). Moreover, the final score in average (presentation plus final test scores) of the students that did the experience with mobile phones is 7.85 (deviation of 0.66 with N=59) over the 7.50 (deviation of 0.64 with N=84) that did the experience with the web (lower image in Figure 8) [Quest-Score-Phase3, Presentations-Score-Phase2]. Although the differences in scoring between the EG and the rest were not very high, open questions in the mandatory questionnaires show that these students did more precise descriptions of the University service's locations and included more original contents in their presentations than those who only did the exploration via web [Presentations-Score-Phase2, Quest-Reflection-Phase3]. For example, one of the students explained "*...on the walls of the bar you can find advertisements offering or asking for rooms to rent or notes demanding lost objects. There you also find a microwave for warming up the food you bring from home...* [Quest-Campus-Phase1]" and other mentioned one of the most famous instruments created in the department "*On the third floor there is the MTG (Music Technology Group) which created the Reactable* [Quest-Campus-Phase1]". Most of experimental students' comments had to do with information included only in the tags or part of the university building, contents not possible (or at least not easy) to be found in the web of the university. Furthermore, students that worked only with the web did errors in their descriptions and tended to copy directly the content from the web when describing the services [Quest-Campus-Phase1].

The second finding proves that the CSCBL facilitates the students to have a first contact with the University methodologies and services useful for them in the future. When students reflected about their preferred experience the opinions were variable: 14 (out of 175) preferred the activity of studying the presentations of their colleagues, 33 (out of 175) preferred working in groups, 20 (out of 175) preferred the individual questionnaires, 91 (out of 175) preferred the campus exploratory experience and 17 (out of 175) answered that they do not know [Quest-Reflection-Phase3]. These data stand that including different types of activities in the same experience increases the possibilities of satisfaction of a higher spectrum of students, which augments their possibilities of success. Students also valued as very positive for their learning the fact of combining working individually and in groups and mixing exploratory with more reflective activities. 61 over 174 students considered that the group activity helped them very much to reflect about the exploratory experience and 54 said that the activity simply helped them [Quest-Reflection-Phase3]. Working in groups formed based on the students' personal experience is shown to be a successful mechanism for promoting collaboration. Most of the students successfully adapted to the work group imposed by the teacher and were aware of the benefits of this activity as a mechanism to experiment new work methodologies and to acquire new competences: "*Working in groups has helped me a lot because I've exchanged information and I've learnt new methods for searching for information* [Quest-Reflection-Phase3]" or "*...Working in groups allows each of the members to contribute in the task and meet new people* [Quest-Reflection-Phase3]". Students underlined the relevance of mixing activities for learning about services useful for their studies in the future. One student mentioned "*... this activity has shown me how to do essential resources such as the copy machine or the book search of the library website* [Quest-Reflection-Phase3]", another said "*this activity have served me to know about the library services* [Quest-Reflection-Phase3]". All students succeeded on managing the University Moodle platform for delivering their assignments and answering the questionnaires [Quest-Score-Phase3].

{Insert here: *Figure 8. Presentations score separated by type of groups (upper figure) and mediums used for the exploratory activity (bottom figure).*}

The second focus (2) of the research was to detect the motivational benefits of the CSCBL experience and to understand its innovative educational aspects. We compared the observations and comments of the experimental (EG) with the control group (CG). The rationale behind this decision relies on the fact that, for us, the innovative aspect of the CSCBL scenario is the integration of an exploratory activity with mobile phones for influencing next activities in the workflow. 74 over the 241 potential students participated voluntary on the activity [Quest-Experience-eg]. 46.25% of the participants did the activity because considered it innovative and 47.50% because were curious [Quest-Experience-eg]. Students used adjectives such as "*fun*", "*different*" and "*useful*" for describing the experience and recommended it because of its innovation and usefulness for learning [Quest-Experience-eg]. One participant declared "*I would recommend the experience with the mobiles because it is an innovative activity (from my point of view) that helps you on discovering lots of hidden corners of the campus through an innovative and curious mechanism* [Quest-Reflection-Phase3]". Students preferred this type of activities instead of the tests. A student pointed out "*the activity is interactive, whereas the questionnaires can be answered only with the web site of the University, but in that case you loose the information of the physical situation of the buildings* [Quest-Reflection-Phase3]". Even more, some students that did not perform the mobile activity would do it if they had a new chance [Quest-Reflection-Phase3]. Students also valued the fact of learning *in situ* for having a more detailed perspective of the campus: "*the exploratory experience has been the most funny activity and has helped me on knowing the campus and discovering research works developed here* [Quest-Reflection-Phase3]". Finally, 113 from the 176 students that performed the last voluntary questionnaire for reflecting about the experience answered that they would repeat the activity [Quest-Reflection-Phase3]. Therefore, we can affirm that students highly appreciated the CSCBL activity because of the innovative use of technologies and its usefulness for learning about the campus.

The second finding is related to the previous one and proves that **the type of exploratory experience proposed enhances students' interest in technology and enacts their motivation with regard to their studies, engineering research and teaching activities**. The observations gathered from the researchers confirm the positive attitudes that the experience enacted on the students to discover the research aspect of the University. Two observers wrote *"students enter in any opened room and get surprise when they find a playstation* [observer2]*"* and *"when students see (in a video content) a robot from the SPECS research group they ask whether it has been done here* [observer3]*"*. Other explained "*I have learnt how to manipulate technology such as mobiles and tags* [Quest-Reflection-Phase3]*"*. Whereas other comments show that the integration of this type of activities enhance the interest on the studies *"(...) and the service that I liked to discover the most were the technological installations for image and audio because this type of technology is the reason that made me choose these studies* [Quest-Reflection-Phase3]*"*. It is important to mention that since the students using the mobiles phones decided themselves to carry out such activity, they might already be more motivated that the other group of students. However, it is also true that the activity with mobile phones was performed in the afternoon while the in-class activities are always in the morning, and a significant number of students work or have another activity in the afternoon that may had hindered the participation in the mobile experience. Finally, students considered the activity helpful for meeting the campus and suggested increasing the time for the exploratory activity: "*The exploratory experience with the mobiles is a very good activity* *because it allows you to start being familiar with the campus. Nevertheless, I suggest extending the time for the exploration because, in half an hour, you have not enough time to visit all the buildings* [Quest-Reflection-Phase3]".

The final focus (3) of the analysis is related to the orchestration aspects of the CSCBL experience and the technological environment developed for its support. The first finding shows that the actual technology used during the activity was easily adopted and highly accepted by students and teachers. Regarding the mobile technology, 81.40% of the 73 students participating in the exploration with mobile devices perceived the use of NFC technology as useful or very useful [Quest-Reflection-Phase3]. Teachers succeeded on implementing the part of the activities with the mobile phones helped by an expert in NFC and managing the Moodle platform. Their comments have to do more with the preparation of the material for the activity than with the technology itself: "*With some help from experts on NFC we were able to implement the part of the activity with the mobile phones. Creating the content was time consuming but not difficult* [Quest-teachers]". Moreover, teachers valued the technological environment because it allowed the possibility of saving the actions of the students with the mobile phones, to have a vision of what happened during the experience and to organize the groups according to the students' actual experiences. Nevertheless, observations from the researchers and suggestions from students point out some technological problems that emerged during the activity. One of the major concerns of the participants was the volume of some of the audio-contents. Most of students had problems listening to the explanations from the mobile devices in open spaces because the sound was very low [Quest-Experience-eg, observer3]. The video images show how the students used their hands as amplifiers for listening to the audio better [video-Learn3-Transcriptions]. Proposals were to use headphones or improve the quality of the audio. Finally, the results show that the adoption of the Jigsaw CLFP and the technological environment developed is a good approach for generating and orchestrating rich collaborative blended learning flows with potentially effective educational benefits. For the first exploratory phase, when students who did the mobile experience were asked whether the activity was useful for learning 71 out of 74 answered 'yes' and appreciated the balance between the guidance supported by the mobile devices and the freedom enabled by the informal activity [Quest-Campus-Phase1]. Comments from the students corroborate this affirmation: "*with the mobiles you can obtain a better guided visit of the campus* [Quest-Experience-eg]", "*... it is a good way of discovering the campus because, when you are a new student, you are lost* [Quest-Experience-eg]". For the preparations of the second phase, results show that mobile technology with the NFC tags and log files is a good approach for recording the actions of students occurring in different spaces and for proposing group distributions by fostering collaboration. It is also manifested that these actions, in combination with online questionnaires is a good solution for supporting the experts' groups' formation. Most of the comments were related to the learning benefits of working in groups and one of the students realized about their expertise relation: "*My group helped me because all the members were interested in the same area of the campus and, when there are common interests your motivation is increased and you do things better* [Quest-Reflection-Phase3]". Teachers qualified the activity and the technological environment as very helpful for supporting learning and gave different reasons for maintaining this experience in next courses: "*1. The activities are more significant to them (they experience the services of the University vs. they just hear about the services). 2. Students are active in the whole activity, besides working physically with what they are learning, they have the opportunity to discuss with other peers about the buildings/services of their interest, to discover other buildings/services by explanations of their own classmates, etc. 3. Students make use of ICT technologies, what they will be learning in the studies they are just starting (again enhances the* *significance of the activity)* [Quest-teachers]". As a weak point of the experience, teachers qualified some logistic aspects as demanding and time consuming. The coordinator of the activity said: "*Once the whole activity was set-up, I think it was more a matter of complexity than of difficultness. Again the logistic was the more demanding issue: managing groups (creating groups, informing students about the groups, orchestrating their tasks depending on the groups, managing and analyzing their outcomes in order to propose them the following tasks, managing their outcomes in order to facilitate the assessment of their learning, etc.)* [Quest-teachers]". A mechanism for helping teachers in processing the data from the questionnaires and log files as well as in automatically organizing the students in groups would improve these logistic requirements.

6. Summary and Conclusions

This paper has presented a case study carried out in an introductory course of engineering education in which a Jigsaw CLFP with mobile and network technologies have been combined to generate a CSCBL scenario for facilitating students' transition from the High school to the University. The main findings of the case study give us the clues for understanding whether the CSCBL scenario proposed is a suitable solution. Looking back to the main findings, we found evidences that support that the objectives of the course were fulfilled. One of the aims of the activity was to make students familiar with the campus structure and the University services. The findings confirm that all students succeeded in answering the individual questionnaire about the campus and that those who experienced the exploration with mobile phones obtained slightly better marks and more precise and original descriptions in their presentations. Another objective was to make students familiar with the University methodologies that they will use during their studies. The combination of activities and methodologies in the same experience is a good approach to bring students closer to the different methodologies that they will find along their engineering studies. Finally, the findings demonstrate that the CSCBL activity was very well accepted by the students and the teachers. Although some technological and usability issues were detected, students preferred the CSCBL type of experience compared to others activities and teachers underlined the learning and motivational benefits provided by the experience. Therefore, we can affirm that the CSCBL experience presented and the technological environment developed for its support reported significant and motivational learning benefits to students. Moreover, the results show that this approach is an innovative mechanism for alleviating students' transition from the High School to the University.

Another contribution of the study is the CSCBL approach itself. In particular, the experience presented is an example of how the workflow of the Jigsaw CLFP with an appropriate use of technology can be adapted for supporting and facilitating the orchestration of formal and informal collaborative activities occurring in different spatial locations. The technological environment consisting of a combination of mobile phones, NFC tags and software tools such as Moodle and Google Docs was a good means for integrating different activities into a unique learning setting. Mobile phones combined with NFC technologies enabled capturing the activity of the students when visiting the campus whereas Moodle and Google Docs were employed for structuring and guiding the activities at home and at class. Similar technologies such as GPS or Bluetooth might be employed as a support in this scenario, but an appropriate technological system should assure their integration in order to support all the activities included in the CSCBL scenario. However, the technological solution adopted in this study aims at being an example of how to benefit from good educational practices and novel technology, which can be extrapolated to other innovative collaborative blended learning scenarios. Altogether shows how network, computer technologies and learning techniques complement each other for the generation of new fruitful educational scenarios that open up new opportunities for learning through collaboration.

New case studies in different learning contexts are needed to further evaluate the suitability of the approach proposed. More experiences using mobile applications with NFC and other technologies, such as GPS, are planned. Currently, we are analyzing the results of a similar collaborative experience carried out with secondary school students for supporting assessment *in situ*. The limitations and problems reported in this case study have been taken into account for designing the activity and improving the technology for automating some aspects of the orchestration such as functionalities for grouping students according to the expertise or visualizing the historic of the participants. Additionally, the main outcomes from this study and next experiences put on the foundations towards a model for generalizing the main factors that should be considered when orchestrating potentially effective computer supported collaborative blended learning experiences.

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Tables

Table 1 Number of students that answered the questionnaires classified by the type of exploration performed

Exploration type	Answered the questionnaire
Expl. with mobile phones	63 (in front of the 74 we have logs from)
Expl. by walking	25
Expl. by web	108
Expl. using three mediums	8
Expl. mobile & web	1
Expl. mobile & walk	2
Expl. web & other (already visited, ...)	9
Already knew the campus	2
Total answering the questionnaire	218
Do not answer	23
Total	**241**

Table 2 Number of tags available per building and minimum number of tags required for becoming an expert in each of the buildings

Building	Number of tags available	Number of tags required for becoming an expert in the building
Roc Boronat (52 and 53)	13	More or equal to 4 (Most of the students only accessed to the tags located in the first floor of the buildings)
La Nau	8	More or equal to 5
Tanger	11	More or equal to 4
Tallers	4	More or equal to 2
La Fàbrica	10	More or equal to 4

Table 3 Number of students for each of the group types defined (including only those students that finally delivered the final presentation)

Type of group	Number of groups	Experimental students	Control students	Total of students
Only Mobile	11	43	2	45
Other mediums	37	6	136	140
Mixed	14	27	29	56
Total	**62**	**74**	**167**	**241**

Table 4 Workflow and outcomes of the CSCBL scenario

Learning Flow Phase	Teacher	Student	Data for the orchestration/Outcomes: Teacher	Data for the orchestration/Outcomes: Students
Discovering the campus	Preparation of the activity "Discovering the campus": • Preparing the tags' content • Recording the contents on the tags • Locating the tags on the campus	Choose the exploration activity: • Activity "Discovering the campus" with mobile devices • Walk around the campus • Visit the web page of the campus	NFC tags	Log files recording the activity of the students' actions during the exploration with the mobile devices (73 participants)
	Preparation of the test "Discover the learning environment"	Answering the individual questionnaire "Discover the learning environment"	Individual Mandatory Questionnaire "Discover the learning environment " in Google Docs	Answers "Discover the learning environment" (241 participants)
Explaining the campus	Preparation of the activity "Explaining the campus": • Experts definition depending on students' activity and preferences • Form expert groups and assign them an area of the campus Prepare list of groups	Preparing the presentation: • Locate group members • Prepare 6-slides' presentation and upload to the Moodle Course	List of expert groups assigned to an area of the campus	Presentation of the area assigned
Reflecting about the campus	Preparation of the activity "Reflecting about the campus": • Review and score presentations • Prepare the mandatory questionnaire in the Moodle platform "Reflecting about the campus" • Final score: Average of Questionnaire + Presentation Scores	Perform the activity "Reflecting about the campus": • Review other groups' presentations • Answer the mandatory questionnaire	Mandatory final questionnaire. Scores of the presentations and of the final questionnaire	Answers to the mandatory questionnaire
	Prepare the voluntary test for reflecting about the whole experience	Answer the voluntary questionnaire giving the opinion about the whole experience	Voluntary questionnaire about the experience	Answers of the voluntary questionnaire about the experience

Table 5 Data sources for the evaluation of the case study and labels used in the text to quote them.(* eg stands for Experimental Group because only those students using mobile phones answered this questionnaire)

Data source	Type of data	Labels
Questionnaires about the exploratory experience of the campus with mobile phones (only performed by those students who made the experience with mobile devices)	Qualitative numeric data, comments and opinions	[Quest-Experience-eg]*
Mandatory Questionnaire about the "campus exploration"	Quantitative data about the places visited Qualitative data, comments and opinions of the different areas	[Quest-Campus-Phase1]
Grades of the presentations resulting from the Phase of Experts	Quantitative results obtained from the average of the final score given to each presentation by two different teachers	[Presentations-Score-Phase2]
Questionnaire about the "campus knowledge acquired"	Quantitative results from an automatically evaluated questionnaire performed in Moodle	[Quest-Score-Phase3]
Optional final questionnaire about the grouping policies carried out in the experience	Quantitative ratings and qualitative opinions about the whole activity process focusing on the policies used for the group assignments	[Quest-Reflection-Phase3]
Observations from four researchers external to the case study	Record of direct observations during the experience by 4 different researchers	[observer1, observer2, observer3, observer4]
Videos of the students performing the experience with mobile phones	Qualitative data	[video-Learn3-Transcriptions]
Questionnaire about the orchestration process for the teachers	Qualitative data	[Quest-teachers]

Table 6 Main conclusions offered by the research carried out along the case study

Findings	Partial results	Support data
Focus 1. Meaningfulness of the CSCBL activity generated.		
Applying a CLFP to a blended learning scenario using mobile technologies is a good approach for supporting the integration of formal with informal exploratory activities.	- The students that were physically in contact with the campus show more precise descriptions of the university service's locations that those who only did the exploration via the web. - The scores of the whole activity show that students in the experimental group show better results in average and have developed more original contents in their presentations. - Groups formed by students from MOBILE and MIX groups have better scores that those from the WEB group. - The students from WEB group did more errors in the individual questionnaire when they were asked to locate some of the services of the University. - Students contact with the different services of the university and activities of the department.	[Quest-Campus-Phase1] [Quest-Reflection-Phase3] [Presentations-Score-Phase2] [Quest-Score-Phase3]
The CSCBL experience, which combines informal with formal activities and individual with group ones, facilitates the students to have a first contact with the academic methods and useful services that will help during their engineering studies in the future. Moreover, working in groups formed based on the students' personal experience is shown to be a successful mechanism for promoting collaboration.	- The combination of informal and formal activities is a good support for learning non typical contents about the campus and services. - The variety of activities makes it easier to make students comfortable with the activity as a whole. - The combination explorative activities in combination with reflective tasks such as the individual questionnaires reinforce learning. - Combining types of individual activities with work in groups is a good mechanism for learning about the different studies' methodologies. - Students have adapted to work with the group imposed by the teacher and collaborated successfully. - The grouping policies based on log files are a good method to facilitate the students to meet meet each other. - The experience is successful in promoting collaboration.	[Quest-Score-Phase3] [Quest-Reflection-Phase3]
Focus 2. Motivational benefits of the activity proposed and its educational innovation with respect to more classical introductory exp.		
Students highly appreciate the CSCBL scenario compared with their previous experiences in terms of innovation, use of supporting technology and discovery.	- The exploration using mobile technology is a good support for learning and discovering more about the campus structure and services in comparison with other activities. - Students value experiences that combine technologies such as mobile devices as very fun, innovative, interesting and useful. - Students recommend the activity because of the innovative use and manipulation of technology.	[Quest-Experience-eg] [Quest-Reflection-Phase3] [video-Learn3-Transcriptions]
The inclusion of free exploratory experiences technologically supported in a formal sequence of activities fosters the students' motivation on the studies, the University services and their interest on technology.	- The use of mobile technologies for the exploration-type of activities supports the discovery of different places and enacts the motivation of students with regards the university activities (including research). - Students value the CSCBL experience as very good for discovering departments and services of the university that will be useful for them in the future. - The majority of the students will repeat the explorative experience of the campus and recommend others to perform it because of its utility to learn about it.	[observer1, observer2, observer3, observer4] [Quest-Reflection-Phase3]
Focus 3. Successful aspects and the limitations experimented by teachers and students during the orchestration of CSCBL experience.		
The network and computer technology used in the CSCBL experience (mobile phones, NFC/RFID, Moodle platform and Google Docs) has been easily adopted by the students and the teacher during the whole activity. However, some usability and integration aspects should be improved.	- Students suggest other technologies such as PDAs for facilitating the access to content such as video or images. - The use of mobile devices enables the generation of informal activities that balance flexibility and guidance. - Students have easily managed the University's Moodle platform. - The audio-contents should be improved by turning up the sound of the registrations. - The mobile device application could be improved by including the possibility of accessing the same tag with two different mobiles at the same time and making it more robust for reading the tags.	[observer1, observer2, observer3, observer4] [video-Learn3-Transcriptions] [Quest-teachers] [Quest-Reflection-Phase3] [Quest-Experience-eg]
The CSCBL scenario and technological environment developed is shown as a good solution for integrating informal exploratory activities with formal activities, for fostering collaboration and supporting its orchestration. However, an integrated system for blended activities flow would facilitate the data acquisition from the exploratory activity and help in the group formation processes for a better adoption of the CLFP.	- Log files for storing the actions of the students during the exploratory experience are a good support for the integration of formal and informal activities occurring in different spaces. - Log files capturing the actions of the students in combination of online questionnaires is a good technological support for defining expert groups by fostering collaboration. - Students highly appreciate the experience with the mobile devices and suggest increasing the time of the exploratory experience. - Results show that the best policy for acquiring good learning outcomes is to group people with the same interests (in this case interested in doing the exploration with the mobile phones) or mix them in equilibrated groups (two from each type). These types of grouping policies are possible thanks to the NFC technology or other tracking tooling.	[Quest-Campus-Phase1] [Quest-Experience-eg] [Quest-teachers] [Quest-Reflection-Phase3]

Figures

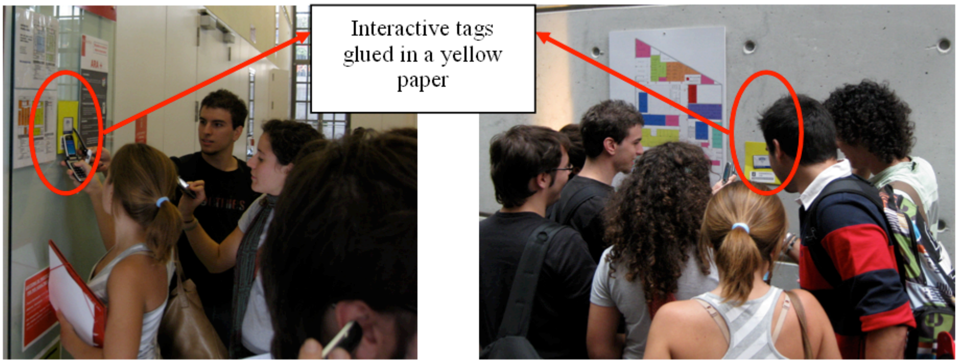

Figure 1 Students interacting with the 46 NFC Tags distributed around the campus. The tags are glued in a yellow card to make them more visible. Students access the information hidden in the tags with mobiles that integrate NFC reader and that were facilitated for the experience.

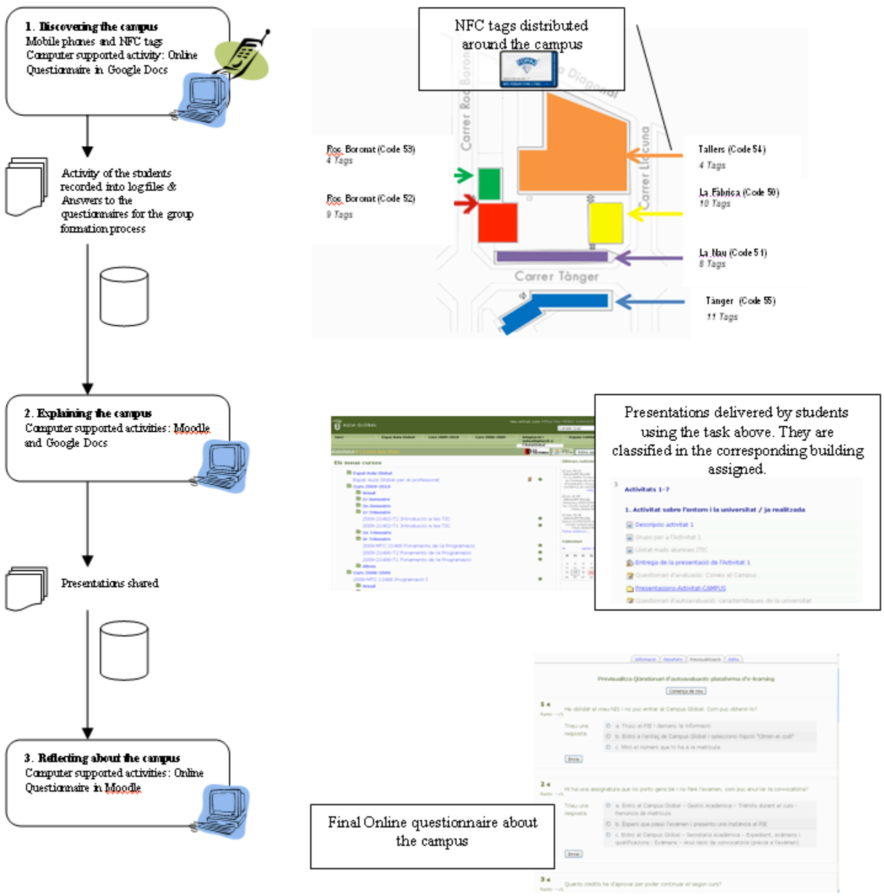

Figure 2 Technological environment: A combination of mobile devices with an integrated NFC reader, NFC tags, a Moodle Platform and Google docs allows an integration of the different activities of the learning flow into a unique learning setting.

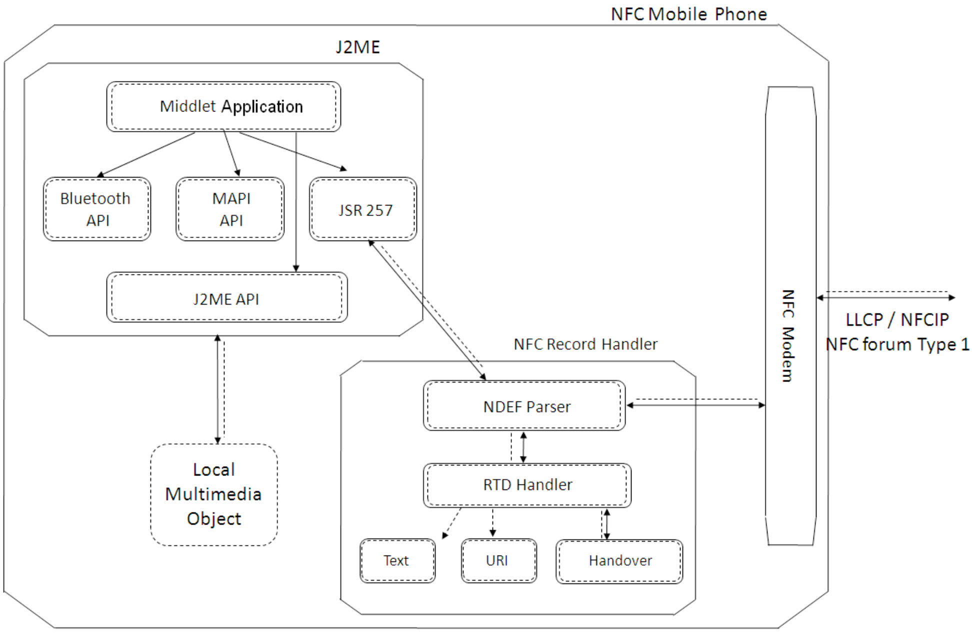

Figure 3 Detailed architecture of the NFC mobile phones employed for the experience

Figure 4 NFC Player application usage.

Figure 5 ReadOnlyBD application usage.

Figure 6 ReadWriteTags application usage – "Write" functionality.

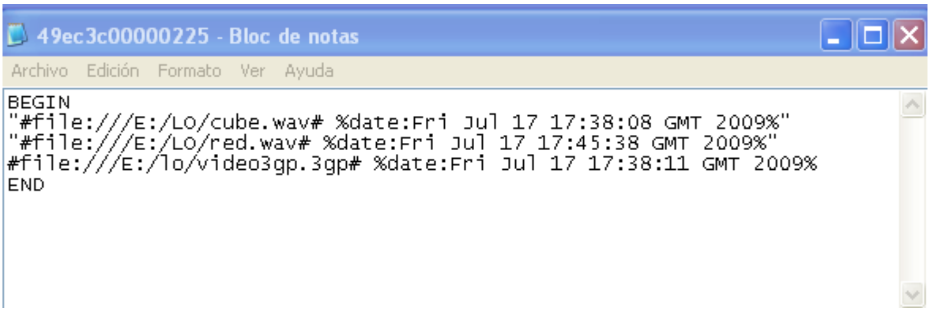

Figure 7 BT Bridge application usage – Log file generated and stored in the computer after the exploratory activity. There is one log file associated to each of the students participating in the activity.

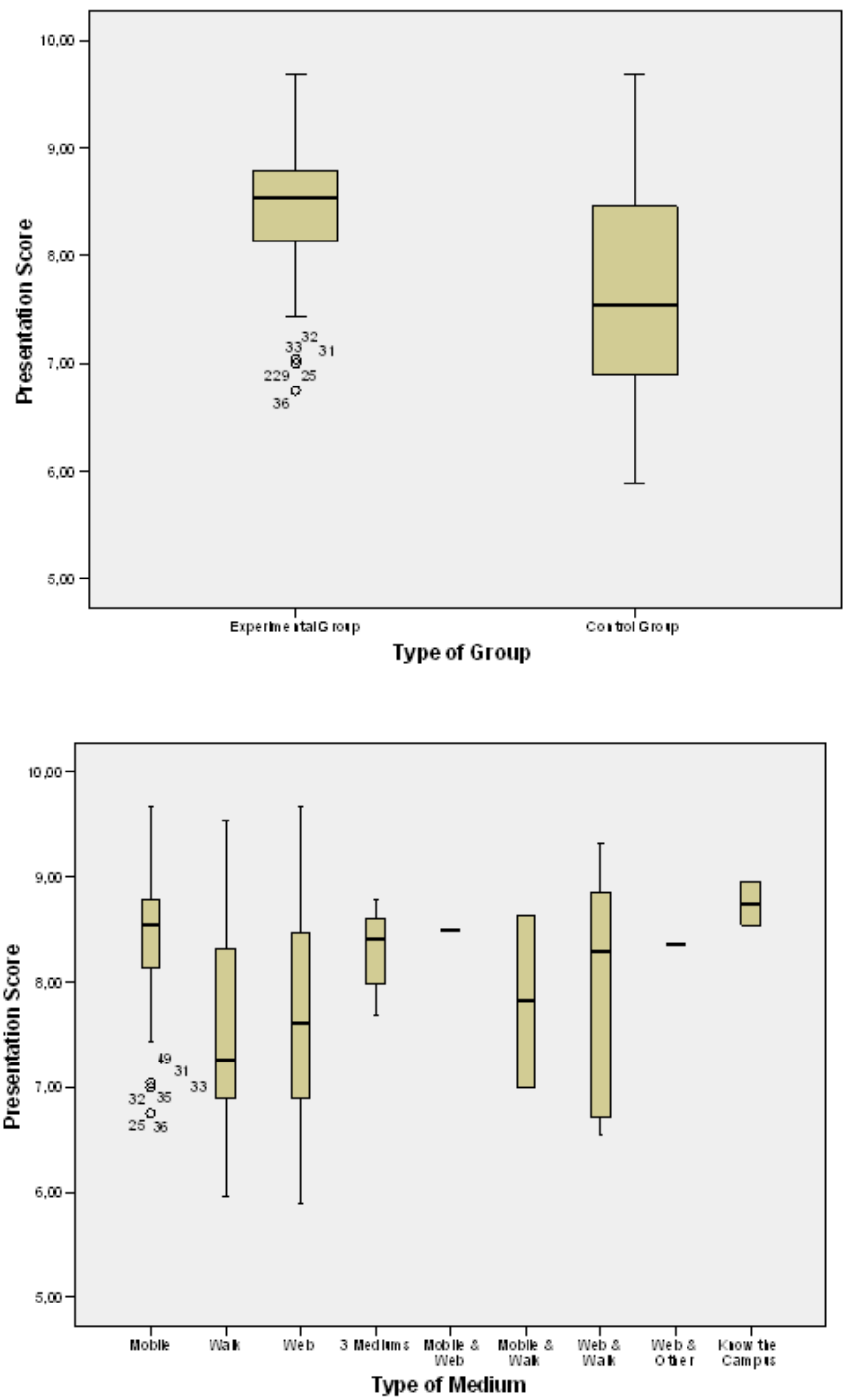

Figure 8 Presentations score separated by type of groups (upper figure) and mediums used for the exploratory activity (bottom figure).

Paper V

Pérez-Sanagustín, M.; Hernández-Leo, D.; Santos, P.; Blat, J. *How to design a collaborative learning scenario blending spaces: A case study applying 4SPPIces* International Journal of Computer Supported Collaborative Learning (*accepted conditionally*).

Abstract Computer Supported Collaborative Blended Learning (CSCBL) scenarios are learning situations in which formal and informal activities occurring in different spatial locations are combined and integrated into a unique learning setting. This paper presents a case study where a CSCBL scenario and the technological environment for its support are analyzed in the context of a Geography course at a high school in Catalonia. The scenario is proposed as a solution to deal with the limitations detected in previous academic years, in which students visit Barcelona in order to reflect about its urbanism and socio-geographical characteristics. The resulting experience combines individual with collaborative activities supported by mobile and computer-based technologies conducted at the classroom, home and the city. The design of the scenario and the associated technological environment is supported by 4SPPIces. 4SPPIces is a conceptual model that facilitates communication between practitioners and technicians when addressing the design and enactment of CSCBL scenarios. The case study reports: (1) the participatory design process followed with two teachers of the high school to define the scenario and the requirements for its technological support using 4SPPIces and (2) the results of conducting the scenario in the actual learning context to analyze whether it fulfills the targeted learning objectives. The conclusions achieved, in the participatory design process and in the enactment of the scenario, show that the support provided by 4SPPIces was helpful to enhance a previous practice providing new learning and motivational benefits.

How to design a collaborative learning scenario blending spaces: A case study applying 4SPPices

Abstract

Computer Supported Collaborative Blended Learning (CSCBL) scenarios are learning situations in which formal and informal activities occurring in different spatial locations are combined and integrated into a unique learning setting. This paper presents a case study where a CSCBL scenario and the technological environment for its support are analyzed in the context of a Geography course at a high school in Catalonia. The scenario is proposed as a solution to deal with the limitations detected in previous academic years, in which students visit Barcelona in order to reflect about its urbanism and socio-geographical characteristics. The resulting experience combines individual with collaborative activities supported by mobile and computer-based technologies conducted at the classroom, home and the city. The design of the scenario and the associated technological environment is supported by 4SPPIces. 4SPPIces is a conceptual model that facilitates communication between practitioners and technicians when addressing the design and enactment of CSCBL scenarios. The case study reports: (1) the participatory design process followed with two teachers of the high school to define the scenario and the requirements for its technological support using 4SPPIces and (2) the results of conducting the scenario in the actual learning context to analyze whether it fulfils the targeted learning objectives. The conclusions achieved, in the participatory design process and in the enactment of the scenario, show that the support provided by 4SPPIces was helpful to enhance a previous practice providing new learning and motivational benefits.

Keywords *Computer Supported Collaborative Learning, Blended Learning, Mobile learning, Case Study, Educational Design*

Introduction

In recent years, devices such as mobile phones or PDAs combined with wireless connectivity are changing the nature of educational scenarios. Now learners are not at a fixed predetermined location (O'Malley & Fraser, 2004) and can move across different spaces. Also, the new possibilities for interaction offered by these technologies pose new challenges for learning, and especially for learning through collaboration. Collaboration can occur inside and outside the classroom and combine formal and informal activities that can be monitored and coordinated between different locations (Kukulska-Hulme & Traxler, 2005). We term these new learning situations as Computer Supported Collaborative Blended Learning (CSCBL) scenarios. CSCBL scenarios are combinations of formal and informal (collaborative) learning activities occurring in different spatial locations beyond the class, supported (at least one) by technology and integrated through a data-flow into a *unique learning setting*. We refer to a *unique learning setting* when the connection within activities is produced through the data used and produced in each of them. Therefore, the main interest of CSCBL scenarios falls on their blended nature.

The combination of activities and spatial locations makes CSCBL scenarios specially innovative in terms of technology usage and rich in terms of learning benefits. For example, a study by Facer et al. (2004) proposes using mobile phones for supporting a collaborative experience in which children are invited to understand the animal behavior in a savannah in direct physical interaction with space. The results show that, despite of its complexity, the experience fostered students' motivation and helped on the acquisition of concepts. In another study by Ruchter, Klar, & Geiger (2009) mobile devices are used by a group of users as a guide for supporting environmental learning. The conclusions of this study show that using mobiles leads to an increase in students' environmental knowledge and in their motivation in environmental education activities. Other studies analyze the way students' appropriate mobile devices for learning by generating their own learning content (Cook, Bradley, & Haynes, 2006; Cook, 2007). All these works are examples of meaningful CSCBL scenarios that offer learning opportunities difficult to achieve with other practices. But, what makes all these studies especially interesting for learning is that the use of technology is always driven by educational considerations. That is to say, the technologies employed are selected not only for the functionalities that they offer but also for the way in which their functionalities effectively support and enhance the learning purposes.

Computer supported collaborative learning (CSCL) is characterized for being an interdisciplinary field that appropriately combines computer support and collaborative learning to effectively enhance learning (Stahl, 2005). The multidisciplinary nature of this field implies a balance between technology and education when addressing the design of any CSCL practice or application. As Larusson & Alterman (2009) state, "any CSCL application combines a learning activity with a collaborative environment". But to keep this balance in CSCBL scenarios is even more complex and challenging than in other situations (Kukulska-Hulme & Traxler, 2005; Park, Parsons, & Ryu, 2010). New factors such as the spatial locations and the interplay between formal and informal activities play a crucial role in the design of CSCBL scenarios that have to be understood from both educational and technological perspectives. Therefore, to address the design of these scenarios requires the intervention and the mutual understanding of mainly two different actors: practitioners (experts in educational issues) and technicians or technologists (aware of the technologies available and their potential) (Dimitriadis et al., 2003). From the educational perspective, it is necessary to encourage practitioners to think about practices that involve formal and informal activities in different spatial locations. Technologically, collaborative environments have to be designed for supporting, structuring and coordinating (thus, orchestrating (Alavi, Dillenbourg, & Kaplan, 2009) students' and teachers' tasks to produce potentially effective learning outcomes. Both practitioners and technicians have to work hand in hand to end up with meaningful CSCBL scenarios and educationally driven technological environments for effectively supporting their orchestration. As Roschelle (2003) summarizes in one sentence: *"one of the challenges is to create solutions that are educationally appropriate rather than technologically complex, in order to avoid the development of applications that are often let down by complex views of technology and simplistic views of social practice"*.

As an approach towards Rochelle's challenge, this paper presents a case study showing the process for addressing the needs of an actual activity. Every year two geography teachers at a high school (in a town close to Barcelona) organize a visit to Barcelona to foster students' familiarization with the urbanism and the socio-geographical characteristics of the different districts of the city. Although teachers are happy with the past editions of this activity, they set off some limitations of the current practice: (1) the activity is programmed to spend one morning in the city, which constraints the visit to only one area in Barcelona and hinders comparing different districts of the city, (2) the visit is prepared as an individual activity but teachers are interested in introducing a collaborative component to promote student's competences of working in groups and critical thinking and (3) teachers are interested in understanding how technologies can be used to improve the current activity since the government has explicitly asked schools to explore the use Information and Communication Technologies (ICT) as a support to enhance the students' learning and assist practitioners.

To tackle the limitations of previous practices, we propose to collaboratively design with the two teachers a CSCBL scenario and its associated technological environment to be enacted in the context of this geography activity. To understand the complexity of the learning situation and to design the CSCBL scenario consequently, we applied 4SPPIces. 4SPPIces is a conceptual model for supporting communication between practitioners and technicians when addressing the design of CSCBL scenarios and the technological environment for supporting their enactment. Thus, 4SPPIces yields insights in the complexity that the design of CSCBL scenarios entails by facilitating a conceptualization of the elements that describe them and aids reasoning and communication between practitioners and technicians about this complexity. In this context, 4SPPIces is employed as the collaborative design framework to achieve a CSCBL scenario adapted to the needs of the educational context under study. Hence, the main research question faced in this paper is: *Does 4SPPIces help practitioners and technicians on designing a meaningful CSCBL scenario in the context of the geography activity that extend the previous practices for addressing their limitations?*

To answer this research question requires considering the whole lifecycle of a CSCBL scenario implementation, from the design to the enactment. On the one hand, the design process has to be analyzed to understand whether 4SPPIces supports communication among technicians and practitioners in creating CSCBL scenarios adapted to a particular context. On the other hand, analyzing the enactment allows understanding whether the educational objectives have been successfully achieved. Therefore, the main research question can be formulated more specifically through two more concrete questions: (1) Does 4SPPIces help on the design of CSCBL scenarios that cover the demands of the specific context as well as on identifying the requirements for the supporting technological environment? and (2) Does the CSCBL scenario and its associated technological environment, when run into the real educational context, effectively support students' and teachers' tasks leading to the expected learning objectives?

The case study presented in this paper faces these research questions both from the perspectives of the design and the enactment of the CSCBL scenario. Specifically the case study reports: (1) the results of a participatory design process applying 4SPPIces followed with the two practitioners for designing the narrative of a CSCBL scenario (a structured description of the didactical scenario proposed to accomplish the learning objectives) and its associated technological environment and (2) the results of running the CSCBL scenario with 34 students in the real geography activity situation.

After presenting 4SPPIces in the next section, the following section presents the context of the case study, with an emphasis on the limitations that need to be addressed, and transforms the research question into propositions for the case. This section also shows how these propositions are tackled with the analysis of the two different perspectives: the design and the enactment. First, we report the participatory design process followed with the two practitioners. Second, we describe the results of running the CSCBL scenario with the 34 students. A cross-perspective analysis section relates the findings of the design and enactment perspectives with the two propositions. The final section discusses how the results of the case study provide answers to the research questions and draws conclusions concerning the support provided by 4SPPIces.

4SPPIces: a model for designing CSCBL scenarios

4SPPIces is a conceptual model that provides practitioners and technicians with a common language to design CSCBL scenarios potentially meaningful for learning and their associated technological setting supporting their enactment. The methodology followed to propose the model is based on an extensive literature review in three main fields: (1) work and definitions of blended learning which introduce the concepts of space and the interplay of informal and formal activities when designing CSCBL scenarios, (2) CSCL research on tools and theoretical approaches for enhancing learning by structuring or orchestrating collaboration to achieve learning benefits and (3) results from experimental research and case studies proposing innovative uses of technology for enriching current educational scenarios. As a result, 4SPPIces combines four factors conditioning the definition of CSCBL scenarios and the technological requirements for their support: the *S*pace, the *P*edagogical method, the *P*articipants and the h*I*story. These factors have been studied separately in the literature, with special emphasis the pedagogical method and the participants. The novelty of 4SPPIces falls on the explicit definition of the space as a relevant factor in the design of CSCBL scenarios and on highlighting the role of the history for explicitly modeling the relations among the other three factors that affect the enactment of the scenario. Figure 1 shows a schema of the factors considered in 4SPPIces, their facets and how they relate to each other. In the following, we revise the definition of each of the factors and their facets.

{Figure 1 4SPPIces model. Factors and facets to be considered in the design of CSCBL scenarios and the technological environment for supporting their enactment.}

First, the **Space factor (S)** defines the space where the learning activity occurs and its elements (Pérez-Sanagustín et al., 2010). This factor is inspired in ideas coming from research works on learning spaces and ubiquitous computing. Researchers in these fields consider the physical space as a contextual factor that can enable or inhibit learning by shaping users' interactions that can activate collaboration (Ciolfi, 2004; Gee, 2005; Oblinger, 2005; Oblinger, 2006). The characteristics of the elements composing the space determine the interactions that can occur in that space. For example, whether the elements of the learning environment are portable or not, electronic or not, sharable or not conditions the way students are distributed over the space and how they move or interact by affecting not only the orchestration processes but also the way in which the learning flow is defined (Pérez-Sanagustín et al., 2010). In this way, a learning space will be characterized by the *Arrangement* of the elements that compose it (location and organization of the elements composing the space), their *Mobility* (whether they are portable or not) and their *Affordance* (describes whether these elements are used individually, collectively or collaboratively).

The second is the **Pedagogical Method factor (PM)**. The definition of this factor is prompted by the ideas that arise from the CSCL scripting field. Experts in this area state that free collaboration does not necessarily produce learning (Dillenbourg & Fischer, 2007). One of the solutions proposed for reaching this effectiveness is to orchestrate collaborative activities through the so-called CSCL scripts. CSCL scripts are computational mechanisms to guide and structure interactions among learners in order to produce effective learning (Dillenbourg & Hong, 2008; Weinberger et al., 2009). This factor adopts some of the concepts of the scripting practices and proposes: 1) to structure the activities, occurring in sequence or in parallel, in a *Learning flow*, 2) to differentiate the teachers' and learners' tasks through the *Activities*, 3) to define the *Group characteristics* for each activity and 4) to define the inputs and outputs that will be generated from one phase to another, which corresponds to the *Data flow*. The Data flow facet takes into consideration the ideas behind the concept of integrated scripts. These scripts contemplate a computational integration of the data used and produced across the different learning activities to define an integrated learning experience (Dillenbourg & Jermann, 2007). Therefore, the PM is any didactic description of a sequence of activities that define what learners and teachers should perform, the groups' characteristics for producing the interactions to reach the particular learning objectives and the data flow that assures the activities integration.

Third, the **Participants factor (P)** is dedicated to capture those aspects related with the students participating on the activity. This factor is composed by 4 facets. The first takes into account the *number of potential and actual number of participants*. This distinction is considered in order to design technological systems able to lead with the unexpected situations regarding the number of participants during the CSCBL scenario enactment (Dillenbourg & Tchounikine, 2007). The second and third facets are related. On the one hand, the students *Profile* facet takes into account those characteristics of the students that can affect the way in which the activity is structured. For example, we can have advanced and non-advanced students and assign one or another activity to each one. On the other hand, it is possible to group the different students according to the elements defined in their profile such as their language. This is modeled in the *Profile-dependent group formation* facet. Finally, the physical location of the students for each activity is also important. Now it is possible to conceive scenarios in which a group of students from Valencia attends to a class in Barcelona through an audiovisual conference system. Since, in such as cases, the dynamic of the collaborative activity changes depending on the location of the students, the Participants factor includes the *Location* as one of its facets.

Finally, the fourth factor is the hIstory (I). The hIstory describes what happened with respect to the facets of the previous three factors whose (unpredictable) variations affect the potentially fruitful activity enactment. This factor is inspired again in the research on CSCL scripts. The literature distinguishes between three different phases when talking about scripting processes: the design phase (where the script is defined), the instantiation phase (when the script is related to the learning situation) and the enactment phase (when the instantiated design is delivered to the participants as an activity to perform) (Hernández-Leo et al., 2006; Weinberger et al., 2009). Therefore, in order to design a technological support for the enactment of the CSCBL scenario, it is essential to consider those facets implied in all these phases. The nature of the hIstory factor has to do more with those issues that, when the activity is enacted, need to be considered for assuring a coherent and integrated learning setting. For example, the role assigned to a student in the first activity can affect the role that it is recommended (from the pedagogical method perspective) for this student to play in the second phase. Also, if a device implied in the activity fails, it is necessary to have alternative solutions so as to change the activity flexibly. With this aim, the hIstory is characterized by three facets directly registering the flexibility requirements that have to do with the rest of the factors in the model: S events (those flexibility requirements regarding to the Space factor), PM events (those flexibility requirements regarding to the Pedagogical Method) and P events (those flexibility requirements regarding to the Participants factor). The idea behind this factor is to make the users of the model reflect about those relations among factors that can affect the enactment of the experience in order to build up systems and mechanism dealing with them.

Research design: a case study

A research design is the action plan for getting from the research questions to the conclusions. This section presents the details of the case study carried out in this work to tackle the research questions and ensure the clear view of what is to be achieved. First, the rationale behind following a case study methodology is discussed. Second, the information given in the introduction about the context in which this work is framed is extended with an emphasis on the limitations and objectives addressed. Third, we recall the research questions and transform them into propositions. Finally, we provide an overview of the deployment and the data gathering techniques used along the case study.

Why a case study?

Since our research aim focuses on how 4SPPIces is employed for designing a CSCBL scenario for a concrete geography activity, the outcomes of this research should be understood into this particular context. The method that better undertakes an investigation into a phenomenon in its context is the case study.

Zelkowitz & Wallace (2002) identify three categories of software engineering technology validation models: observational (collect relevant data as a project develops), historical (collects data from projects that have already been completed) and controlled (collects data from multiple instances of an observation for providing statistical validity of the results). Case studies belong to the observational category. The other two methods were dismissed for the scope of this study. On the one hand, for adopting historical methods more experiences created with the 4SPPIces would be needed. On the other hand, employing a controlled method is not feasible because the CSCBL scenario analyzed is implemented in an authentic educational context with real users, which makes the exact replication of the experience impossible.

Case studies have traditionally been categorized as lacking rigorousness and objectivity compared with other research methods. One of the major reasons is the difficult generalization of the results because of the poor controls for later replication. However, case studies provide valuable information regarding the influence of technology in a particular context and have proved to be very useful on providing answers to ‘How’ questions (Rowley, 2002). Thus, case studies help on evaluating how technology affect and transforms a context. As Zelkowitz & Wallance (2002) state, case studies enable monitoring an authentic situation by extracting information from the data collected about the different attributes characterizing its development.

Stake (1998) defines two different types of case studies depending on their purpose. When the purpose of the case is to learn about the particular case “itself” it is an “intrinsic” case study. Whereas, when the purpose is to have a general understanding about a research or research questions by studying a particular case it is an “instrumental” case study. Instrumental case studies, beyond learning about the educational situation itself, are instruments for researchers to understand the in the implications of specific interventions in the context of the particular case.

In this paper, we propose an “instrumental” case study as the evaluation method that better fits our research scope. The intervention here has to do with the application of 4SPPIces and the implementation of the CSBL scenario and associated technological environment derived from this application into a real educational context.

Case study’s context and research objectives

The case study takes place in a Geography course framed into the curriculum of the second Bachelor degree at the public high school IES Duc de Montblanc (Rubí, Spain). As mentioned in the introduction, the course topics studied deal with the urbanism of a city and its socio-geographical characteristics (Catalan High School Curriculum, 2008). Aspects such as the infrastructures, the public transport services, the predominant architecture styles or the public or private services available are analyzed as part of the town planning. Teachers traditionally organize a visit to Barcelona to foster students' familiarization with all these concepts.

During the visit, the teachers guide the students through the most significant points of two of the most centric districts of Barcelona while explaining the connections between the planning and the social characteristics of different areas. They foster students' reflection asking questions about different places that learners have to answer individually in a dossier by observing their emplacement. After the visit, each student prepares a document about the activity using the notes and questions completed.

The teachers set off three limitations from previous practices that they would like to improve:

1. Dealing with the limitation of visiting only one district.
2. Introducing a collaborative component into an activity that is been traditionally individual.
3. Introducing the use of technologies into an activity that have traditionally used dossiers to guide and support the students.

These limitations set the basis of this research work.

Propositions of the case study

In order to solve the research questions presented in the introduction, the instrumental case study focuses on analyzing: (1) at design stage, whether the formulation process of the CSCBL scenario narrative and associated technological environment covers the learning objectives by dealing with the limitations detected and (2) at enactment stage, the effectiveness of the CSCBL scenario and technological environment on supporting students' and teachers' tasks.

Notice that we do not explicitly consider the instantiation phase (the particularization of the design to the specific learning situation) and focus on the design and enactment phases. Since the design of the CSCBL scenario already considers the context of the specific learning situation, the boundaries between the design and the instantiation are blurred.

According to Rowley (2002), research questions need to be translated into propositions to make a speculation as to what researchers expect from the case. Then, the data collection and analysis can be structured to support or refute the research propositions. We formulate two propositions related with the questions 1 and 2 in the introduction, respectively:

1. 4SPPIces supports communication among practitioners and technicians when addressing the design of a meaningful CSCBL scenario and its associated technological environment for supporting its enactment support covering the limitations of previous practices with new learning benefits.
2. The CSCBL scenario and its associated technological environment, both designed with 4SPPIces, when enacted into a real educational context effectively support the students' and teachers' tasks leading to the expected learning objectives.

Deployment of the case study

To evaluate the two propositions we need to study the case from two different perspectives according to the stages of the CSCBL scenario implementation: the design and the enactment perspectives. Each perspective has its own information questions, whose findings will provide evaluation results regarding the propositions about 4SPPIces in the context of this case. The data collection and analysis of each perspective of the case study are structured in order to support and refute both research propositions. Using the nomenclature employed in (Hernández-Leo et al., 2010; Stake, 1998), Figure 2 shows the schema of the case study and introduces the sites, deployment, materials and interviewees of each phase as well as the evaluation techniques employed. In the following sections we give more detail about the two perspectives and their results.

{Figure 2 Schema of the case study from the design and enactment perspectives: (1) A team work with practitioners following a Participatory Design technique and (2) An experience with students and teachers in an actual learning situation evaluated with a Mixed Method.}

Design Perspective: designing the CSCBL scenario

This perspective of the case study is devoted to analyze the design of the CSCBL scenario and its technological support. This design is achieved as a result of a teamwork process with two practitioners (the main teacher and an assistant), who are the interviewees of the case study design perspective. This section explains the details of the design process followed and the information questions that guided its analysis. The outcomes of this collaborative design process are also presented: the CSCBL narrative and the technological environment implemented for its support.

A Participatory Design with practitioners

For the collaborative design process of the scenario we followed a Participatory Design (PD) methodology. PD is a field of research and an evolving practice among design professionals. Researchers in this field explore conditions for user participation in the design and introduction of computer-based systems at work (Kensing & Blomberg, 1998). Methodologies in PD imply the use of theories, practices or methods that enable the people destined to use technological solutions to be involved in their design (Schuler & Namioka, 1993). PD can lead to hybrid experiences that share attributes of both the workers' space (in this case the teachers from the high school) and the software professionals' space (researchers as technicians) (Muller & Kuhn, 1993).

In this study, 4SPPIces was the communication instrument employed for supporting the participatory design process with the practitioners. Although the use of the model was transparent for the teachers, the aspects that 4SPPIces defines were employed for structuring the design process during the meetings and to guide the decisions when defining the narrative of the CSCBL scenario, the educational materials needed for the experience and to identify the requirements of the technological environment for its support.

The data collection methods employed in this phase are listed and described in{Table 1. All the materials exchanged with the teachers for the participatory design process can be accessed at: http://193.145.50.210:8080/DUCdata/ijCSCL-data/DiscoveringBCN.html.

The details of the PD process conducted with the teachers as well as the documents generated from this process are documented in this part of the case study. Both the report and the resources generated are the basis for extracting evidences with regard to the usefulness of 4SPPIces on supporting the design process in the context of the case. In this way, we define two different focuses of evaluation related with the two statements about the model under evaluation. For each focus, we formulate a set of information questions to guide the PD process.

- The **first focus relates to the educational characteristics of the CSCBL scenario designed**; i.e. whether the main structure of the CSCBL scenario designed potentially deals with the learning objectives of the experience defined by the teachers as well as with the limitations detected from previous experiences. The questions arising from this first focus are: (1) Does the CSCBL designed enable comparing more than one district in Barcelona? (2) Does the CSCBL designed provide the means for enhancing collaboration among students? (3) Does the CSCBL scenario designed include and require the use of technologies? (4) Does the CSCBL scenario capture the learning objectives of the teachers in this experience?

- The **second focus relates to the aspects regarding the requirements of the technological environment for supporting the CSCBL scenario enactment**; i.e., whether the technological environment designed could potentially support the functionalities related with the CSCBL scenario narrative defined. The research questions in this case are: (1) Does the technological environment proposed provide the functionalities required for supporting the tasks of the CSCBL narrative designed?

The outcomes of this phase are the narrative (or skeleton) of a CSCBL scenario that extends the previous educational activity, the educational materials prepared, and the list of requirements for its technological support with the final technological collaborative environment developed accordingly (see section *Phase 1: Results from the Participatory Design with practitioners*). These outcomes, as well as the participatory design process report will show how 4SPPIces is employed as a communication support in a participatory design process with practitioners to analyze and understand the context of the learning situation.

{Table 1 Data sources used in the participatory design process in the phase 1 of the case study and labels used in the text to quote them.}

Meeting the educational requirements

Two different meetings were carried out with the teachers at the high school. The first meeting was on 4th February 2010 and served to understand which the learning objectives that motivate the experience "Discovering Barcelona" are and how is usually organized. This information is the basis to extract the educational requirements (ER) that motivate the extension of the experience. The second meeting was at the end of the process, on 28th April 2010, and served to revise with the teachers the version of the narrative of the CSCBL scenario resulting from the design process, the materials prepared, the groups of students proposed for the experience and how the technological environment developed work. Due to the availability of the teachers, no more meetings were possible and most of the work was done via e-mail and telephone conversations. Lots of e-mails were exchanged within the two meetings to advance in the definition of the CSCBL narrative.

Both, the information from the meetings and the materials provided via e-mail were structured according to 4SPPIces to propose a narrative of a CSCBL scenario adapted to the educational context. Also, the model was useful as a support for guiding the meetings with the teachers in the discussions about how to enhance the scenario so as to reach the learning objectives and in the identification of the technological requirements.

Table 2 organizes chronologically a summary of the meetings carried out and the e-mails exchanged along the participatory design process. This table also provides a description of the information gathered from the mails and meetings, the outcomes obtained and their relations with the factors and facets of 4SPPIces. As an example of the type of information exchanged with the teachers via e-mail, Figure 3 shows two of the routes that teachers proposed for the activity.

{Table 2 Summary of the meetings and e-mail exchanged during the participatory design process with practitioners and their relation with 4SPPIces for the definition of the CSCBL scenario.}

{Figure 3 Examples of two of the routes proposed by the teachers and sent via e-mail.}

Outcome 1: CSCBL narrative

With the information gathered from the meetings and e-mails and after discussing different proposals of narratives we end up with an experience named "Discovering Barcelona!" structured in a learning flow with 4 phases (only phases 2 and 3 are mandatory). Notice that we relate some aspects of the narrative with facets of the 4SPPIces model that inspire them and that have been already presented in {Table 2:

1) Assigning Districts: The 34 potential students (P, *Number of participants*) are distributed into 6 groups of 5 or 6 people (PM, *Group characteristics*). Each group member is asked to answer individually a questionnaire about the different districts of Barcelona at home using their personal PC (S, *Location*). The objective is to define the students' profile with their initial knowledge from the city is and their main preferences with regard to one or other district (P, *Profile*). The information obtained from this questionnaire is used to assign the groups to a particular district associating them to an area that they do not already know, in order to maximize their potential learning, (P, *Profile dependent group formation*) as follows: when most of the group members fail the questions about a district, the group is assigned to this district. The groups in this phase are the groups for the following phase (I, *Events on PM-outcomes from phase to phase- and Events on P-groups in each phase-*).

2) Discovering the District: This phase is based on the learning flow Collaborative Learning Flow Pattern (henceforth CLFP) Guiding Questions (PM, *Learning Flow and Activities*) (Hernández-Leo, Asensio, Dimitriadis, & Villasclaras, 2010). The idea of this pattern is to provide the students with a list of questions that they should be capable of answering as they advance in the task. These questions are expected to help the student in focusing their attention on the important issues of the task. The questions are distributed and geo-located across 6 different districts in Barcelona forming 6 different routes: Sarrià, Gràcia, CiutatVella, SantMartí, Les Corts and l'Eixample (S, *6 mobile phones available = 6 districts*). This means that in the same phase there are 6 groups performing the exploratory activity simultaneously in 6 different spatial locations (P, students' *Location*). The students answer the questions along the route when arriving to the specific geo-located point. Each question has an associated feedback that guides the students to the next question and gives them hints about the urban and social characteristics of the area.

Also, the activity proposes to assign a role to each of the group members as a means to assure an appropriate task distribution, to foster the individual responsibility, mutual support and positive interdependence (Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010). The roles agreed with the teachers are:

- Mobile Phone Manager: in charge of wearing the device, read the questions to the rest of the group members and answer it according to the whole group opinions.
- Guide: in charge of guiding the rest of the group through the streets with a map created for the different districts.
- Photographer: in charge of taking representative pictures justifying all the aspects specified by the teacher and uploading them to a web application specially developed for the experience.
- Question Helper: in charge of taking notes of the ideas and comments related with each of the questions of the route.
- Observer: in charge of annotating the main aspects and comments related with the characteristics of the district specified by the teacher such as the morphology of the streets, the number of parks or the public services available.

3) Reflect about your district and learn about other districts: In this phase the students prepare a presentation about the district they visited. They can use the notes, observations and pictures taken during the route. Each group has to present their work in the classroom to the rest of the students and deliver it to the teacher two weeks after the exploratory activity. The outcomes from the previous phase are used here as an input for preparing the presentation (PM, *Data flow*).

4) Test your colleagues: Students can propose questions about their assigned district to their colleagues. Then, they can individually choose any of these questions and answer them as a self-assessment activity. Unfortunately, this phase, although was originally present in the scenario designed, was deleted in the last-minute because of time limitations (coincided with the Spanish official end of high school examinations). Therefore, no data about this phase have been considered for the case study evaluation.

Outcome 2: educational materials

The teachers also indicated as necessary to deliver some materials to the students for complementing the activity (which corresponds to the description of the activities in the PD). In particular they proposed to give the students the first day of the experience a dossier with the description of the different phases. In addition, each of the group members was delivered with a different template to fill in during the route according to his/her role in the group.

The teachers also suggested giving a map of the assigned area to the students to help them in following the route and to facilitate having a general overview of the district. For those districts with GPS coverage, the maps did not contain any information about the questions emplacement because the GPS served as a guide indicating where to answer the questions (Figure 4, bottom). In the contrary, those groups without GPS coverage had the questions indicated in the map (Figure 4, top). Using the GPS or not is justified in the next section of technological requirements.

{Figure 4 Maps delivered to the students during the visit. On the top, an example a map delivered to the students assigned to the areas without GPS coverage. On the bottom, an example of a map delivered to the students assigned to areas with GPS coverage.}

Meeting the technological requirements

Teachers gave feedback about both the technological environment and the materials via e-mail [e-mails] and revised the final version in the second meeting [Meetings]. The final version of the materials and technological environment presented in this subsection include the changes suggested by the teachers in the last meeting.

Table 3 shows the results from mapping the main characteristics of the CSCBL scenario narrative with the different factors and facets of 4SPPIces. This mapping allows understanding the relationships between the different factors and extracting the requirements of a technological environment for supporting students and teachers' tasks. Some of the aspects considered in 4SPPIces that are relevant on runtime are emphasized in the table with italics.

{Table 3 Technological requirements extracted from the mapping of the 4SPPIces model facets with the CSCBL scenario. P1, P2, P3 and P4 stands for each of the four phases. Letter S stands for those issues regarding the students and T for those related with the teacher. In Italics those aspects that affected on runtime.}

Grouping the needs detected from the analysis in Table 3, we end up with a list of Technological Requirements (**TR**) that our technological environment, together with the materials provided for the experience, must accomplish:

- **TR1.** To provide the mechanisms for facilitating the teachers and the students with an overview of the complete learning flow and the description of tasks for each phase. The PM factor structures the activity into an interrelated sequence of activities that should be distributed according to the aspects defined by the P factor (students' preferences, groups and location). The I factor highlights these dependencies between the PM and P factors. All this corresponds to 1, 2, 3, 13 partial requirements in {Table 3.

- **TR2.** To provide teachers with the tooling to monitor the students' position on runtime. The S factor shows that there are 7 spatial locations (home for the 1st, 3rd and 4th phases, classroom for the 4th and 6 different districts for the 2nd). For phase 2 students' devices are required to be mobile. Besides, the teacher should be aware of the students' actions occurring on 6 spatial locations simultaneously. The relationships between the P and S factors that will condition the CSCL are highlighted in the I factor. All this corresponds to partial requirements 2, 8, 9 10, 11, 12, 14 in {Table 3.
- **TR3.** To provide the facilities for grouping the students according to their previous knowledge about the city and distribute the activities accordingly. This corresponds to partial requirements 5, 6, 7 in {Table 3.
- **TR4**. To store the data flow connecting the different activities. The important aspects to be stored are defined by the data flow in the PM. This corresponds to partial requirements 6, 4 in {Table 3.
- **TR5**. To save the information about students' profile evolution (depending on the tasks they perform). This corresponds to partial requirements 6, 7, 13 in {Table 3.

Different technological solutions can be adopted. The only constraint is that any solution has to accomplish all the requirements in order to potentially support the proposed collaborative learning experience. In the following subsection we describe the technological environment defined for this experience as an example.

Outcome 3: collaborative technological environment

The technological environment is composed of four technologies/applications: a Moodle Platform (Dougiamas & others, 2004), Google Docs (Google, 2011), an application specially developed for the experience called QuesTInSitu (QuesTInSitu website) and the location-based system Mscape (Clayton et al., 2009; Stenton, 2007). Figure 5 shows a schema of the technological environment generated for the experience. {Table 4 summarizes the resulting CSCBL scenario with the technologies and material employed in each of the phases to complement the information in Table 3.

{Figure 5 Schema of the technological environment generated for supporting the students' and teachers' tasks during the enactment of the CSCBL scenario.}

{Table 4 Brief description of the different phases of the CSCBL scenario and the technology employed for their enactment.}

- **A Moodle platform for structuring the learning flow, manage the data flow and organize the groups of students:** The overview of the complete learning flow (TR1) is provided through a Moodle course[1] (Figure 6). Each phase is represented as a topic of the course. Both, students and teachers access the system with an individual credential. From this course students and teachers can also access other applications or functionalities developed as a support for a particular activity.

  The Moodle course is also used as a mechanism to manage the data flow connecting the different activities (TR4). The list of groups' assignments and a space to deliver the outcomes from the different phases is provided via Moodle. The Moodle course is also employed as the communication tool for the students and teachers to organize the activity learning flow. Other storage mechanisms associated to applications developed specially for the experience are employed. In the following, we detail the characteristics of these applications by emphasizing

[1] http://gti-learning.upf.edu/moodle/

these storage mechanisms.

The task assignments for the different groups are managed via the credentials facilitated to the different users for accessing the applications. Each student has his/her individual credentials to access to the Moodle course and a group credential to access to the rest of the applications. In this way, it is possible to store the activity of the students as individuals or as a group member and to manage the task assignments for the different groups (TR5).

{Figure 6 Moodle course developed to provide teachers and students with an overview of the learning flow. This course was used to centralize the access to the rest of the applications developed for the experience to support the different activities of the learning flow.}

- **QuesTInSitu and mobile devices:** To provide teachers with a mechanism following the students' activity on runtime in different spatial locations at the same time (TR2) we developed a system called QuestInSitu (QuesTInSitu, webpage). QuesTInSitu is a web-based application that enables the generation of questions compliant with the standard IMS Question & Test Interoperability and to associate them to a geographical coordinate with GoogleMaps (Google Maps, website). QuesTInSitu integrates the NewAPIS engine. Thanks to this engine, the questions are automatically corrected, scored and stored in a database of the application (i.e., who answered the questions and their scores). QuesTInSitu includes a functionality to create routes complemented with a monitoring system. Routes are sequences of geo-located questions created and organized by the user. The routes are visualized in a Google maps as a set of markers. The monitoring system provides information about the students' evolution of these routes at runtime. When a user answers a question the database of the system is updated and the marker associated to this question changes from green to red. The teachers can visualize the progress of the students along the route at runtime by looking at the red and green markers. Clicking on the markers, the teacher can also know who answered the question and the score.

  QuesTInSitu allows two types of mechanisms for answering the questions: (1) answering the questions online by accessing the application through a browser (Assessment in *virtual* situ) and (2) using a portable device to answer a question at the same geographical location to which the question is associated (Assessment in *real* situ). Since the exploratory activity requires different groups performing the activity simultaneously in different locations of the city, for this experience we used the second option. Both the assessment in *real* situ as well as the monitoring system are used in the *Discovering the District* phase. The students answer the questions with Samsung Omnia I and II mobile devices.

- **MScape**: Although QuesTInSitu enables relating a question to a geographical coordinate; the application does not integrate a module for detecting the actual position of the students at runtime. MScape application (Clayton et al., 2009) is employed to provide a more intuitive and integrated experience for the students. MScape is a mobile media platform for generating what is called a mediascape. Mediascapes are maps that associate a digital media file with a GPS position. These maps can be installed in GPS mobile devices or PDAs. The GPS device senses their position of the user and throws the media file associated to this geographical coordinate. Since some of the districts in Barcelona do not have good GPS coverage and the GPS devices do not work properly in these areas (Girardin & Blat, 2010), the Mscapes were used for the whole route only into two districts (Eixample and Les Corts) and in a part of the SantMartí route. For the rest of the districts the students were provided with a map indicating the location of the different questions.

- **Google Forms for the group formation:** The pre-questionnaire for identifying the students' knowledge about the districts and their previous knowledge (TR3) was created with the Google spreadsheets tool (Google Spreadsheets, website). This tool enables visualizing in a simple table the answers of the different students. With this information the teacher assigned each group to a district: Sarrià (5 students), SantMartí (6), CiutatVella (6), Gràcia (5), Eixample (6) and Les Corts (6).

Discussion from the design perspective

We go back to the information questions related with the design perspective of the case study to see how the data collected along the participatory design process ([e-mails], [meetings], [documentations]) and the outcomes obtained (scenario narrative, materials, technological environment) lead to findings framed in the two focuses of analysis.

First, the narrative of the CSCBL scenario proposes a combination of activities that enables comparing more than one district in Barcelona: 6 groups explore simultaneously a different district in Barcelona and prepare a presentation to show the information collected during the visit to the rest of their course colleagues. Second, the CSCBL scenario proposes a role distribution for the group activities as mechanism to promote each member to contribute with a different perspective about the district assigned by facilitating and fostering collaboration. Third, the CSCBL scenario proposed integrates ICT technologies as an essential means to structure the learning flow and guide the activity. Moreover, the combination of mobile devices with other computing tools becomes a necessary requisite to provide the teachers with a monitoring functionality to follow students' activity at runtime and for the students to answer the questions *in situ*. Finally, as the meetings and e-mails exchanged with the practitioners evidence, the learning objectives have been captured in each of the activities and materials designed.

The second focus of analysis intends to get evidences about whether the technological environment developed provides the functionalities required for supporting the tasks defined in the narrative of the CSCBL scenario. Although the enactment perspective will shed more light on this focus of study, the previous section explains in detail how the implemented technical environment satisfies, one by one, the technological requirements identified with 4SPPIces as a result of the participatory design process.

Enactment perspective: experience with students and teachers

As Zelkowitz & Wallace (1998) states, "experimentation is a crucial part of attribute evaluation and can help determine whether methods used in accordance with some theory during product development will result in software being as effective as necessary". Then, this section embraces the enactment of the CSCBL scenario with 2 teachers (one main teacher and one assistant) and 34 students (both interviewees in this perspective) with the aim of understanding whether it is effective into the real educational context it has been designed for. This section describes the Mixed Method methodology employed for analyzing this enactment, the information question that guided the analysis and the findings obtained.

Mixed Method

The enactment perspective of the case study involves an authentic learning situation, which includes many factors such as contextual issues, characteristics of students and educators, the achievement of the educational benefits, and the impact of software tools. Therefore, we use a Mixed Method evaluation combining quantitative and qualitative data gathering techniques. The quantitative data are useful for showing trends, and the qualitative data provide an in-depth understanding of the CSCBL scenario enactment. In particular, we use closed questions in the students and teachers questionnaires as quantitative sources and open questions in the students' and teachers questionnaires and observations taken by the researchers during the experience as qualitative sources. The concrete data sources used for the evaluation are explained in Table 5 and the original data employed for the evaluation can be accessed at: http://193.145.50.210:8080/DUCdata/ijCSCL-data/DiscoveringBCN.html. In the analysis of the qualitative data we use the "triangulation" method so as to achieve trustworthy findings (Gahan & Hannibal, 1998; Guba, 1981). This method consists in reinforcing each of the interpretations extracted through a comparative analysis of evidence provided from different sources. That is, to analyze each conclusion from a different perspective in order to have several confirmations supported by both qualitative and quantitative data. Even more, for increasing the validity of the findings, two researchers analyzed the qualitative information separately following a member checking approach for comparing and contrasting the main results (Guba & Lincoln, 1994).

{Table 5 Data sources used for the evaluation of the experience with teachers and students and labels used in the text to quote them.}

Following a Mixed Method evaluation approach requires defining a scheme of categories according to the specific objectives of the experience. Aliened with the main aim, we define two different focuses for the evaluation that are related with the two propositions and will help on defining the scheme of categories. We formulate for each focus a set of associated information questions to guide and be more concrete on the evaluation process of the CSCBL enactment.

- The **first focus relates to the innovation and added value of the CSCBL scenario enactment**; i.e. whether the CSCBL scenario enactment solves the limitations of the previous practices covering the main learning objectives highlighted by the teacher and adding value to similar experiences. Four different questions arise from this evaluation focus: (1) Which is the added value of the CSCBL scenario in terms of learning benefits related with the course contents, collaborative practices and motivational aspects? (2) Does the mixture of formal and informal activities promote students reflection about the contents worked in class? (3) Which is the added value in terms of learning benefits offered by the use of technology in this experience compared with non-technology enhanced experiences? (4) Is the activity innovative with respect to previous editions and which are the aspects that make it innovative?
- The **second focus relates to the capabilities of the collaborative technological environment designed as well as the activities proposed for supporting the students' and teachers' tasks during the CSCBL scenario enactment**. This focus regards to the appropriateness of the combination of technologies and the suitability of the learning activities proposed for supporting teachers' and students' tasks during the collaborative scenario enactment. The strengths and limitations experimented by both, teachers and students, during the enactment are also considered in this point for further improvements. The questions that guide the evaluation are: (1) Is the combination of the technologies proposed appropriate for supporting teachers' and students' tasks during the enactment? (2) Are the role task distribution and district assignments policies satisfactory for learners and teachers? and (3) Which are the successful aspects, limitations and suggested improvements of the technological collaborative environment?

The results of this perspective will show the effectiveness of the CSCBL scenario when enacted into a real context in terms of educational outcomes and of the support provided to students and teachers during the enactment. The findings obtained are evidences that complement the conclusions of the design perspective towards supporting the two research propositions. The two following subsections details the findings and the data supporting them.

Findings from the enactment evaluation

In order to facilitate the readability of the findings of the enactment perspective we present them organized according with the two focus of study abovementioned.

Focus I: Innovation and added value of the CSCBL scenario

The findings of the first focus of study as well as the partial results that support them are summarized in {Table 6.

{Table 6 Summary of findings and partial results related with the focus I}.

The **first finding** (1 in {Table 6) evidences that the *Discovering the district* activity included in the **CSCBL scenario *copes successfully with the limitations detected by the teachers in previous editions of the experience and entails new learning benefits***. On one hand, observations and comments of the students after the exploratory experience show that the experience ***promotes students' autonomy and active learning***. Teachers stress the autonomy of the students during the experience: "*I found very interesting performing a guided activity across an urban space in which the students are autonomous. (...)*" [Q-t-route] and the notes taken by the researchers show that students appreciate having an active role [Observations]. On the other hand, students' and teachers' comments at the end of the experience suggest that ***the usage of mobile phones and GPS is perceived as an opportunity to practice and enhance technological and orientations skills not commonly worked in the traditional activities*** [Q-st-route, Q-t-route, respectively]. For example, the main teacher says: "*Working with mobile devices allows arriving to another learning objectives such as how to locate themselves in a city, research or a more personal observation of the environment*" [Q-t-route]. Teachers and students also agree with the idea that using ***mobile phones and automatic assessment functionalities helps on focusing the attention to the environment and on better retaining and reflecting about the contents***. As one teacher affirms: *"Students can observe the elements on the urban environment: streets, buildings, services, noises of the city…"* [Q-t-route], while students comment: "*I think that (I learn more with mobile phones) because you answer the questions in situ and, on the street, you realize better the important things than when you are doing an exam*" [Q-st-route], "*I liked knowing my mark (when answering the question) because then you can know if you are paying enough attention to your environment"* [Q-st-route]. Also, the observations of an expert about the teachers' comments at the end of the activity evidence the reflective added value of the activity: "*The teacher thinks that students have learnt urban information in this activity and that, in an exam they will just 'vomit' all what they know. However, going to the particular locations and think about the place, make them reflect about what they learn*" [Observations]. Finally, teachers also highlight that the activity, compared with previous experiences, ***enables learning about different areas of the city with new important benefits***. One teacher comments the added values of the experience: *"Using these tools – ICT - in an urban environment and having the possibility of learning about more districts of the city"* [Observations]. Other quantitative results support the abovementioned added values of the experience. 28/34 (82%) students, when asked after the exploratory environment whether they learn more using the mobile *in situ* than filling a dossier or doing an exam answered that with the mobiles. Only 4/34 (12%) says that using a dossier could be also beneficial. The rest (2/34, 6%) do not answer the question. Finally, 33/34 (97%) of the students indicated after the whole experience that the activity helped them to learn new concepts about the districts. Moreover, 23/34 students (68%) value their feeling of learning with 4 points over 5 in a likert scale from 1 to 5.

The **second finding** (2 in {Table 6) shows that **structured group activities integrated into the CSCBL scenario promote the collaboration and cooperation between students by enhancing teamwork skills.** Different partial results support this finding. Comments from the students and observations by experts suggest that the activity ***promotes students discussions***. A student states *"Yes (I liked the role distribution), because we could contrast ideas and it has been funny"* [Q-st-route] while another value the fact of courting with "*different options and criteria"* [Q-st-route]. Other students' comments and reflections suggest that ***the CSCBL scenario promotes students' communicative and social skills***. One student reflect about the advantages that working in groups suppose for taking decisions and arriving to an agreement: *"With Rubén, we were in charge of taking pictures and guide the group through the neighborhood. I think that it is a good idea to have a leader for each task because, in case the group does not agree with something, this person is the one making the last decision"* [Q-st-route]. Besides, the notes taken by the observers during the route show that an exploratory activity based on questions made the students work in groups to find out the appropriate answer: *"(...) Students are not sure about whether the street grid is regular or irregular. They discuss about it: 'They are big and regular, we have been walking through very wide streets'. Another student is not very sure about that. They look at the map to see whether the street grid is regular. Finally they agree about the answer, select it and it is correct!"*[Observations]. Finally, students' answers support another partial result indicating that the ***scenario enhances cooperation between group members***. Some students explicitly appreciate the role distribution as a mechanism to make all group members feel that all are participating and cooperating and are conscious of the positive interdependence among group members that this generates."*I think it is good to have a role because it allows you to pay more attention to your task, although it is always complemented with the rest of the group members"* [Q-st-final], says one student. *"To have a role makes one to feel usefulness"* [Q-st-final], says another one. In the final questionnaire, a student comments: *"I think that it was a very good idea that every group member had a role because it is a good way of distributing the work in a coordinated way"* [Q-st-final]. Finally, the video presentations evidence that all group members contribute in the group tasks because everyone presents [Video-presentation] and that students value this work group: *"Students comment that the activity enhanced cooperation between group members and relate this with the role distribution policy (if one fails, everybody in the group fails)"* [Observations].

The **third finding** (3 in {Table 6) indicates that the CSCBL **scenario is a motivational and innovative activity for students and teachers compared with previous experiences**. On the one hand, students punctuated with high ratings the *Discovering Barcelona* phase: 24/34 (71%) of the students qualified it with 4 over 5 and 10/34 (29%) with 5 over 5. Also, 34/34 (100%) of the students and the two teachers would repeat the activity on another course for learning about another district [Q-st-route, Q-t-route]. In a question asking about the experience as a whole, 31/31 students (3 students did not attended to the class that day) say that they prefer this activity compared with similar ones [Q-st-final]. Student's comments about the exploratory activity support this result: *"I liked the activity because it is an activity very different from the rest (of the activities out of the classroom)"* [Q-st-route] or *"The experience changed the way in which we are used to do school trips"* [Q-st-route]. When referring to the whole experience they say: *"It (the experience) has been more interesting than the 'typical museum visit' and it has been funnier"* [Q-st-final]. Besides, students use positive adjectives such as different, interactive, funny, dynamic and interesting for describing the activity. For example, when asking to the students whether they prefer this activity compared with similar experiences their comments are: *"I think that these types of activities are a different and an original way of what we normally do. It is more dynamic"* [Q-st-final] or "*Yes. This activity is better and funnier compared to other activities (such as going to a museum). Moreover, this activity allows us to work in groups in a very funny way"* [Q-st-final]. Finally, a last finding indicates that students perceived the CSCBL scenario as an innovative experience compared with previous similar ones also because of the use of technology and, in particular, mobile phones. Both, *students and teachers, see the use of ICT as one of the aspects that make the experience innovative and different from others*. Students see that working with mobile and GPS is an original and motivating experience and stress the fact that it is not common to use technological devices in educational activities. Some students comment: *"What I've preferred the most is to carry the GPS device... It's been very dynamic. It has been an original activity, different to what we are used to. A way of guidance"* [Q-st-final] or *"What I liked the most is to work in groups using the new technologies"* [Q-st-final]. On the other side, teachers also say that they had never imagined an activity like that and consider that *"(...) using the new technology is an step forward (compared with other activities)"* [Q-t-final].

Finally, the **fourth finding** (4 in {Table 6) shows that the ***integration of the exploratory activity with the presentation task into the same learning setting promotes students' reflection about the contents studied in class and in other courses***. The teachers also see this blend of activities as ***a condition necessary to provide a complete evaluation of the activity***. Different partial results support this finding. On the one hand, observations by experts show how students, during the route, made references to concepts and topics worked in class: *"Some of the students know things about the area and they explained them to the rest of the students during the visit ''this is a xamfrà[2]"* [Observations]. Students also reflected about concepts worked in other courses. For example, one of the experts observed how shocked the students were when they realized the actual characteristics of a square that is used as a title in one of the most famous books of the Catalan literature: *"When students arrive to the Plaça del Diamant students are shocked because of the sobriety of the square. They expected a flashier square since it is famous because of a book of the Catalan author Mercè Rodoreda"* [Observations]. Students explicitly comments on this issue when highlighting the aspects learnt during the activity: "*It has been useful for learning how to apply the contents worked in class"* [Q-st-route]. On the other hand, observations taken during the students' presentations and comments by the teachers show the importance of integrating exploratory with more reflective activities into the same learning setting. Moreover, the observations taken from the videos of the presentations and their contents show that the students used multiple sources of information to complement their explorative experience [Presentations, Videos-presentation]. Finally, teachers stress the idea that the visit and the presentation activities are complementary [Observations] and a good mechanism to *"apply in a concrete way the contents explained in class"* [Q-t-route]. Therefore, all these partial results show how both, teachers and students, perceive the different phases of the activities as a unique learning setting.

Focus II: Findings evidencing the CSCBL script as a mechanism for supporting and facilitating the orchestration of CSCBL scenarios

The findings of the second focus of study as well as the partial results that support them are summarized in {Table 7.

{Table 7 Summary of findings and partial results related with the focus II.}

The **first finding** (1 in {Table 7) shows that ***the mobile and GPS devices combined with the monitoring functionalities included in QuesTInSitu and complemented with a Moodle platform are a good support for teachers to control the groups' progress during the whole experience, especially during the Discovering Barcelona phase.*** One of the most complex orchestration tasks is the

[2] "**Xamfrà"** is a Catalan term used to describe an architectonic element introduced by the Catalan architect Cerdà. It refers to the cut vertex of a square that was employed to enhance the visibility of the drivers on the streets of the Eixample in Barcelona.

exploratory phase. In this activity, teachers have to control the activity of 6 different groups in 6 different spatial locations simultaneously. The notes taken observing the teachers during this particular phase as well as the comments indicate that ***the technology designed reduce the orchestration efforts***. Teachers could easily and successfully follow what the students were doing *on runtime* while discussing about the answers given by the different groups [Observations]. Moreover, when teachers are asked after the exploratory activity regarding their preferred functionality they both selected the *Monitoring* [Q-t-route]. Their comments explain this tendency: *"I found very interesting (the monitoring system) because it enables seeing how the activity evolves and, at the same time, it enhances the autonomy of the students"* [Q-t-route], says one of the teachers, *"I'm interested in the route evolution and in the development of the programmed itineraries around the neighbourhoods"* [Q-t-route], mention the other. Both teachers also valued the intuitiveness of this functionality with the highest mark (5 in a scale from 1 to 5). At the end of the exploratory activity, when teachers are asked about how they perceived the whole technological environment developed in relation with the functionalities provided and the organizational and management benefits that they carry, one of them answers: "*I think that all that you have designed is correct: applications, servers, webs… practical, functional, organized, clear, easy and comprehensive"* [Q-t-route].

The **second finding** (2 in {Table 7) evidences that ***the mobile devices completed with a map as well as the questions feedback are a successful mechanism to organize, structure, support and guide the student's actions during the exploratory tasks***. Notes by the experts during the exploration activity show that all groups used the feedback messages from the mobile and the map as a guide to find the different locations on the route: *"(The students) answer correctly the question and continue the activity following the indications from the feedback"* [Observations]. Teachers also liked *"The way in which the questions were structured with the mobile devices"* [Q-t-final]. However, from the comments of the students we see that there are some differences on the students' perception about the guidance level depending on whether they used the GPS or not. Concretely, from the comments of the 10 students' that performed the activity with GPS (groups Eixample and Les Corts) we infer that they felt well-guided during the route. The students' answers [Q-st-final_GPS] corroborate this statement: *"Yes. I found using the GPS useful and comfortable. Moreover, the device tells you the answer to the question immediately after answering it and guides you through the way towards the next one"* or *"Yes. It is (found using the mobile devices) useful because everything is guided and structured easily. Once you understand the messages, the feedback is very easy!"*. Moreover, 6 of them answer (4 do not answered this question) that they could have performed the activity without a map. On the contrary, the comments from those that did not used the GPS during the exploratory activity (groups Gràcia, Sarria and CiutatVella) show that they had difficulties on finding some locations of the route and would find useful to use the GPS: *"I think that the GPS would have been useful because sometimes, when answering the questions and listening to the clues for the next question we were confused because we were not correctly located"* [Q-st-final_NoGPS]. Furthermore, when the 6 students that employed the GPS during half of the route (group Sant Martí) were asked to compare the two situations they remarked that they prefer using the GPS because it is faster, easier and practical. Students' comments support this partial result: *"Yes. I found easier using the mobile phones to walk around the indicated streets. It was harder when we did not have connectivity and we had to find the way only with the map"* [Q-st-final_GPS].

For the *Discovering the district!* phase, different roles were assigned to each of the group members. The **third finding** (3 in {Table 7) ***suggests that using a role distribution for orchestrating the exploratory is perceived by teachers and students as a successful mechanism to structure collaboration with good learning benefits.*** Also***, the students feel comfortable with the pre-test policy employed for assigning the groups to a district***. First, students consider that playing a particular role, they could concentrate more on one their tasks and, consequently, perform them better: *"I think that it is a good idea to distribute roles because each person can be concentrated in what s/he has to* *do and s/he does it better"* [Q-st-final]. Second, students also see the role assignment good for assuring an active participation from all group members (individual accountability)*: "I think that the role distribution is good because everyone participates in the activity"* [Q-st-final]. And third, both, students and teachers agree with the idea that the role distribution helped on structuring and organizing the activity making it more dynamic. One student highlights: *"I believe that performing a role distribution is good because it helps on organizing the activity and making the visit easier"* [Q-st-final]. Whereas another student mentions: *"I think that distributing roles is a good mechanism to have everything more organized. In that way, everybody does their part and afterwards, everything is merged"* [Q-st-final]. Moreover, although the role distribution was performed randomly the same day of the task, students felt comfortable with this mechanism [Observations]. Students also felt happy with the pre-test policy employed to assign the groups to the different districts [Q-st-route].

Finally, the **fourth finding** (4 in {Table 7) evidences that the technology employed in the CSCBL scenario was usable and appropriate for the experience for both students and teachers. The quantitative results of the [Q-st-route] indicate that 32/34 (94%) *answered that they preferred the mobile* when they were asked to choose about using mobile phones, filling a dossier or doing an exam in class. Only 2/34 (6%) students indicated that they preferred a dossier. When justifying their answers, most of the students comment that *mobile phones allow them to be directly in contact with the environment*, which makes it *easier* to answer the questions and to *pay attention to the details*. One student states that when using mobile phones *"you see the buildings directly and you can answer better. If you answer later in a dossier or in an exam you cannot remember everything"* [Q-st-route]. Students successfully and easily managed the QuesTInSitu application (33/34, one student forgot to answer this question, answer that this application was easy-to-use). However, some problems were detected with the GPS. One student comments the GPS failed in particular points of the route with lower coverage: *"The GPS device didn't work in all the streets"* [Q-st-route]. Nevertheless, observations evidence that students didn't have any problem resetting the device and launching again the application in case of error *"The GPS fails again and the students go directly to the next question. I seems that they are already familiar with the procedure and the use of the device"* [Observations]. Teachers also suggest improving the monitoring functionality by adding an audiovisual module to see the students' actions on *runtime*: *"It would be very interesting, if it's possible, to see a video of the students while they are performing the activity to follow them audio-visually"* [Q-t-route].

Discussion form the enactment perspective

Similarly as with the design perspective, we go back to the information questions related with the enactment perspective and summarize the obtained findings according to the two focuses of analysis.

On the one hand, 4 different findings evidence that the CSCBL scenario enactment is innovative and adds value to previous practices. First, the "anywhere" capabilities of mobile devices have proved to be a good mechanism for extending the previous editions of the activity involving the visit of new areas of the city. Partial results show that students get familiar with the urbanism and socio-geographical characteristic in a direct exploration of one city district and with other 5 areas through the presentations of their classmates. Second, the combination of formal and informal activities in structured work teams promotes students to think and reflect about what they discovered during the route and helps teachers on having a complete overview of the concepts acquired during this experience. Third, using technology also implies an improvement of the students learning experiences by supporting a more active and personalized participation in the activity. Finally, results evidence that the innovative use of technology in this context has also a direct and positive impact on students' perception of learning.

On the other hand, 3 findings evidence that the combination of technologies and the suitability of the learning activities proposed successfully support teachers and students tasks in the CSCBL scenario enactment. First, mobile and GPS devices with the monitoring functionalities of QuesTInSitu, specifically developed for the experience, are a good support for the teachers to follow and control the progress of the students during the whole activity and, in particular, during the exploratory phase. Second, findings indicate that these technologies complemented with the maps and educational materials designed (including the questions and associated feedbacks) are a good mechanism to organize, structure and guide the students in the exploratory experience. Third, the district assignment policies as well as the role-distribution proposed for the exploration are perceived as successful means for structuring and facilitating collaboration among group members. Forth, both teachers and students find the technology employed usable and appropriate for the experience although some aspects could be improved.

Cross-perspective analysis

Previous sections present the findings obtained from the two different perspectives of analysis of the case study: design and enactment. This section undertakes the cross-analysis of both perspectives with the purpose of supporting or refuting the research propositions derived from the main research question stated in the introduction: (1) **that 4SPPIces supports communication among practitioners and technicians when addressing the design of a meaningful CSCBL scenario and its associated technological environment** and (2) **that the CSCBL scenario and the technological environment designed with 4SPPIces, when enacted in the real educational context, effectively support students' and teachers' tasks leading with the expected learning objectives.**

{Table 8 summarizes the outcomes and findings obtained from the design and enactment perspectives of the case study and show how they relate with the two propositions.

{Table 8 Cross-analysis perspective summary. P1 stands for Proposition 1. P2 stands for Proposition 2.}

Regarding the first proposition, the **case study shows that 4SPPIces is useful as a support for designing a meaningful and innovative CSCBL scenario with its associated technological support by extending an already existing practice in the context of a Geography course at a high school**. On the one hand, outcomes from the **design perspective** depicts how using 4SPPIces enabled organizing the information and educational requirements facilitated by the teachers and on supporting technicians in showing the possibilities offered by ICT and mobile devices for creating an innovative experience adapted to the educational needs of their particular context. The structure in phases of the scenario as well as the technology for their support was inspired mainly by the *Space* and *Pedagogical method* factors. The different district areas were represented through the Space factor, whereas the evolution of the exploratory activity guided through questions and the reflective phase was a matter of the Pedagogical Method. The result of the collaborative design with the teachers is (1) a narrative of a CSCBL scenario that deals with the limitations of previous practices combining formal and informal technology-enhanced collaborative activities across different districts, (2) a set of educational materials that capture the main aspects of teachers' learning objectives and (3) a technological environment supporting the students' and teachers' tasks defined in the CSCBL narrative (D1 and D2 in Table 8).

On the other hand, the findings from the **CSCBL scenario enactment** evidence the learning benefits that the experience entails at different levels. First, all the learning objectives regarding the contents of the course imposed by the teachers are covered. Students learnt about the urbanism and geo-sociological characteristics of the different districts (E-I.1 in Table 8). Second, the way in which the activity is orchestrated provides new educational benefits related with the collaborative nature (E-I.2 in

Table 8). The combination of an explorative-type structured work activity with a final presentation in class promoted the active participation of all group members making them discuss, argue and think critically by enhancing collaborative and communicative skills (E-I.4 and E-II.3 in Table 8). Also, technologies (and mobile devices in particular) were perceived as easy to use and as an innovative and appropriate element that enabled the students, while learning about the different districts in Barcelona, to practice their technological and orientation skills (E-II.4 in Table 8). Moreover, findings also show that using technology made the experience more dynamic, original and funny for the students, which had a direct impact on their motivation and, therefore, on their knowledge acquisition (E-I.3 in Table 8). Finally, both, teachers and students perceived the combination activities as a unique learning setting, suggesting that the integration of the different phases was successfully achieved (E-I.4 in Table 8).

With regard to the **second proposition, the results show that the enactment of the CSCBL scenario assists students in achieving the learning objectives and that the students' and teachers' tasks were successfully supported by the technological environment developed**. The **participatory design** process with practitioners served for defining the educational needs and for understanding the limitations from previous practices. This information was employed to key out how these limitations could be tackled and on identifying the technological requirements needed for supporting the students' and teachers tasks defined in the CSCBL scenario narrative. First, related with the PM factor, the Moodle platform provided an overview of the complete learning flow with the description of the different phases and activities. Second, the monitoring functionality was proposed as a mechanism for leading with the requirement related with the Space factor model, which made explicit the 6 districts involved in the experience. And third, the databases of the Moodle and QuesTInSitu applications provide the needed technological infrastructure to store all the information about the different phases of the activity and for establishing the relationships between each phase (*hIstory* factor) (D3 and E-I.1 in Table 8). The outcomes of the **CSCBL scenario enactment** show that the combination of technologies is useful to support teachers' organization and management of the experience (D3 in Table 8). On the one hand, the relations between the Pedagogical method and the hIstory factors help on defining the successful for the group distributions and the management role-assignments (*Participants* factor) (E-II.3 in Table 8). On the other hand, even those activities such as the exploration of the city, which required a complex management *at runtime,* were carried out successfully (E-II.1 and E-II.2 in Table 8). Finally, the technological environment complemented with other materials such as (maps, guides…) helped in organizing, structuring, supporting and guiding students' actions (E-II.1, E-II.2, E-I.4 in Table 8). Then, we can affirm that 4SPPIces helped on identifying the main requirements of a technological environment to support the enactment of a CSCBL scenario by hindering the teachers the complexity that the orchestration of these experiences entails. Nevertheless, the results also indicate that functionalities such as the monitoring could be improved by adding an audiovisual system to communicate with the students on runtime.

Conclusions and future work

The main research question that motivated this work was whether 4SPPIces is a useful model to support practitioners and technicians when addressing the design of a meaningful CSCBL scenario as a solution for extending an actual activity of geography and solving its limitations. To tackle this question, we formulate two related research questions. These research questions, translated into propositions, are evaluated through an instrumental case study. The case study analyzes the role of 4SPPIces in an implementation process of a CSCBL scenario from two perspectives: design and enactment. These two perspectives enable a deep understanding of the research question, although the enactment is not explicitly considered in the formulation of the question. The cross-analysis of the findings resulting from each perspective supports the two propositions. Then, since these propositions are directly derived from the research questions, these findings lead us to answer affirmatively the main research question. On the one hand, results revealed that 4SPPIces helped on the design of a CSCBL scenario and on extracting the requirements of an associated technological environment for its support. On the other hand, the findings show that the CSCBL scenario was successfully enacted covering the needs associated with the particular experience and the concrete learning objectives that it pursues.

In conclusion, we can state that, in the context of this case study, 4SPPIces has been a useful model to design a meaningful CSCBL scenario in collaboration with practitioners that successfully extends an actual geography activity. The findings presented in this paper are the result of an extensive work of data analysis combining quantitative and qualitative sources. They show how 4SPPIces can be employed for transforming an actual activity by generating an innovative collaborative learning scenario in the blend, keeping the balance between technology and education.

4SPPIces is being applied to other cases in order to obtained findings framed in different contexts. In particular, two other CSCBL scenarios have been generated. One has been already carried out and evaluated (Pérez-Sanagustín et al., submitted) while the other, based on a preliminary proof-of concept (de-la-Fuente-Valentín et al., 2010), is still under analysis. We are also comparing the results of these case studies towards a cross-case analysis, shaped as a multicase study, in order to achieve contrasted evidences about the usefulness of the model. Finally, with the aim of guiding the design of CSCBL scenarios and facilitate the computer-supported collaboration between practitioners we are currently developing a web-based application based on 4SPPIces.

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Table 3 Technological requirements extracted from the mapping of the 4SPPIces model facets with the CSCBL scenario**. P1, P2, P3** and **P4** stands for each of the four phases. Letter **S** stands for those issues regarding the students and **T** for those related with the teacher. In Italics those aspects that affected on runtime.

Facets	**Description of the facets**				**Requirements**
			Pedagogical Method		
Learning flow	**P1. Assigning Districts**	**P2. Discovering the district**	**P3. Reflect about your district**	**P4. Test your colleagues**	1. To organize the sequence of phases
Activity/ies	**S:** Pre-web-questionnaire about Barcelona **T:** Check questionnaire answers	**S: (1)**Visiting thedistrict, answering the questionnaires and taking notes and pictures (Mandatory) **(2)** Uploading the pictures to QuestInSitu (Mandatory) **T:**Monitoring the visit	**S:(1)**Preparing a presentation (Mandatory). **(2)**Performing the presentation (Mandatory) **T:**Downloading and evaluating presentations	**S: (1)**Adding questions in QuesTInSitu (Optional). **(2)**Answering proposed questions (Optional) **T:** Checking students contributions	2. To organize students groups, roles assignments and activity distribution
Group Charact.	Individual	**6 Groups** of 5 to 6 people	Equal than in phase 2	Individual	3. To distribute the activities according to the groups.
Data flow	Outcomes from Pre-questionnaire [Quest1-PreRoute.doc]	- Students' deliverables according to their roles - Questions marks - Pictures	Presentations delivered	Questions generated	4. To store the data generated from phase to phase
			Participants		
Number participants	Potential participants: 34 *Actual participants: 19* *It affects the group distribution.	Potential students: 34 *Actual students: 34* * It does not affect the activity enactment	Potential students: 34 *Actual participants: 34* * It does not affect the activity enactment	Potential students: 34 *Actual participants: ?* *It does not affect the activity enactment	5. To provide the mechanisms for flexibly managing last-minute changes in groups.
Profile	- Students Name& Group - District Pre-knowledge - Group preferences - Teachers' suggestions	*The profile of the students is updated depending on the role assigned in this phase*	-	-	6. To save the information about the students' profile
Profile-dependent group	Students grouped by their preferences and district pre-	-	-	-	7. To group students according to their preferences and assign them to a district

Profile-dependent group formation	Students grouped by their preferences and district pre-knowledge	-		-	-	7. To group students according to their preferences and assign them to a district
Location	Students' Home	Assigned district		Home and Classroom	Students' Home	8. To provide mechanisms for monitoring students at each phase
				Space		
Elements	PC or Device with Internet access	Portable device with Internet access	Device with Internet access	Projector & PC - Internet access	PC or Device with Internet access	9. To understand which of the devices available best fits with the needs of each phase.
Arrangement	Students' home	Students' location (distributed into 6 districts)	Teachers' location	Classroom	Students' home	10. To support the arrangement in each phase.
Affordance	Individual	Collective	Collective/ Individual	Collective	Individual	11. To support the affordance associated to each phase
Mobility	Fixed or Portable	Portable	Fixed/ Portable	Fixed or Portable	Fixed or Portable	12. To support the portability requirements associated to each phase
				hIstory		
Events PM	Missing pre-questionnairedata	-		-	-	13. *Preferences of students that do not answer the pre-questionnaire are not considered*
Events P	Save students' preferences to define groups	Register the groups' locations during the visit		-	-	14. To be aware of the students' location on runtime

Table 4 Brief description of the different phases of the CSCBL scenario and the technology employed for their enactment.

	Brief Description of the phase	Technologies and Materials employed for the enactment
P1. Assigning Districts	Students answer individually a pre-questionnaire about Barcelona districts. According to the responses, the teacher assigns the different groups to a district.	- Moodle platform for a complete overview of all the phases in the learning flow. - Google Forms for the pre-questionnaire and organization of the students in groups.
P2. Discovering the district	Groups of students perform a visit of its assigned district guided by a set of questions that they answer through a QuesTInSitu application on their mobile phones. Each of the group members plays a different role in the activity. Teachers monitor the activity through a QuesTInSitu functionality.	- QuesTInSitu applications for students and teachers. - Paper-templates for the roles and tasks distribution. - Cameras for taking pictures during the visit.
P3. Reflect about your district and learn about the other districts	Students prepare a presentation about their district using the information from the visit and the main aspects worked in class.The presentation is delivered to the teacher via Moodle and presented in class to the rest of the class.	- QuestInSitu to extract the information about the route. - Moodle for delivering the presentations - Projector as a media display device for the presentations.
P4. Test your colleagues	Students can create their own questions about their districts and answer the questions created by their colleagues.	- QuestInSitu to create and answer the questions online.

Table 5 Data sources used for the evaluation of the experience with teachers and students and labels used in the text to quote them.

Data source	Type of data	Labels
Students' questionnaire about the exploratory phase *Discovering the district*	Qualitative numeric data, comments and opinions	[Q-st-route] (st, students)
Students' questionnaire about the whole experience (exploratory phase *Discovering the district* + presentations of the districts in phase *Reflect about you district*)	Qualitative numeric data, comments and opinions	[Q-st-final]
Teachers' questionnaire about the use of the QuesTInSitu application during the exploratory phase *Discovering the District*	Qualitative numeric data, comments and opinions	[Q-t-route] (t, teachers)
Teachers' questionnaire about the whole experience (exploratory phase + presentations of the districts)	Qualitative numeric data, comments and opinions	[Q-t-final]
Observations from 8 researchers external to the case of study about students' and teachers' behaviour during exploratory phase and during the presentations	Record of direct observations of student's behaviour during the route Record of direct observations of teachers' behaviour during the route Notes about students' opinion about the route and presentations	[Observations]
Videos of the students performing exploratory phase	Notes and observations transcribed from the videos	[Videos-route]
Videos of the students performing the presentations	Notes and observations transcribed from the videos	[Videos-presentation]
Presentations	Notes and observations obtained from the analysis of students' presentations	[Presentations]

Focus I. Added value and innovation of CSCBL scenario		
Findings	**Partial results**	**Support data**
1. The CSCBL scenario copes successfully with the limitations detected by the teachers in previous editions of the experience and entails new learning benefits.	- Students stress as the learning benefits of the *Visit the District* phase: 1) their freedom and active participation, 2) the dynamism of the activity, 3) learning about how to use a GPS, 4) the possibility of answering the questions in situ, which facilitates paying attention to the environment and better retaining the details of the contents 5) orientation skills acquisition, 6) learning and discovering new location, sociological characteristics, history and infrastructures o *33/34 (97%) of the students indicated after the exploratory phase that they learnt new concepts about the districts* o *28/34 (82%) of the students answered that they learnt more using the mobile in situ for answering the questions than filling in a dossier or doing an exam in class. 4/34 (12%) students indicated that they would have learnt more answering the questions in a dossier. 2/34 (6%) students did not answer this question* o *6/34 (18%) students valued in a likert scale that their feeling of learning after doing the experience was 3/5 points. 23/34 (68%) students valued their learning experience with 4/5 points. 2/34 (6%) students valued with 5/5 points. 3/34 (8%) students did not answer the question* -Teachers point out that the exploratory phase: 1) reinforces students' autonomy, 2) allows students practice their spatial orientation and 3) helps students in the exploration and understanding of the urban space and its elements. -Teachers point out that the exploratory technology-enhanced activity (integrated as part of a learning flow through the CSCBL scenario) allows learning about more districts of the city compared with previous experiences. - The mobile phones with the automatic assessment feedback system helps students on being directly in contact with the environment, focussing the attention on the services and buildings in the area and reflecting about it.	Observations during the exploratory phase, presentations contents, students' and teachers' questionnaires about the exploratory phase and students' questionnaire about the whole experience, video presentations
2. Structured group activities integrated into the CSCBL scenario promote the collaboration and cooperation between students and developing teamwork skills.	-Working in groups with a determined role-distribution supports students' interaction by promoting discussions (critical thinking), facilitating decision making processes (communicative skills) and enhancing cooperation between group members. - Organizing the exploratory phase through a sequence of questions promotes debates that make students' reflect and look for agreements (reflective and explorative learning). -Working directly in contact with the environment enhances student's interactions with people in the city making them to practice their communicative and social skills in situations they are not used to. - All students intervened in the presentations.	Observations during the exploratory phase, presentations contents, students' questionnaires about the exploratory phase and about the whole experience, video presentations
3. Students' comments and observations evidence the CSCBL scenario as a motivating and innovative experience compared with similar ones.	- Students use adjectives as innovative, different, interactive, dynamic, interesting and funny for describing the experience. o *24/34 (71 %) students punctuated the exploratory experience with 4/5 points and 10/34 (29 %) students with 5/5 points* o *All students (34/34 – 100%) and the two teachers indicated that they would repeat the activity another year for learning about a different district* o *31 students (out of 31) answer that they prefer these types of experiences in front of other similar experiences.* - Students enjoyed working in groups and highlight this as one of the most positive aspects of the experience. - Students and teachers see the use of ICT as one of the innovative aspects compared with previous experiences.	Students' questionnaires about the exploratory phase and the whole activity, teachers questionnaires about exploratory phase
4. To combine exploratory activities with the presentation work into an integrated	- Observations by experts and students highlight that they apply the contents worked in class during the exploratory phase. -Teachers stress that the exploratory-type of activities facilitate analyzing on the direct physical environments some of the course contents complementing what have been worked in class.	Observations during the exploratory and presentations phase, presentations contents, students'

learning setting promotes students' reflection about concepts acquired in class and in other courses. Teachers also consider this integration necessary to provide a complete evaluation of the activity.	-Teachers see the exploratory and the presentation phases complementary, which, integrated into the same learning setting, enable a complete evaluation of the students' outcomes. -Students complement the concepts worked during the exploratory phase with other information sources and the topics worked in class.	and teachers' questionnaires about the exploratory and about the whole experience

Table 6 Summary of findings and partial results related with the focus I.

Focus II. Technological environment as a mechanism for supporting and facilitating students and teachers tasks during the CSCBL scenario enactment		
Findings	**Partial results**	**Support data**
1. The mobile and GPS devices combined with the monitoring functionalities included in QuesTInSitu and the Moodle platform are perceived by the teachers as an easy and good support for controlling progress of the groups' activity during the whole activity and, in particular, during the exploratory phase.	-The teachers successfully followed at *runtime* the students' activity and their answers during the exploratory phase, which enable them to discuss about student's progress. -Teachers qualify the monitoring functionality as one of the best functionalities provided by the QuestInSitu application and define it as very intuitive. - Teachers value the level of intuitiveness of the monitoring functionality with the higher mark (5 over 5). - Teachers value positively the whole tooling employed during the experience (Moodle, QuestInSitu and GPS Mobile Devices) and describe it as practical, functional, easy to understand, organized and clear.	Observations during the exploratory phase and teachers questionnaire about the exploratory phase
2. Mobile devices complemented with a map and the questions are a successful mechanism to organize, structure, support and guide the actions during the exploratory phase.	-The map complemented the feedback during the exploratory phase. o *33/34 (97%) students indicated that the feedback helps them to know how to continue in the activity and their progress on it* -Students highlight that mobile devices and the automatic assessment and feedback system are easy to use, useful and a structured and clear way to know which tasks to perform at anytime. -Teachers highlight using the automatic assessment and feedback system with mobile devices as an interesting mechanism that helps on structuring the activity. -Students using GPS during the whole exploratory phase found the device a very useful guide. o *6 (out of 10) students using the GPS during the whole experience answered that they could have performed the activity without map.* - Students from the Sant Marti Group (mixing activities with and without GPS) prefer the activity when it is supported by GPS because it is more interesting, practical and faster. - Students that did not use the GPS during the exploratory experience consider that the GPS was not necessary. However, they comment that it had been useful because they experienced some difficulties on finding some streets and interpreting the map.	Observations during the exploratory phase and the presentations, teachers' and students' questionnaires after the exploratory phase and after the whole experience
3. The role-distribution during the exploratory phase is perceived by teachers and students as a successful mechanism to structure collaboration. The students also feel comfortable with the pre-test district assignments policy.	- Students and teachers agree that the role distribution: 1) helps on focusing on one task and perform the activity correctly (*positive interdependence*), which is more effective for learning, 2) promotes active participation of all group members (individual accountability) and 3) helps on structuring, organizing and making the activity more dynamic o *34/34 (100%) All students answered that it has been helpful working in groups* - Students feel comfortable with role assignment in the exploratory phase and consider that it is a good mechanism to distribute tasks. - Students feel comfortable with pre-test district assignment policy but the process is not transparent to them: o *28 (out of the 34 students) did the pre-activity. From these 28, 13 answered that they expected the assignment and 15 didn't expect. Despite they did not expect the assigned district, they are happy with it*	Observations during the exploratory and presentations phase, students questionnaires about the exploratory phase and students' and teachers' questionnaire about the whole experience

4. Students and teachers find the technology employed in the CSCBL usable and appropriate for the experience. However, students and teachers found the technology employed easy to use, some technical problems were detected and some improvements suggested.	-Students prefer answering the questions in a mobile because it is easier than carrying a dossier with questions. -32/34 (94%) (one did not answer this question) answered that mobile phone QuesTInSitu application was very easy to use. -Some usability problems were detected by the students when using the mobile devices: o *Visualization and interactive problems with the tactile screen* o *The GPS does not always work properly and is very slow. However, students don't experiment problems resetting the device and launching again the application in case of error.* - Observations and teachers' answers highlight that the monitoring system could be improved by adding system to visualize and talk to the students at *runtime* and the final mark of the test.	Students' questionnaires about the exploratory phase and the whole activity, teachers questionnaires about exploratory phase

Table 8 Cross-analysis perspective summary. P1 stands for Proposition 1. P2 stands for Proposition 2.

Table 7 Summary of findings and partial results related with the focus II.

	Findings (summarized)	P 1	P 2
Design perspective	D1- The narrative of the CSCBL scenario designed with practitioners, using 4SPPIces as the structuring communication framework, enables visiting more than one district of Barcelona, integrates structured work activities to promote collaboration and incorporates the use of ICT.	X	
	D2- Educational materials and activity contents capture the main aspects underlying the learning objectives of the activity.	X	
	D3- The technological environment provides the functionalities to support the students' and teachers' tasks defined in the CSCBL narrative.		X
Enactment perspective	E-I.1. The CSCBL scenario copes successfully with the limitations detected by the teachers in previous editions: students learn about sociological and urbanism characteristics of 6 different districts of Barcelona working in groups and using technology.	X	X
	E-I.2. The CSCBL scenario promotes the collaboration and cooperation between students and developing teamwork skills	X	
	E-I.3. The CSCBL scenario is a motivating experience that promotes the active participation of the students and is innovative compared with similar experiences because of the use of technology.	X	
	E-I.4. Combining exploratory activities with the presentation work into an integrated learning setting promotes students' reflection about concepts acquired in class and in other courses. Teachers also consider this integration necessary to provide a complete evaluation of the activity.	X	X
	E-II.1. The mobile and GPS devices combined with the monitoring functionalities included in QuesTInSitu and the Moodle platform provide teachers with a support to follow students' activity.		X
	E-II.2. Mobile devices complemented with a map as well as the questions are a successful mechanism to organize, structure, support and guide the actions during the exploratory phase.		X
	E-II.3. Students and teachers feel comfortable with the pre-test district assignments policy and role - distribution as a successful mechanism to structure collaboration.	X	X
	E-II.4. The technology employed in the CSCBL scenario is usable appropriate for the experience.	X	

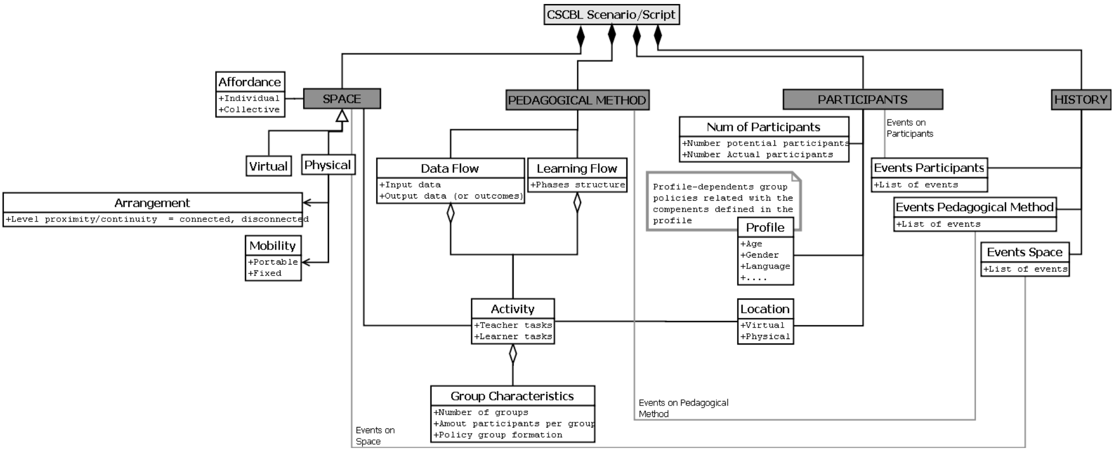

Figure 1 4SPPIces model. Factors and facets to be considered in the design of CSCBL scenarios and the technological environment for supporting their enactment.

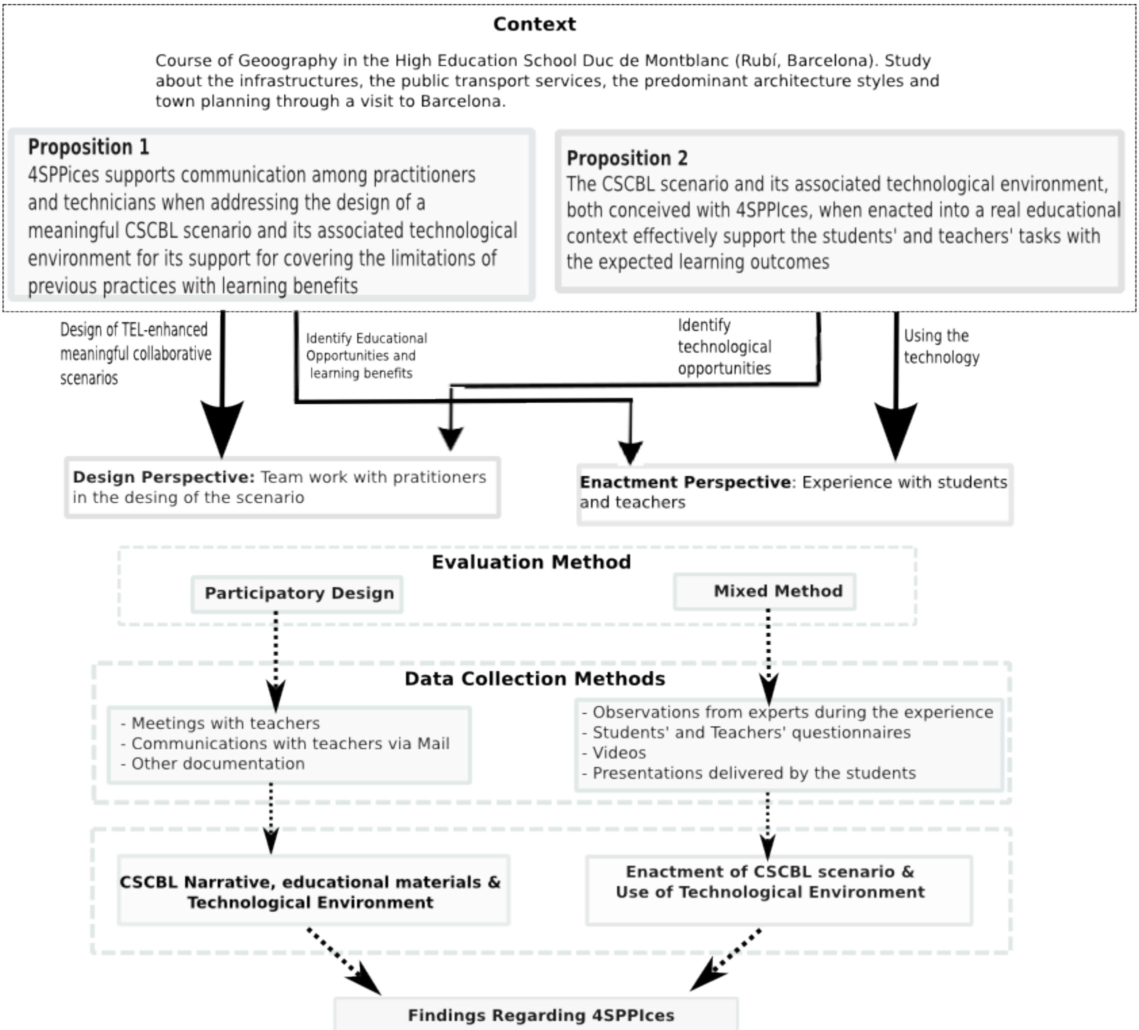

Figure 2 Schema of the case study from the design and enactment perspectives: (1) A team work with practitioners following a Participatory Design technique and (2) An experience with students and teachers in an actual learning situation evaluated with a Mixed Method.

GRUP 2. LES CORTS
Group 2. Les Corts-Zona Universitària
Metro Maria Cristina... Corte Inglés/Pedralbes Center, Illa Diagonal, Carrer Galileu, Travessera de les Corts (mercat), C. de la Maternitat (Camp Nou), C. Menéndez Pelayo, Avgda. Diagonal (Zona Universitària)... Metro Maria Cristina...

GRUP 3. GRÀCIA
Metro Fontana... Carrer Astúries, C. Verdi (Cinemes, mercat), C. Torrent de l'Olla, C. Bonastre, Avgda. Diagonal, Passeig de Gràcia (edificis importants fins Plaça Catalunya).

Figure 3 Examples of the maps with the routes provided by the teachers.

Book chapter

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Abstract When applying a Collaborative Learning Flow Pattern (CLFP) to structure sequences of activities in real contexts, one of the tasks is to organize groups of students according to the constraints imposed by the pattern. Sometimes, unexpected events occurring at runtime force this predefined distribution to be changed. In such situations, an adjustment of the group structures to be adapted to the new context is needed. If the collaborative pattern is complex, this group re-definition might be difficult and time consuming to be carried out in real time. In this context, technology can help on notifying the teacher which incompatibilities between the actual context and the constraints imposed by the pattern. This chapter presents a flexible solution for supporting teachers in the group organization profiting from the intrinsic constraints defined by a CLFPs codified in IMS Learning Design. A prototype of a web-based tool for the TAPPS and Jigsaw CLFPs and the preliminary results of a controlled user study are also presented as a first step towards flexible technological systems to support grouping tasks in this context.

CLFP intrinsic constraints-based group management of blended learning situations

M. Pérez-Sanagustín, J. Burgos, D. Hernández-Leo, J. Blat

ICT Department, Universitat Pompeu Fabra, C/Roc Boronat 138, 08018 Barcelona, Spain

{mar.perez, davinia.hernandez, javier.burgos, josep.blat}@upf.edu.com

When applying a Collaborative Learning Flow Pattern (CLFP) to structure sequences of activities in real contexts, one of the tasks is to organize groups of students according to the constraints imposed by the pattern. Sometimes, unexpected events occurring at runtime force this pre-defined distribution to be changed. In such situations, an adjustment of the group structures to be adapted to the new context is needed. If the collaborative pattern is complex, this group re-definition might be difficult and time consuming to be carried out in real time. In this context, technology can help on notifying the teacher which incompatibilities between the actual context and the constraints imposed by the pattern. This chapter presents a flexible solution for supporting teachers in the group organization profiting from the intrinsic constraints defined by a CLFPs codified in IMS Learning Design. A prototype of a web-based tool for the TAPPS and Jigsaw CLFPs and the preliminary results of a controlled user study are also presented as a first step towards flexible technological systems to support grouping tasks in this context.

Keywords Constraints, Flexibility, CLFP, Group management, IMS LD

1. Introduction

SCRIPTS are the computational solution proposed in the Computer-Supported Collaborative Learning (CSCL) field to guide and support potentially fruitful interactions in terms of learning benefits. Scripting a learning process means shaping interactions without spoiling the natural richness of free collaboration in order to produce situations of effective learning [3, 4]. However, when applying a script to a blended learning scenario - where online, technology supported and face to face (f2f) activities are combined in a given space - some unpredictable situations arising from the context force the scripts' constraints to be re-defined *on the fly*. One of the main aspects usually affected by this contextual variability is the group organization and the role distribution along the script's phases. When these situations occur, it is necessary to re-distribute groups of participants and roles in a flexible manner to adjust the script to the actual situation without violating its principles; i.e. the constraints that structure the collaboration. Different solutions and tools have been developed to provide support to collaborative practices [6, 9, 14]. Nevertheless, these systems are still too rigid to capture the unexpected changes occurring in educational contexts and, in particular, in blended learning contexts. Specialized and interoperable tools are needed for supporting these flexibility demands.

This work proposes a flexible solution for managing groups of students according to the variability of the context and the intrinsic constraints stipulated by Collaborative Learning Flow Patterns (CLFPs) codified with the IMS LD specification. CLFPs capture the essence of well-known techniques for structuring the flow of learning activities to potentially produce effective learning from collaborative situations [5, 7]. Whereas, the IMS Learning Design (IMS LD) specification allows its formalization into a computer-interpretable design. Taking as a basis a constrain-based framework proposed by Dillenbourg and Tchounikine we analyze the flexibility requirements of two representative examples of complex CL (Collaborative Learning) activities: the TAPPs and Jigsaw CLFPs. With the results of the analysis we implement a Web-based prototype for flexibly supporting the group management both examples.

Section 2 discusses the concept of flexibility, presents some of the existing approaches for supporting the group management that inspired this work and gives an overview of the solution proposed. Section 3 presents the results of studying the intrinsic constrains for the TAPPS and the Jigsaw CLFPs and their representation in IMS LD. Section 4 explains the web-based prototype and its architecture. Finally, section 5 and 6 report the preliminary results obtained from a controlled user study, the main conclusions and future work.

2. Flexible solutions for supporting CSCL scripts

Using a script means to structure the learning flow and organize groups of students to constrain collaborative interactions. If these constraints are too strong, the script can spoil the natural richness of free collaboration; whereas if the constraints are too weak, the expected interactions might not be produced [2, 3, 4]. Consequently, the design of technological settings for supporting CSCL scripts must be sufficiently flexible for dealing with the main dimensions that arise from these two aspects. It must help to structure collaboration, but should also support some variability when applied into a real context. This section reviews some of the studies that inspired this work. In one hand, we discuss the concept of flexibility adopted as a basis for the solution proposed. On the other hand, we go through some approaches developed for supporting the group management in collaborative practices and highlight their limitations. Finally, we introduce our proposal for supporting teachers in the group organization and adaptation that will be developed in the next sections.

2.1. Flexibility as disjunction of intrinsic and extrinsic constraints

Dillenbourg and Tchounikine (2007) support the idea that, due to the unpredictability of the script during the enactment phase, the teacher and the student must be able to modify some script features. Based on this, they propose a conceptual constraint-based framework that defines flexibility in terms of intrinsic and extrinsic constraints [4]. The intrinsic constraints arise from the principles from which the script has been generated and must be respected in order to get a fruitful collaboration. The extrinsic constraints arise from those elements induced by the technology of contextual factors (limitations in the number of students, evaluation elements ...). The dissociation of constraints proposed marks the boundaries of flexibility for the teacher and students, and provides the basis for a computational platform of interaction. This platform should be sufficiently flexible to maintain interaction patterns in the space of extrinsic constraints, without violating the intrinsic constraints in each of the phases of the script development process (edition, instantiation and enactment). As a conclusion, Dillenbourg and Tchounikine propose addressing the operationalization of CSCL scripts by handling multiple representations of the same script: the script to be executed; the current interaction patterns or emergent organization of teams; the intrinsic and extrinsic constraints that result respectively from the pedagogical design; and from the decision and the visual representations of the script for the students and teachers.

In this work, we adopt the dissociation between intrinsic and extrinsic constraints proposed in this constraint-based framework for delimiting our notion of flexibility and the scope of this work.

2.2. Limitations in supporting group management in collaborative blended learning scenarios

Several approaches have been developed for technologically supporting the group management in collaborative learning. However, and despite of their potential for solving some aspects of collaborative tasks, they lack on facing some of the problems arising when enacting collaborative learning flows in blended learning scenarios. Here we classify, describe and analyze some of these approaches under the idea of flexibility introduced in the previous section.

Specialized grouping tools

A study by Ounnas proposes a framework for learner group formation, based upon satisfying the constraints of the teacher by reasoning over semantic data about the potential participants [13, 14]. As a technological support based on this framework, Ounnas proposes a tool that enables forming groups of students according to a set of constraints defined by the user and the semantic data that characterize the potential students participating in the activity. The result is a simple and powerful solution for easily allocating all students in groups. In the same line, an study by Hwang et al [9] proposes a genetic algorithm as a basis for an assistant system for organizing efficient cooperative groups that fit the learning objectives set by the instructor.

Despite of the potential of these approaches, they propose solutions for supporting the group organization for a particular activity and not for sequences of activities following a learning flow such as those defined by scripts. Thus, these solutions do not consider the relations established within group members from a set of interrelated activities, i.e. group formation according to the students roles in previous activities. Moreover, these applications do not assist the teacher in understanding the adaptation needs that emerge from the contextual situations and their relation with the intrinsic script constrains.

Specialized grouping tools conforming with IMS LD

One of the best-established modeling languages that are used to develop applications in educational contexts is IMS Learning Design (IMS LD) [10, 11, 12]. This specification enables the computational representation of learning flows according to a wide range of pedagogies in online learning. These computational learning flows are defined in different phases: learning flows are typically determined according to the educational objectives at design time, particularized to the specific learning situation at instantiation time and delivered to the participants as an activity to perform at enactment time. In CSCL, different approaches conform to IMS LD have been developed to support one of these phases. These computational representations are suitable to be interpreted by a compliant system as a way of alleviating teacher and learner management tasks.

As a support for the design time, Hernández-Leo *et al* propose an authoring tool for the edition of designs based on Collaborative Learning Flow Patterns conforming to IMS LD [8]. These patterns represent the techniques used to structure the flow of types of learning activities involved in collaborative learning situations. As a result, this tool provides the educator with a computational learning flow suitable to be interpreted by a system conformig to IMS LD that organizes groups of students within an activity sequence during the edition time, but not during the enactment. Therefore, no changes on group organizations are possible with this tool.

For the instantiation phase, Hernández-Gonzalo *et al* propose an IMS LD compliant tool called iCollage [6]. This is a graphical tool for the particularization of role/group structures aiming at facilitating the creation of instances and population of groups. One interesting innovation that this tool features is that groups can be defined during the instantiation phase instead of during edition, allowing the user to adapt group structures to the real contextual situation. However, this tool only provides graphical support for the group population according to the previous structures determined during the script edition. Thus, it fails to allow modifications during the script enactment, in which the extrinsic constraints can force changes in the structure planned during the edition process.

Finally, Zarroandia *et al* proposes a mechanism for the introduction of small variations in the original IMS LD learning flow during the enactment [16]. This tool allows changing some aspects of the activity such as the title, the resources associated or the structure of the learning flow. Nevertheless, the group hierarchies and the roles defined during the edition phase cannot be changed during the enactment.

The main problem of these approaches is that they treat separately the edition from the instantiation and enactment phases. This means that the group structures planned during the edition cannot be adjusted to the contextual situations during the enactment.

2.3. Considering the intrinsic constraints of two IMS LD CLFPs

This work proposes a solution for flexibly managing groups of students according to Collaborative Learning Flow Pattern (CLFP) principles when applied to blended learning contexts. For the proposal we adopt: (1) the constrain-based framework proposed by Dillenbourg and Tchounikine as a basis for understanding the flexibility requirements that arise from collaborative learning practices and (2) the IMS LD specification as the de facto standard for our implementations for assuring the interoperability with the current developments and an easier integration with the existing tooling conform to this specification.

The solution is based on a conceptual model developed by the authors in a previous work. This model proposes four factors conditioning the group management in blended learning scenarios [15]: the Pedagogical Method (the activity workflow that defines the groups and role distributions), the Participants (potential and actual people participating in the activity), the History (the unexpected events fruits from the context) and the Space (elements of the space involved in the activity). The first three factors proposed in the model are the basis for identifying the main aspects to be considered when analyzing the requirement of a system for supporting the group management. The Space factor will be considered in future studies. As the Pedagogical Method factor we adopt a CLFP codified with the IMS Learning Design specification.

For addressing the flexibility requirements of the group organization we analyze two particular CLFPs, Jigsaw and TAPPS (Thinking Aloud Pair Problem Solving) by dissociating the constraints intrinsic to the pedagogical design of the script from those induced by the contextual factors. From the analysis, we extract a set of constraints for each of the CLFPs and map them with some of the elements of their IMS LD codification. This mapping leads to a formal representation of the educational flexibility requirements. The results define the foundations of a technological architecture based on a notification system for facilitating the adaptation of the CLFPs to the unexpected events arising from the learning context by preserving their main rationale. In the following sections, the analysis of the constraints, their mapping with the IMS LD and the web-based prototype resulting from this proposal are detailed.

3. Flexibility constraints for TAPPS and Jigsaw

To study the flexibility requirements for the group management in the Jigsaw and TAPPs CLFPs we follow the definitions given in [7]. We adopt the main indications regarding the group composition and the role distribution along phases for extracting the intrinsic constraints. The aim at selecting these concrete CLFPs is to consider two CLFPs with different levels of complexity in order to understand the effectiveness of using technology for supporting these practices. This section presents the 1) description of both CLFPs, 2) the analysis of the intrinsic constraints regarding the group management, 3) the notification messages proposed in case that these constraints are violated for guiding the users through the best grouping solution according to the actual circumstances and 4) the mapping of the IMS LD codification and these intrinsic constraints.

3.1. Jigsaw and TAPPS CLFPs

The Jigsaw CLFP organizes a complex learning flow for a context in which several small groups are facing the study of a lot of information for the resolution of the same problem [7]. The activity flow is structured in three phases: i) a first phase in which an individual or initial group studies a particular subproblem, ii) a second phase in which the students that are involved in the same problem are grouped in *Expert groups* for exchanging ideas, and iii) a third phase in which the students are grouped in *Jigsaw groups* formed by one expert in each subproblem to solve the whole problem. It is based on the principle that to solve a complex divisible task collaboratively promotes three main educational benefits: positive interdependence, discussion and individual accountability.

Table I analyzes the intrinsic constraints for the Jigsaw pattern. The intrinsic constraint (a) is related with the minimum number of students with a different expert role necessary for applying this pattern. Since the main script principle is based on the division of the task, applying this script requires, at least, having an enough number of students to define two different expert roles. Otherwise, the system should notify the teacher that the script could not be applied. The constraint (b) regards with the difference between the number of potential (E) and actual (E') students. A non equilibrated number of students per expert group can lead to an inconsistency when forming jigsaw groups, such as having a jigsaw group without one of the expert roles. For that reason, a variation on the number of expected students should be notified to advice the teacher that s/he should adjust their jigsaw groups in the next phases. Constraints (c), (d) and (e) have to do with the requirements of jigsaw groups (J). This CLFP defines that the appropriate number of students per jigsaw group is within 4 to 5. Although the script could be applied with three students per group, the system notifies the teacher that the restrictions imposed by the CLFP are not accomplished (notifications (c) and (d) in the table). Finally, in case of having jigsaw groups without one expert of each type, the teacher is advised that it is necessary to re-adjust the jigsaw groups for reaching the expected learning objectives defined by the script.

TABLE I Intrinsic constraints of CLFP Jigsaw

Intrinsic Constraints	Violations	Notification of the system
a) # E >=2	#E=1	Not.: You need at least 2 different expert groups for applying this pattern.
b) EG must be formed by the same # of students. The EGs must be equilibrated.	#E≠#E'	Not.: Be careful when creating the Jigsaw groups in the next phase. You have a non equilibrated group of students in each EG.
c)#J in JG <=max size JG (by default)	#J in JG > max size JG	Not.: The number of students in Jigsaw groups is different than the one stipulated by the CLFP
d)#J>min size JG (by default)	#J<min size JG	Not.: The number of students in Jigsaw groups is different than the one stipulated by the CLFP.

e) JG are formed by at least one E from each topic	JG<#E de un EG diferent	Not.: Your jigsaw groups don't contain members of the different expert groups. Please, review the proposed distribution and adapt your groups to this restriction.

E/ E'=# (potential/actual) students with Expert role J= # students with Jigsaw role, EG=Expert Group, JG=Jigsaw Group; T=total students

The TAPPs CLFPs gives the organization for a context in which several students are paired and given a series of problems [7]. Each member of the pair is given a role of Problem Solver and Listener that switches for each problem. The Problem Solver reads aloud and talks through the solution of the problem. The Listener follows the problem solver's steps, catches the errors and asks questions for guiding the problem solver to the solution.

Table II analyzes the intrinsic constraints of the TAPPs pattern. Constraints (a) and (b) regard with the number of students (T) and the roles distribution. Since the script proposes working in pairs, if the number of students is odd, the system should notify the teacher that it is necessary to create a group of three persons and distribute the roles of listener and problem's solver accordingly. A group of three must have only one problem solver at once per phase. Constraint (c) is related with the role of the students. In case of having pairs, the role between listener and problem solver switches each phase. However, if there is a group of three, the teacher should control that one of the students in this group repeats the same role in two consecutive phases.

TABLE II Intrinsic constraints of the TAPPS CLFP

Phase 1: Individual or initial group

Intrinsic Constraints	Violations	Notification of the system
a)T is pair	T is odd	Distribute the students in pairs and locate the orphan student in one of the groups and assign him the listener role. Not.: The number of students is odd and we propose you to do one group of three persons.
b)In a P there should be, at least, one L and one PS.	There are groups of three persons.	Not.: You have one group of three. Pay attention for the role distribution in this group. Be sure that there is only one problem solver at once per phase.
c) The P switch roles each phase. In case of having a group of three one student plays the same role in two consecutive phases (N, N+1)	If P>3, 1 PS and 2 Listeners.	Not.: You have one group of three. Be sure that one of the members in this group plays the same role of listeners in two con-

secutive phases.

T= total students in class; P=pair, L=Listener; PS=Problem's solver

3.2. Representing the intrinsic constraints with IMS LD

We take as a starting point two CLFPs codified as a Unit of Learning (UoL) in IMS LD that we created with Collage [5, 8] and Recourse [17]. For the UoLs' definitions, we follow the guidelines specified in [7] and we configure them as the minimum units needed for representing the CLFPs in IMS LD. A UoL is composed by a set of resources and an *xml* file called *manifest* that relates them. We benefit from the *manifest* definition for extracting the intrinsic constraints defined in tables I and II of the previous section.

The component `<imsld:roles>` defines the *hierarchy* of the groups by setting the different roles that will be involved in the activity (Fig. 1). By default, IMS LD distinguishes between two types of roles: learners and stuff. Another attribute defines the minimum (`min-persons`) and the maximum (`max-persons`) number of persons playing the same role. This corresponds to the *size* of the groups and gives implicit information about the *amount of groups*. The last element is `create-new`. When it is set to "`allowed`" indicates that it is possible to create occurrences of groups of the same type, i.e. groups of people with the same role.

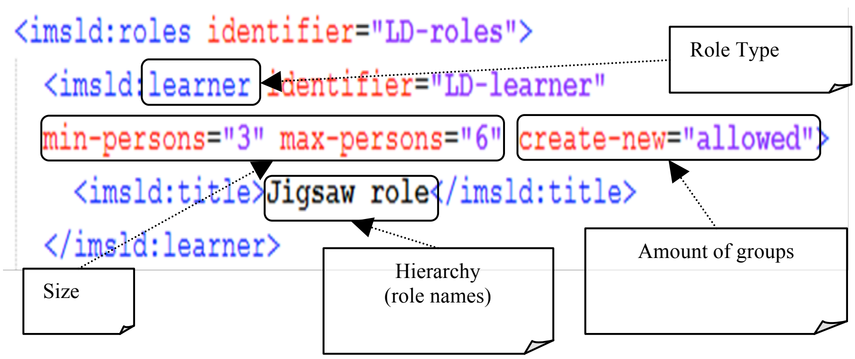

Fig. 1 IMS LD elements of the *manifest* defining the characteristics of the roles and groups

The learning flow with its activities and the activity-dependent-associations or *dynamic formation* are defined in the `<imsld:method>` (Fig. 2). This section defines a set of `<imsld:act>`. Each act refers to a sequence of activities defined in the `<imsld:activities>`, in which are also described the roles taking part in each activity (`<imsld:role-part>`).

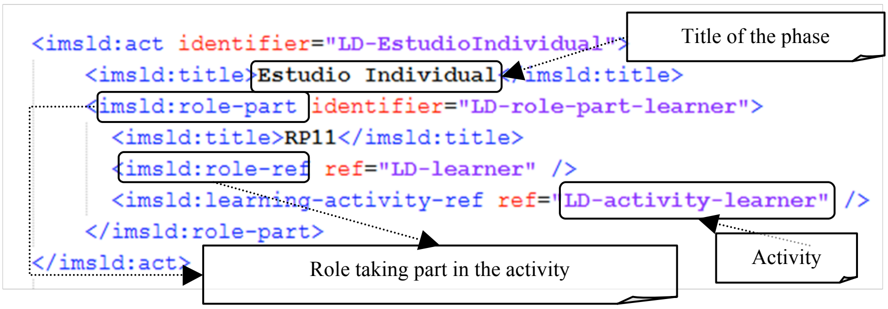

Fig. 2 IMS LD elements from the *manifest* defining the sequences of activities and the activity dependent associations.

4. Supporting flexibility for group management: A web-based tool

We present here below a prototype as a first effort for supporting group management in blended learning scenarios where CLFPs are applied. This prototype has been designed for the two particular CLPFs Jigsaw and TAPPs taking as a basis the analysis and representation of the intrinsic constraints presented in sections 2 and 3.

4.1. A web-based application

We developed a web-based application that distinguishes between a view for the teacher and a view for the learner. The teacher's view includes functionalities for allowing the management of Participants' factor manually or automatically. When using the automatic distribution the system provides always the best possible distribution trying to respect as much as possible the intrinsic constraints. However, the teacher has always the flexibility to change the group distribution proposed (without changing the number of phases or the roles' definition). In case that one constraint is violated, the teacher will be notified but will be always free of leaving the organization as desired. The students view only shows the general group distribution for each phase and the position of the student accessing the system highlighted in another color. The student cannot change any configuration but access to the information stored about his role in other phases.

4.2. The architecture

As a basis for the architecture we use three of the factors conditioning the group management to blended learning scenarios defined in [15]: the Pedagogical Method, the Participants and the History (Fig. 3). The Pedagogical Method defines the learning flow of the collaborative activity and it is represented here by a CLFP codified in a UoL conforming to IMS LD. Concretely, the flow of activities and their associations are represented by the elements described in section II, which are parsed from the *manifest* and codified as the intrinsic constraints in the system according to the tables I and II. The Participants factor is directly associated, in one hand, to the list of potential students that the teacher can upload to the system during the preparation of the group distribution and, on the other hand, to the actual students during the development of the activity. Finally, the History factor stores the information about the group distribution and the new group configurations that occur during the activity development. The unexpected events affecting the group composition are stored as extrinsic constraints. A constraints' controller is always listening to the system for notifying the user if any of the intrinsic constraints have been violated. In this case, it will propose an optimal distribution of the participants according to the Pedagogical and the History factors. The system will always propose an alternative, except when the actual number of participant's configuration makes it impossible to satisfy them. In such cases, the system proposes the best alternative or recommends using other CLFPs for this learning scenario. Fig. 3 shows a general picture of the main elements of the system.

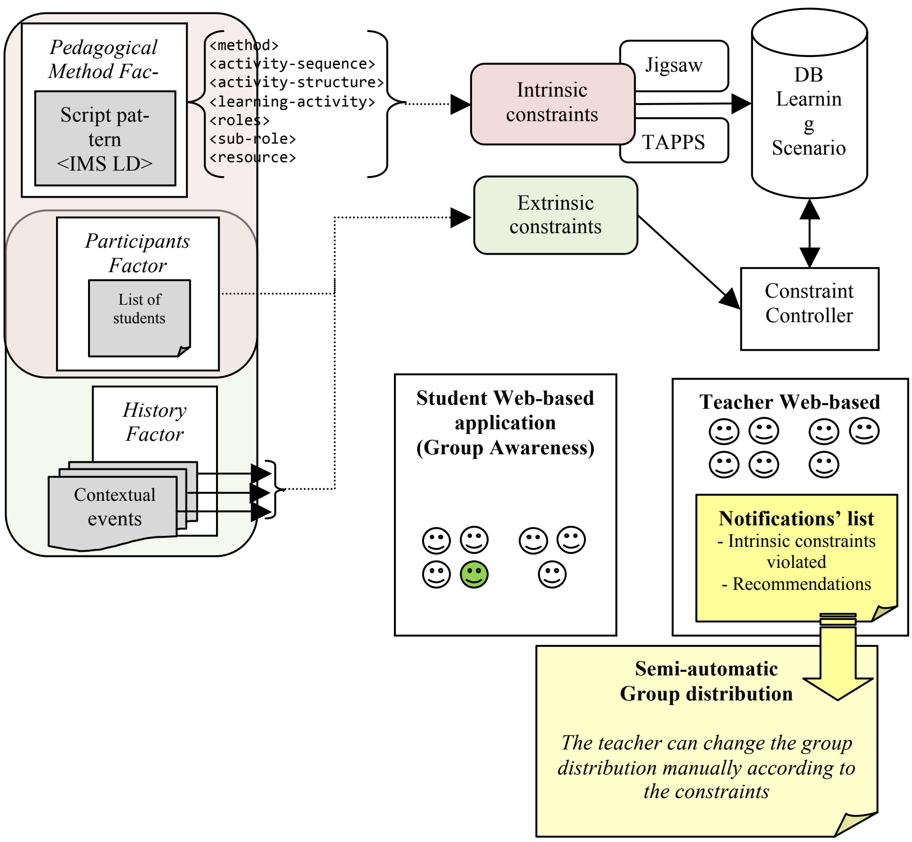

Fig.3 . Schema of the architecture underlying the prototype. The three factors are represented: the pedagogical method, the participants and the History

5. Preliminary user study evaluation

With the aim at obtaining the first evaluation results of the prototype we conducted a preliminary controlled user study. The study focuses on understanding the effectiveness of a tool for flexibly supporting the group management in front of a manual process and indicating in which situations this approach is useful. The main questions of interests were: 1) Do the users find helpful to have a semi-automatic tool for the group management in collaborative activities? 2) Is the tool flexible enough to freely adjust the groups to the unexpected situations? 3) Does the tool support correctly the whole process and in which situations?

5.1. Description of the user study

For the user study we prepared two different scenarios: one for the Jigsaw and the other for the TAPPS. Both scenarios described a CLFP in the context of an e-Learning course of 13 students. The task of the teacher consisted in organizing the students in groups according to the restriction imposed by the collaborative activity proposed. The scenarios were delivered in a document containing an introduction to the context and the description phase by phase of the CLFP pattern that should be applied. For analyzing the strategies used during the whole process we proposed two different tasks: (1) prepare the group distribution of the potential students from a list according to the requirements of the activity before the class and (2) adapt the groups previously defined to a set of unexpected situations that were described in the scenario as a simulation of the type of events occurring in real educational contexts (i.e. one of the potential students leave the class at the second phase of the activity or a new student joins the class when the activity have already started). In all cases, the restrictions imposed by the CLFP needed to be accomplished. Since the focus of the study was to understand if the tool facilitates the group management in comparison with a manual process we asked the users to perform the two tasks twice, firstly by hand and secondly using the tool. Therefore, the evaluation process was divided in 3 phases: (1) familiarization with the CLFP and the context, (2) group management by hand and (3) group management using the tool.

5 university teachers with 1 to 8 years teaching experience participated in the controlled use case. 2 of them were experts in CSCL practices whereas the other 3 had never prepared a collaborative activity following a CLFP. We assigned the Jigsaw scenario to the 2 experienced users and to 1 inexpert and the TAPPS for the remaining 2. This distribution was focused on comparing the usefulness of the solution in relation to the complexity of the collaborative activity. After a brief explanation of the activity the users started the exercise by performing the group distribution manually. In the second phase, we de-

voted 5 minutes explaining the main functionalities of the tool and the users repeated the exercise using the tool. Since the objective of the evaluation was to understand the whole process and not the design or usability of the prototype, the users were allowed to ask about the functionalities during the experience. Fig. 4 shows the picture of two of the participants of the experience during the two different phases. Two different researchers were recording the observations on how the participants planned their group distributions and their spontaneous comments. During the whole process the users were guided through the different situations by a template with a set of steps. For each step they were asked to explain the strategies followed for the group management and their final students' distribution. All the resulting strategies and distributions were collected. Finally, the users answered a test with close and open questions in which they compared both, the manual and the technologically-supported processes. Table III summarizes the different data sources considered in the evaluation.

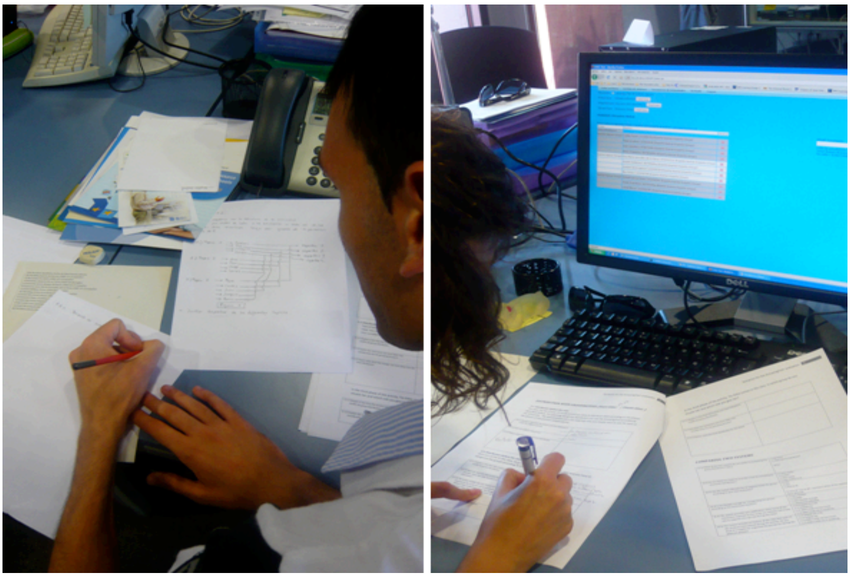

Fig. 4. Teachers participating in the experience. The picture on the left shows the phase in which the activity is carried out by hand and the one on the right corresponds to the phase carried out with the application.

Due to the characteristics of the user study and the objectives of the evaluation, we followed a mixed evaluation method combining and triangulating [1] the qualitative and the quantitative data obtained from the different sources in Table III. As the objective of the evaluation was focused on the process, the qualitative results were used as the main reference for understanding the strategies of the users for solving the unexpected situations and to identify the necessities emerging from this type of practices.

TABLE III Data sources for the evaluation

Data source	Type of data	Labels
Process and outcomes described by users in a template	Qualitative descriptions and draws.	[Quest-JigsawX]
	Qualitative comments and opinions.	[Quest-TAPPSX]

		Where X is the number of the user, from 1 to 5
	Screenshots of the students' distribution resulting from the whole process step by step.	[ToolDistribution-JigsawX] [ToolDistributionTAPPSX]
Observations	Record of direct observations during the experience by 2 different researchers.	[Observer1] [Observer2]
Final questionnaire	Quantitative ratings and qualitative opinions comparing the manual and the technologically-supported process.	[Quest-comparison-JigsawX] [Quest-comparison-TAPPSX]

5.2. Results

To have a general view of the results we answered the main questions of interests by joining the results from the final questionnaire of the Jigsaw and the TAPPS scenarios (Table IV). A detailed analysis of these general results with the qualitative data permits extracting a generic picture of the tool's effectiveness in front of the manual distribution, understanding how helpful is this approach for the users and which the missing requirements are.

Results of question 1 in table IV show that the users found the tool a good support for managing big groups of students in complex collaborative tasks and for having general visualization of the full group distribution. The users performing the more complex activity (Jigsaw) had a better perception of the tool than those doing the simple one (TAPPS). This supports the idea that such type of solutions are helpful in case of having activities with many constraints to be accomplished and a big number of students to organize. As one of the users performing the easiest task said "*In small groups of people with few changes it's easier by hand. You don't need to form the groups with the tool. However, for big groups it would be useful.*" [Quest-Tapps2]. The draws of the users as outcomes from the manual part (see Fig. 5) also evidence the utility of having a graphical support showing the general group distribution.

TABLE IV Questions of interest and main results achieved in the user study.

Questions	Results
1) Do the users find helpful to have a semi-automatic tool for the group management in collaborative activities?	*The 3 users that performed the Jigsaw scenario spent an average of 10 minutes less doing the exercise with the tool than by hand. Whereas the users performing the TAPPS scenario spent 5 minutes less in average by hand. Nevertheless, the two TAPPS' users commented that it would be very useful in case of having a bigger number of students,

	like 30 or 50. More time devoted for familiarization with the tool would decrease the average time spent in the semi-automatic management. *4 of the users preferred managing the groups using the tool instead of doing it by hand. The user that preferred doing it by hand commented that, in case of having more students s/he would have chosen the tool. *All the participants considered the tool very useful for managing groups. They mainly highlighted the automatic group distribution functionality and the visualization of full group organization in which the students are labeled with the name of the group they belong to.
2) Is the tool enough flexible to freely adapt the groups to the unexpected situations?	*All participants found the tool flexible or very flexible for reorganizing the groups according to the contextual situation. One of the users considered necessary to include the possibility of creating groups whenever s/he wanted (the tool only included the possibility of creating a new group in the first phase of the activity).
3) Does the tool support correctly the whole process and in which situations?	*All participants doing the Jigsaw scenario found that the notifications provided by the tool when a constraint was violated helped them to understand the errors that they need to solve in order to continue the activity correctly. From the users performing the TAPPS scenario one considered the notification system helpful whereas the other one marked that it did not helped him at all. Nevertheless, this last user answered in a previous question that it was helpful to understand the restrictions imposed by the CLFP. *All participants used the History of the students for confirming that the distribution proposed by the system was correct and to check the role of the students that they needed to re-allocate for adapting the groups to the real context. Only one user from the TAPPS scenario considered the History not very helpful, however, from her/his comments and the observations, it arises that s/he used it for controlling the role of the students.

With regards to the flexibility of the tool (question 2) for managing groups, the results show that all the users freely change their planned distribution according to the necessities required by the unexpected events. However, they missed the possibility of creating groups at any phase: "*I would like to have the possibility of creating new groups*" [Quest-Tapps2].

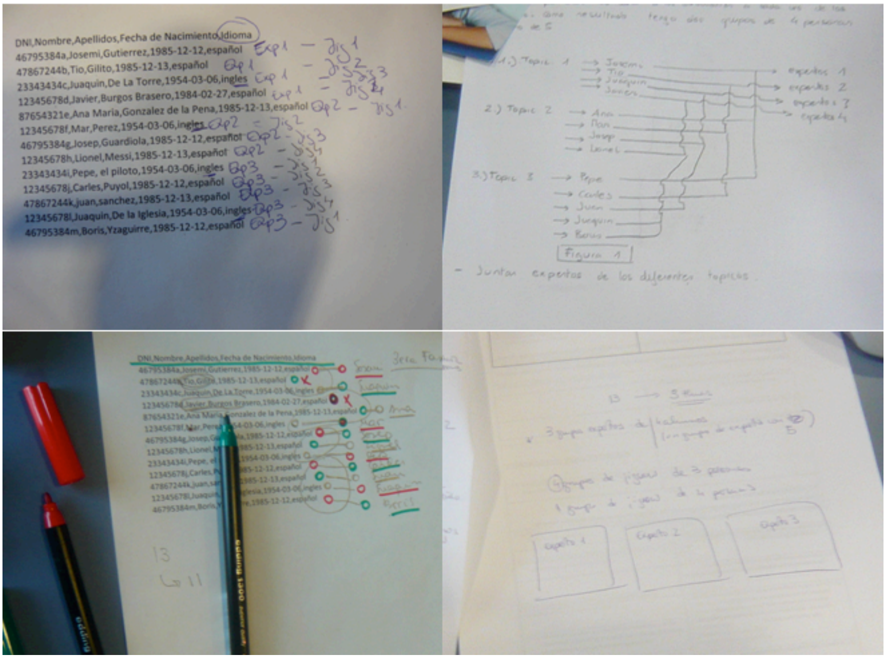

Fig. 5. Draws for organizing the group structures in the Jigsaw scenario.

Finally, the notification and the History of the students serve as a support in the whole process (question 3). All the users re-organized the groups following the notifications provided by the tool and using them as a guide for understanding the constraints that were not fulfilled in their group structure (see Fig. 6 for an example of a screenshot of the process). They used as well the History for checking their final distribution and the list of the students available, thus the potential students that were missing in some of the phases: *"I found it very useful to have the list of the students available (although deleted from the activity)"* [Quest-Jigsaw1]. One of the more interesting results was that all users agree with the necessity of adding a button for automatically providing in each phase the best group distribution according to the CLFPs' restrictions.

Some other suggestions for improving the usability of the tool were proposed: 1) change the way that the notifications are showed to the user: "*I found the notifications useful just to be sure that everything is ok. However, I will put the warning in yellow and not in red because it seems an error instead of a notification* [Quest-Tabbs2]", 2) use more intuitive systems for manipulating the user in the list and change them from one group to another: "*It would be useful to have a drag&drop functionality to locate the students in the different groups* [Quest-Jigsaw1]".

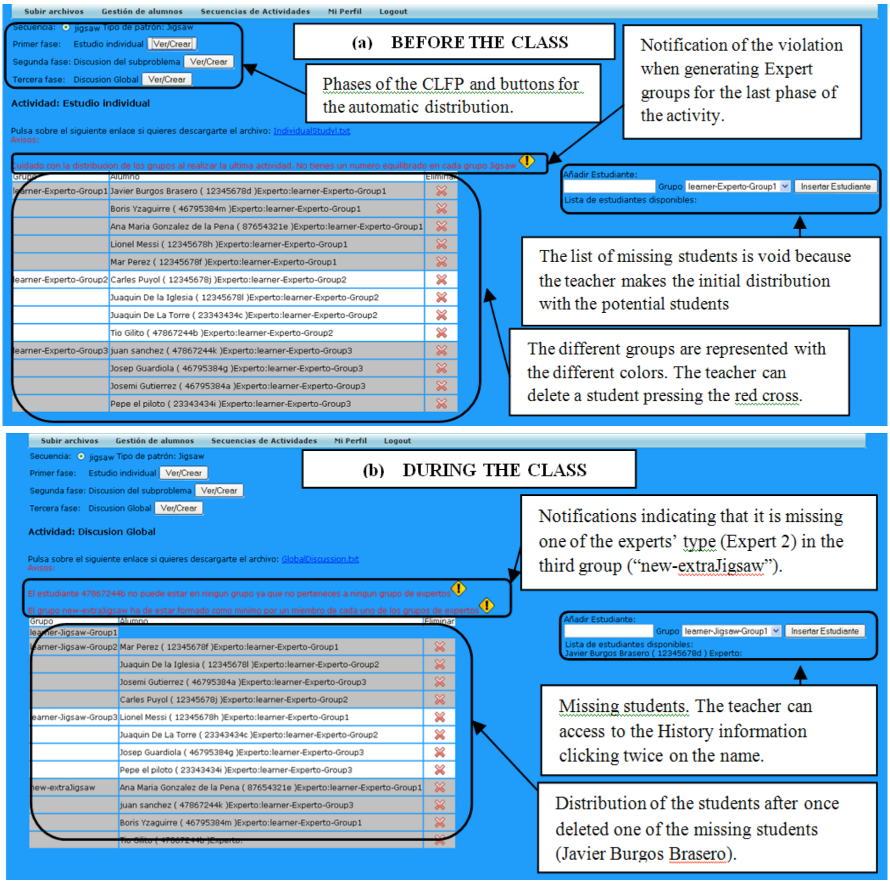

Fig. 6. Screenshots of the prototype. (a) Group distribution before the class. The system proposes the best distribution when clicking on the buttons next to each phase. (b) One of the students is missing and the final distribution is incorrect according to the CLFP's intrinsic constraints. The teacher manually deletes the missing students and attends to the notifications of violations for the final distribution.

6.2. Future developments

Future developments are planned to improve the web-based prototype. The first improvement consists on adding the functionalities suggested by the users. According to the users' suggestions, we have already incorporated in the tool an automatic re-distribution button. This new functionality provides the teacher with the best students' distribution according to the intrinsic constraints and the contextual circumstances. We have also changed the color of the notifications from red to yellow for making them less aggressive for the user.

We also consider extending the tool by providing more sophisticated and formal mechanisms for proposing the best group organization fulfilling the constraints. This requires a further study of the intrinsic constraints for producing a hierarchy ordered depending on whether they are strong (i. e. the number of students is not enough for applying the script) or weak (i. e. although the students' distribution does not fulfill the requirements of the script, the activity can continue without affecting to the final learning outcomes). This classification of constraints would allow at providing more accurate suggestions to the user.

Currently, as an extension of the prototype presented, we are working on functionality for enabling the specification of the Space as a conditioning factor in the design and enactment of the scripting processes. This extension relates with the work of the authors in which the Space, understood as the place *where* the learning activity occurs and *which* elements compose it, is considered as a factor influencing the how the groups are distributed for in the design and the enactment of collaborative learning flows [15]. Thus, depending on the characteristics of the physical space where the activity is carried out (with places for working or groups or not), the movement of the students when applying a Jigsaw CLFPs will be possible or not. This physical arrangement will affect on the way students are grouped for the expert groups.

7. Conclusion and future work

This work presents a web-based prototype as a solution for flexibly supporting teachers in organizing the groups during the edition according to the principles stipulated by the Jigsaw and TAPPS CLFPs and guiding their re-distribution when unexpected situations occur. The preliminary evaluation results from a controlled user study show that such type of solution is useful mainly in two cases: 1) when performing complex collaborative learning activity in which there are many constraints to control and 2) when preparing activities with a big number of students. The evaluation also evidences that the introduction of a notification system and the History of the students is a good mechanism for guiding the users along the best solution for solving the non-fulfilled constraints. Although a more exhausted evaluation is needed, these preliminary results demonstrate that to consider the intrinsic constraints and the history of the activity facilitates the adjustment of the pre-defined groups to the variability of the context.

As next steps, we aim at performing an evaluation of the tool in a real learning scenario for studying how the notification system and the usability can be improved. We also plan to study the intrinsic constraints of new CLFPs to have a more extensive variety of collaborative situations to enact. The results from the planned evaluation will serve as a basis for improving the notification system by introducing a more sophisticated mechanism for guiding the user in the group adjustments according to the solutions adopted by other practitioners.

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Appendix C

Publications by the Author

Submitted

- Pérez-Sanagustín M.; Hernández-Leo D.; Santos, P.; Blat J.; 4SPPIces Model: designing Computer-Supported Collaborative Blended Learning Scenarios and Scripts, Journal of Computer Assisted Learning (*accepted with conditions*)

- Pérez-Sanagustín M.; Hernández-Leo D.; Santos, P.; Blat J.; How to design a collaborative learning scenario blending spaces: A case study applying 4SPPIces, International Journal of Computer Supported Collaborative Learning (*submitted*)

- Santos, P., Pérez-Sanagustín, M., Hernández-Leo, D., & Blat, J.; QuesTInSitu: Implementing test based Assessment in situ activities, Computers & Education Journal (*submitted*)

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