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TESIS DOCTORAL:

Linking scripting and monitoring in blended CSCL scenarios

Presentada por María Jesús Rodríguez Triana para optar al grado de doctora por la Universidad de Valladolid

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Tesis Doctoral

Linking scripting & monitoring support in blended CSCL scenarios

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Abstract

Among the multiple concerns and tasks involved in the orchestration of Computer-Supported Collaborative Learning (CSCL) scenarios, many are oriented to foster effective collaboration. Several strategies may be adopted to support collaboration, assuming either a Learning Design or a Learning Analytics perspective. Before the interaction begins, scripting defines (within Learning Design approaches) the sequence of learning tasks, resources, and scaffolds that the students will need throughout the learning situation. From a Learning Analytics perspective, monitoring analyses students' interactions during the enactment of the learning scenario, and facilitates interventions to steer the situation towards a more productive state.

Although these two strategies (scripting and monitoring) may help teachers in the orchestration of CSCL scenarios, their application is not without problems. Eventualities may emerge during the enactment that jeopardize the initial plan represented in the scripting of the learning scenario. Furthermore, even if the analysis of the students' interactions generates useful insights on how the learning process unfolds, the information that current monitoring proposals provide to the teachers is not always easy to interpret. Thus, teachers often lack relevant information to intervene and adapt their plans as the learning scenario evolves.

Several researchers point out the potential synergies that may be derived from the alignment between scripting and monitoring, such as improving the monitorable evidence from the learning scenario, or providing teachers with data analyses connected to the pedagogical decisions described at design-time. In addition to these conceptual proposals, there exist few technological solutions that support such alignment, through ad-hoc integration into specific learning tools, such as scripted forums and collaborative canvases. However, despite the benefits of the alignment envisioned by the theoretical proposals and the positive results identified by the technological solutions, to the best of our knowledge, there is no research work dealing with the generic needs of blended CSCL scenarios (i.e., independent of specific tools or types of activities, and taking into account both face-to-face and computer-mediated learner interactions).

In response to these needs, our main research objective is to help teachers monitor the accomplishment of their design decisions in the context of blended CSCL scenarios. Following the aforementioned alignment between scripting and monitoring, we propose to provide teachers with design and management support capable of linking their pedagogical intentions and awareness needs. Furthermore, in this dissertation we pay special attention to learning scenarios supported by Distributed Learning Environments (DLEs), which integrate existing learning platforms (e.g., mainstream Virtual Learning Environments such as Moodle or Sakai) with external tools (typically, Web 2.0 tools such as wikis, blogs or Google applications). These technological environments are becoming increasingly popular in current pedagogical practice but, at the same time, make the design and management of the learning scenario even more challenging.

Our proposal aims to address several challenges that teachers face in trying to align these two strategies. The first challenge we encounter is the *lack of attention to teachers' awareness needs* in the process of designing the learning scenario, which may hinder the effectiveness of such monitoring. We propose a *monitoring-aware design process of CSCL scripts*, to support teachers in identifying and including monitoring aspects throughout the design process of CSCL scenarios. This process describes the steps that teachers should follow during the design of CSCL scenarios, in order to reflect on their own monitoring needs and express their expectations about the students' interactions.

The fact that *monitoring solutions usually do not take into account teachers' design decisions* is another challenge of this alignment. In this dissertation, we aim to inform teachers about the accomplishment of their design decisions, therefore contributing to the detection and regulation of emerging eventualities during the course of the learning situation. For that purpose we have formulated a *script-aware monitoring process of CSCL scenarios.* This process defines how the design-time pedagogical decisions captured in the script may guide the data gathering and analysis in order to provide teachers with monitoring information connected to the concerns such design expresses. Furthermore, we have defined a *monitoring-aware model of CSCL scripts* to connect the design and monitoring processes. Aside from describing the connections between scripting and monitoring, the model also supports the data flow between the two aforementioned processes proposed in this dissertation. From the design point of view, the model represents the output of the "monitoring-aware design process", providing a joint picture of the pedagogical and monitoring decisions made by the teacher. From the monitoring perspective, the model specifies the data to be gathered and the analysis criteria.

The third challenge to be overcome deals with the *problems that hinder the data gathering and integration in CSCL scenarios supported by DLEs*, due to the increasingly heterogeneous and distributed nature of such technological environments. For example, the data to be gathered are decentralized and each tool follows its own formats and models. Moreover, sometimes the data relevant to the learning situation are not generated automatically through technological means (e.g., through log files), but rather in an ad-hoc manner by participants themselves (e.g., teacher's observations of the learning situation). To address these challenges we have proposed an *architecture for data gathering and integration in DLEs* that provides a conceptual solution for gathering and integrating participants' actions during the CSCL scenario, throughout the DLE.

To achieve our objective of helping teachers monitor the accomplishment of their design decisions in blended CSCL scenarios over DLEs, we followed a Design-Based Research (DBR) approach involving three iterations and a total of seven studies in authentic CSCL scenarios. The first and second iterations were mainly exploratory and led us to the formulation of the four proposals presented in this dissertation. The third iteration focused on the evaluation of these proposals. The design of the third (evaluative) iteration has been supported by the CSCL-EREM framework (Computer Supported Collaborative Learning Evaluand-oriented Responsive Evaluation Model), which is especially appropriate for the evaluation of CSCL strategies and tools. In this case, our mixed-methods evaluation involved a variety of techniques for data gathering and analysis, during two authentic classroom experiments.

The evaluation results suggest that the proposed model, processes and architecture can help teachers in the alignment between their pedagogical and monitoring concerns. Moreover, according to the teachers involved in the evaluation, the aforementioned proposals are likely to be used in real practice. Besides, this alignment has proven to be useful in supporting teachers in the orchestration of authentic CSCL scenarios. However, the evaluation also found shortcomings, hinting at paths for future research: providing teachers with technological support that enable them to design and monitor students in an autonomous way, investigating the possibilities of the provision of monitoring information to learners, or finding ways to scale up the innovations developed during the dissertation.

Resumen

Entre las múltiples preocupaciones y tareas que conlleva la orquestación de escenarios de Aprendizaje Colaborativo Soportado por Ordenador (CSCL en su acrónimo inglés), gran parte surgen como consecuencia de fomentar la colaboración. Diversas estrategias son las que se pueden adoptar para dar soporte a la colaboración, bien con propósitos de diseño de aprendizaje (área conocida en inglés como Learning Design), bien a fin de analizar dicho aprendizaje (área de investigación referida en inglés como Learning Analytics). Por ejemplo, dentro de las aproximaciones de diseño, el guionado define a priori la secuencia de tareas, recursos y otros elementos de apoyo que ayudarán a los alumnos a interactuar y colaborar a lo largo de la situación de aprendizaje. Desde el lado del análisis del aprendizaje, un tipo de estrategia es la monitorización, la cual analiza las interacciones de los participantes durante la situación de aprendizaje y facilita la intervención a fin de redirigir dicha situación de forma que sea más eficiente.

Aunque estas dos estrategias (guionado y monitorización) pueden ayudar a los docentes en la orquestación de los escenarios CSCL, su aplicación no les exime de problemas. A pesar de haber definido un guión de aprendizaje, pueden sugir contratiempos que pongan en riesgo el plan incial. Además, aunque el análisis de las interacciones de los alumnos puede proporcionar información relevante sobre cómo se desarrolla el proceso de aprendizaje, los resultados que las propuestas existentes suelen ofrecer no son fáciles de interpretar. Por ello, los docentes carecen a menudo de información relevante que les permita intervenir y adaptar sus planes a medida que evoluciona el escenario de aprendizaje.

Son varios los investigadores apuntan que la alineación entre el guionado y la monitorización puede traer consigo sinergias como mejorar las evidencias monitorizables o proporcionar al docente análisis relacionados con sus decisiones pedagógicas. A mayores de estas propuestas teóricas, existen algunas soluciones tecnológicas que dan soporte al alineamiento através de herramientas concretas como foros o lienzos colaborativos. Sin embargo, pese a la ventajas previstas por las propuestas teóricas y los resultados positivos obtenidos por las soluciones tecnológicas existentes, no hemos encontrado trabajos que estudien las sinergias entre guionado y monitoriación en relación a las necesidades genéricas de los escenarios CSCL mixtos (i.e., sin estar vinculados a un tipo concreto de herramienta o actividad, y teniendo en cuenta tanto las interaccciones cara a cara como las mediadas por tecnología).

Para dar respuesta a estas necesidades, el principal objetivo de esta investigación es ayudar al docente a monitorizar si se verifican su decisiones de diseño en contextos CSCL mixtos. Siguiendo la aproximación de hacer converger guionado y monitorización, proponemos proporcionar al docente con soporte para el diseño y la gestión que le permita conectar sus intenciones pedagógicas y sus necesidades de monitorización. Además, en esta tesis se presta especial

atención a los escenarios de aprendizaje soportados por Entornos de Aprendizaje Distribuidos (DLEs, del inglés Distributed Learning Environments), los cuales integran plataformas existentes (e.g., entornos de aprendizaje virtual como Moodle o Sakai) con herramientas externas (típicamente, herramientas Web 2.0 como wikis, blogs o editores colaborativos on-line). Estos entornos tecnológicos son cada vez más comunes en la práctica docente actual pero, al mismo tiempo, hacen el diseño y la gestión del escenraio de aprendizaje, si cabe, más complejo.

Nuestra propuesta pretende abordar varios retos a los que el profesorado debe enfrentarte cuando trata de alinear las dos estrategias mencionadas anteriormente. El primer reto que nos encontramos es la *falta de atención a las necesidades de monitorización que tiene el docente* cuando este diseña el escenario de aprendizaje, causando, en ocasiones, trabas a la monitorización. En esta tesis se propone un *proceso de diseño de guiones CSCL que integra los aspectos de monitorización*, para ayudar al profesor en la identificación e inclusión de dichos aspectos a lo largo del proceso de diseño de un escenario CSCL. Este proceso describe los pasos que el docente debe seguir durante el diseño a fin de reflexionar en sus necesidades de monitorización y expresar sus expectativas sobre las interacciones de los estudiantes.

El segundo reto al que nos enfrentamos es el hecho de que *las propuestas actuales de monitorización no contemplan las decisiones de diseño del docente*. En este trabajo pretendemos informar a los profesores sobre el cumplimiento de sus decisiones de diseño, contribuyendo así a la detección y regulación de problemas que emerjan durante la situación de aprendizaje. Para este fin, ha sido formulado un *proceso de monitorización de escenarios CSCL que tiene en cuenta el guión elaborado por el docente*. Este proceso expone cómo las decisiones pedagógicas recogidas en el guión pueden guiar la recogida y análisis de los datos, para así proporcionar al docente información de monitorización relacionada con el diseño de aprendizaje. Además, hemos definido un *modelo de guiones CSCL que integra los aspectos de monitorización* para conectar los procesos de diseño y monitorización. Aparte de describir las relaciones entre el guionado y la monitorización, el modelo también da soporte al flujo de información entre los dos procesos propuestos en esta tesis. Por un lado, el modelo representa el resultado del proceso de diseño, ofreciendo una vista conjunta de las decisiones pedagógicas y de monitorización tomadas por el profesor. Por otro lado, el modelo especifica los datos que han de recogerse y los criterios de análisis que han de ser aplicados en la monitorización.

El tercer reto que ha de ser superado en el contexto de esta tesis se refiere a *los problemas que dificultan la recogida e integración de los datos en escenarios CSCL soportados por DLEs*, derivados de la naturaleza heterogénea y distribuida del entorno tecnológico. Por ejemplo, los datos que han de recogerse están descentralizados y cada herramienta utiliza sus propios formatos y modelos para almacenarlos y representarlos. A ello se añade que, en ocasiones, los datos no sólo son generados automaticamente por el soporte tecnológico (e.g., mediante logs de eventos), sino también ad-hoc por los propios participantes (como puede ser el caso de las observaciones realizadas por el docente). Para superar estos obstáculos hemos propuesto una *arquitectura para la recogida e integración de datos en DLEs*, que proporciona una solución conceptual para la recogida e integración de las acciones realizadas por los participantes durante la situación de aprendizaje, en entornos distribuidos.

La metodología aplicada en esta tesis sigue una aproximación de investigación basada en diseño (Design-Based Research, DBR). El proceso de investigación está compuesto por tres iteraciones y un total de siete estudios en escenarios CSCL auténticos. Las dos primeras iteraciones fueron principalmente exploratorias y nos llevaron a la formulación de las cuatro propuestas presentadas en este documento. En cambio, la tercera iteración se centró en la evaluación de tales propuestas. El diseño de la tercera iteración fue guiado por el Método de Evaluación Receptivo centrado en el Evaluando CSCL (en inglés, Computer Supported Collaborative Learning Evaluand-oriented Responsive Evaluation Model, CSCL-EREM), el cual está especialmente dirigido a la evaluación de estrategias y herramientas CSCL. El proceso de evaluación se centró en dos estudios realizados en contextos CSCL auténticos en los que se aplicaron métodos mixtos, i.e., utilizando varias técnicas de recogida y análisis de datos tanto cuantitativas como cualitativas.

Los resultados de la evaluación sugieren que el modelo, los procesos y la arquitectura propuestos en esta tesis pueden ayudar a los profesores en el alineamiento entre sus intereses pedagógicos y de monitorización. Además, de acuerdo con las profesoras que participaron en la evaluación, las propuestas mencionadas anteriormente son susceptibles de aplicarse en la práctica real. Además, la alineación entre el guionado y la monitorización ha probado ser útil para dar soporte a las profesoras en la orquestación de escenarios CSCL auténticos. No obstante, la evaluación también permitió identificar algunas deficiencias, apuntando así algunas líneas de trabajo futuro: proporcionar al docente con soporte tecnológico que le permita diseñar y monitorizar a los estudiantes de forma autónoma (sin la intervención por parte del investigador), explorar la posibilidad de proporcionar información de monitorización al alumnado, o buscar formas de escalar las propuestas desarrolladas en esta tesis.

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Chapter 1

Introduction

Summary: This chapter describes the general research context of the dissertation, its goals and the methodology followed to attain such goals. The dissertation deals with the alignment of Learning Design and Learning Analytics approaches in blended CSCL. Particularly, we intend to provide teachers with design and enactment support capable of linking pedagogical intentions with monitoring needs for orchestrating blended CSCL scenarios, in the technological context of DLEs. To achieve this objective, we have identified three main problems to overcome: at design-time, teachers do not frequently reflect on their awareness needs regarding the learning process; monitoring solutions usually do not take into account teachers' design decisions; and gathering and integrating data in such heterogeneous and distributed contexts represents a technological challenge in itself. Following a DBR methodology that entailed seven authentic studies, we have formulated four contributions, targeted mainly at teachers and developers, in order to address the aforementioned problems that hamper the alignment between scripting and monitoring. For the evaluation of our solutions, we use a mixed-methods approach framed within a responsive, evaluand-oriented model for evaluation of CSCL (CSCL-EREM). Finally, this chapter outlines the general structure of the rest of the dissertation.

1.1 Introduction

With the introduction of ICTs (Information and Communication Technologies) in education, new learning contexts have emerged. Nowadays, it is increasingly common to encounter *blended learning* [Gra05] scenarios that combine face-to-face and distance activities, developed at different social levels (individual, group or whole-class) and across different locations (classroom, home, museums, etc.) [Sha12]. Besides, *Distributed Learning Environments* (DLEs) [Mac10] that combine learning platforms (e.g., mainstream Virtual Learning Environments such as Moodle or Sakai) with external tools (typically, Web 2.0 tools such as wikis, blogs or Google applications) are becoming popular in current pedagogical practice. The new opportunities that these technologies offer usually go hand in hand with a number of challenges dealing with their integration in authentic educational settings. Both of them, opportunities and challenges, are addressed by the Technology-Enhanced Learning (TEL) research community.

The management of technology-enhanced classrooms, also known as *orchestration* [Dil11b], represents one of the grand challenges of the TEL community [Sut12]. Although the orchestration load may be distributed among the participants of a learning scenario, teachers are frequently the ones in charge of it. Among the tasks that this teacher orchestration entails, we can mention the structuring of learning activities, intervening at any time to adapt these activities, re-organising groups, etc. Acknowledging the complexity and time-demanding nature of these tasks, research areas such as Learning Design (LD) and Learning Analytics (LA) have tried to support teachers and students in this endeavour. For instance, some LD solutions guide practitioners in the definition of the learning plan, and a number of LA works provide feedback that may inform different orchestration aspects like awareness, assessment, or even design [Sie12a].

Although orchestration is crucial in most forms of TEL, it is especially critical in areas such as *Computer-Supported Collaborative Learning* (CSCL) [Sta06], where one of the major difficulties relies on orchestrating the learning scenario so as to produce effective collaboration [Fis06] [Dil13]. Also in the area of CSCL, several strategies may be adopted to support collaboration, assuming either a Learning Design or a Learning Analytics perspective [Jer04]. An example of LD approach to promote collaboration is *scripting*. This technique is oriented to define, before the interaction begins, the sequence of learning tasks, resources, and scaffolds that will help students to interact and collaborate throughout the learning situation [Dil02a]. From a LA perspective, *monitoring* also aims at fostering effective collaboration by analysing participants' interactions at run-time, to facilitate interventions that make the collaborative situation more productive [Sol05]. These two strategies, far from being incompatible, complement each other: even if we script the learning scenario beforehand, eventualities may emerge at run-time that jeopardize the initial plan – and monitoring may help to detect and act upon such deviations [Dil11a].

Previous research has pointed out that synergies may appear when learning design and analytics are aligned. As some authors state, this tandem offers the opportunity to better understand student behaviour and provide pedagogical recommendations when deviations from the original pedagogical intention emerge [Loc11] [Loo11]. More concretely, in the area of CSCL, Lockyer et al. propose a conceptual framework to consider learners' expected behaviours and interactions in the learning analytics process of CSCL scenarios [Loc13]. With this framework, its authors address one of the challenges posed by LA: interpreting the resulting data against the original pedagogical intent and the local context, to evaluate the success (or otherwise) of a particular learning activity [Sut12]. Goodyear and Dimitriadis highlight that the designers of a learning scenario should not just focus on what students are expected to do. Rather, they should also look forward and take into account other aspects such as orchestration (providing support for the teacher's work during the learning process [Kar10]) or reflection (ensuring that actionable data is gathered at learn-time, to inform awareness [MM11b] and assessment [VF09b]) [Goo13]. Furthermore, Martínez-Monés et al. suggest that the alignment between pedagogical and informational needs is crucial in order to integrate Learning Analytics into mainstream CSCL practices [MM11b]. In addition to these conceptual works, there exist a few concrete technological solutions that implement such alignment, for tasks involving collaborative canvases [Gij13] and scripted forums [Mag10].

Despite the benefits of the alignment envisioned by the aforementioned theoretical proposals, and the positive results identified by the concrete technological solutions, to the best of our knowledge there is no work dealing with its generic application to blended CSCL scenarios. Additionally, none of the existing technological solutions addresses (as far as we know) the case of DLEs, which are becoming increasingly popular in current pedagogical practice but, at the same time, make the design and management of the learning scenario even more challenging. Thus, this dissertation aims to advance in the understanding of this alignment between scripting and monitoring techniques, aiming to support teachers in the orchestration of authentic CSCL scenarios supported by DLEs.

In order to introduce the reader to the work carried out in this dissertation, the rest of this chapter is structured as follows: the following section details the main goal of the dissertation, as well as the partial objectives that have been set towards such goal; Section 1.3 describes the methodology that has been used throughout the research process; and Section 1.4 summarizes the structure and contents of the rest of the document.

1.2 Dissertation goals and contributions

Given the research context mentioned above, we can formulate the *main objective* of the thesis as: *"To provide teachers with design and enactment support capable of linking*[1] *pedagogical intentions with monitoring needs for orchestrating blended CSCL scenarios supported by DLEs"*. From the pedagogical point of view, we have focused this dissertation on blended CSCL, since the orchestration of this type of scenarios is especially complex and demanding for teachers [Dil07b] [Dia10]. In addition, we have chosen DLEs as our main technological context because gathering and integrating heterogeneous and scattered data in this kind of technological context is still an open issue for TEL researchers [Scl08] [Fer12], which has not been addressed in the existing proposals related to the alignment between scripting and monitoring in CSCL (see the previous section).

In order to achieve the aforementioned main objective we have defined three *partial objectives* summarized below, and depicted in Figure 1.1:

1. **To support teachers in identifying and including monitoring aspects throughout the design process of CSCL scenarios (OBJ_DES).** As Martínez et al. already mentioned in [MM11b], monitoring concerns are not usually taken into account during the design of the learning scenario. Supporting teacher reflection about their monitoring needs is crucial because the decisions made at design-time may affect the quality of the monitoring results (e.g., the selection of learning tools has an influence on the data that can be retrieved). In addition, guiding teachers to express their monitoring needs may contribute to provide more suitable information for the regulation of the learning process (e.g., what information they need to know [Dyc13] or when they need to receive this information [Vat11]). Thus, in this dissertation we propose and evaluate a *monitoring-aware design process of CSCL scripts (C#1)*, to help teachers take into account their monitoring concerns in the design process of CSCL scenarios. Concretely, this process addresses macro-scripts (as opposed to micro-scripts), which are characterised by their coarse granularity and their emphasis on the orchestration of learning activities [Dil07a].

2. **To provide teachers with awareness information about the evolution of the CSCL situation, related to the learning design decisions (OBJ_MON).** Even if

[1] Even though the terms 'link', 'alignment' and 'integration' may have different connotations for the reader, we should notice that, throughout this manuscript, these terms are frequently used as synonyms when we refer to the relation that we want to establish between scripting and monitoring.

the analysis of the students' interactions may generate useful insights on how the learning process unfolds, teachers often lack relevant information to eventually intervene and adapt their plans at run-time [Gwe11]: the information that current proposals provide to the teachers is not always easy to interpret [Sut12] or does not respond to teachers' concerns [Dyc13]. Besides, existing learning analytics solutions frequently provide highly detailed accounts of the collaboration (e.g., by means of semi-automatic analysis of audio or video data) that are difficult to handle [Dri05] [Kah11]. To solve this problem, researchers in TEL suggest that teachers need meaningful information presented in an efficient and useful way, connected to their pedagogical intentions, that allow them to monitor their students in learning-time [Sut12]. As Soller et al. point out, contextualizing the analysis of the students' interactions with the pedagogical decisions made at design time may offer a perspective of the learning situation closer to the teachers' point of view, and be more actionable in order to regulate the learning situation [Sol05]. To provide teachers with meaningful data, we propose to inform them about the accomplishment of their design decisions (i.e., the scenario's 'desired state'). Moreover, to ease the use of this information during the enactment of the learning scenario, we hypothesise that providing coarse-grained feedback may simplify the interpretation. The definition of the 'desired state' of the learning situation leads towards the formulation of a *monitoring-aware design model of CSCL scripts (C#2)*, which integrates the pedagogical and monitoring decisions made during the aforementioned design process (C#1). The steps required to gather and model the data available in the learning scenario (i.e., the 'current state') as well as the comparison with the 'desired state' are compiled in a *script-aware monitoring process of CSCL scenarios (C#3)*, another contribution of this dissertation.

3. **To support the automation of the monitoring data gathering and integration tasks in blended CSCL scenarios supported by DLEs (OBJ_DAT).** Although technology enhanced learning contexts (such as CSCL scenarios) offer the possibility to store and analyse large amounts of educational data [Sie11], there are some problems that hinder the data gathering and integration [MM11b]. For example, some tools do not register users' interactions; there is no standard format to store and model these data, and consequently each tool follows its own approach; and frequently, applications do not provide ready-to-use data (rather providing streamed data or low-level interactions). These obstacles enlarged whenever the technological context is heterogeneous and decentralised, as it happens in DLEs, or whenever monitoring data are not generated automatically through technological means, but rather provided ad-hoc by the participants. Thus, the use of architectures that integrate the different data sources plays a crucial role. Due to the complexity of the data gathering and integration [Fer12] and the time required to carry them out manually, the automation of these tasks seems a clear need. This is especially the case if we expect teachers to react on time during the enactment of the learning situation [Gwe11]. To address this challenge we have proposed an *architecture for data gathering and integration in DLEs (C#4)* that represents the fourth contribution of this thesis.

It should be noticed that, due to the nature of the methodological approach chosen in this dissertation (Design Based Research), both the main and the partial objectives have emerged and evolved throughout the research process itself, as we will describe in Chapter 3. However, for the sake of clarity we will present them here in their final state. The partial objectives tackle three outstanding challenges emerging from the literature on the alignment of monitoring and scripting, as well as from our own observations in CSCL scenarios (see Chapters 2 and 3). Even though these contributions address different problems and can be used separately (e.g., using only the design process, or just the architecture), they are closely connected and they have informed each other during the research process.

1.3 Research methodology

The work presented in this dissertation is framed within the multidisciplinary CSCL paradigm [Kos96] [Sta06]. In our case, the factors that impact the research questions were expected to emerge and evolve during the process, as a consequence of the knowledge gained by the researchers throughout the different phases of the study [Bro92]. The nature of this research context and of the goals pursued in this work made us discard a positivist methodological approach, where all the variables are known in advance and can be controlled. Rather, as several researchers suggest, the multidisciplinary nature of CSCL implies a need for mutual understanding among the involved stakeholders, demanding active participation of all these stakeholders during the whole development cycle of CSCL solutions [H02̈] [Sta06]. Hence, since teachers are our target users, we decided to involve them from the very beginning in the formulation of our proposals [Ken98] [Mul93]. These research context characteristics led us to choose *Design-Based Research* (DBR) [Bar04] as the methodological framework for the research work reported in this dissertation.

Design-Based Research is a systematic but flexible research approach aimed at improving educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories [Bar04]. The research work presented in this dissertation complies with the main DBR criteria [And12]:

- **Iterative research process.** Following the DBR approach, we defined a set of research questions (listed in Table 1.1) related to the dissertation goals presented in Section 1.2. These research questions were broken down into exploratory and evaluative questions [And07], and three iterations –two exploratory and one evaluative– were carried out to answer them (see Figure 1.2). Regarding the number of iterations, since most DBR projects go through three or more iterations [And12], we have tried to achieve this number within the time-frame available for the development of the thesis.

  The main purpose of the first and second iterations was to gather information about the exploratory questions (addressed in Chapter 3). Based on the results obtained, we proposed a model to represent the relations between scripting and monitoring, formulated design and monitoring processes for CSCL scripts to support teachers in the integration of pedagogical and monitoring concerns, and proposed an architecture that enables the data gathering and integration of users' interactions in DLEs (that is, the four contributions presented in Section 1.2).

- **Research situated in real educational contexts.** CSCL research's focus on the social context, as well as the importance of contextual factors in orchestration, led us to evaluate our contributions in authentic educational settings. This approach fits properly with

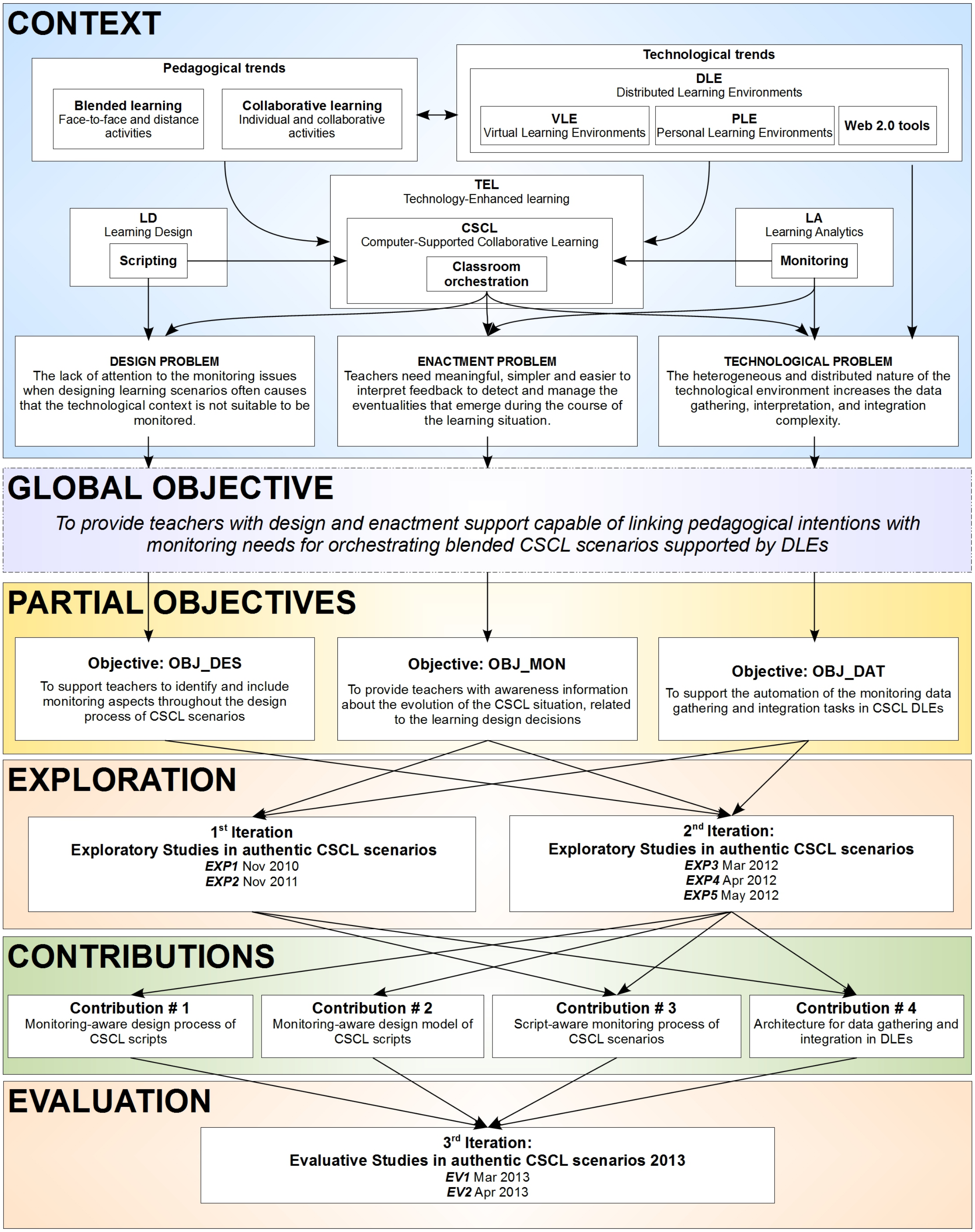


Figure 1.1: General overview of the context, objectives and contributions of this thesis, as well as the exploration and evaluation work carried out during the research process. The labels EXPn designate the exploratory studies and EVm, the evaluative ones.

Table 1.1: Research questions addressed in this dissertation. The labels *RQ_DES*, *RQ_MON*, and *RQ_DAT* depict research questions related to the design, monitoring and data gathering and integration in CSCL scenarios, respectively.

Main Research Question
Does the alignment of scripting and monitoring provide teachers with relevant information about the learning process in CSCL scenarios supported by DLEs?
Secondary Research Questions
RQ_DES: How can we support teachers in taking into account monitoring concerns in the design process of CSCL scenarios? *RQ_MON*: What script information is necessary to guide teachers and technology in the monitoring process of CSCL scenarios? *RQ_DAT*: How can we facilitate the data gathering, interpretation and integration of users' interactions in blended CSCL scenarios supported by DLEs?

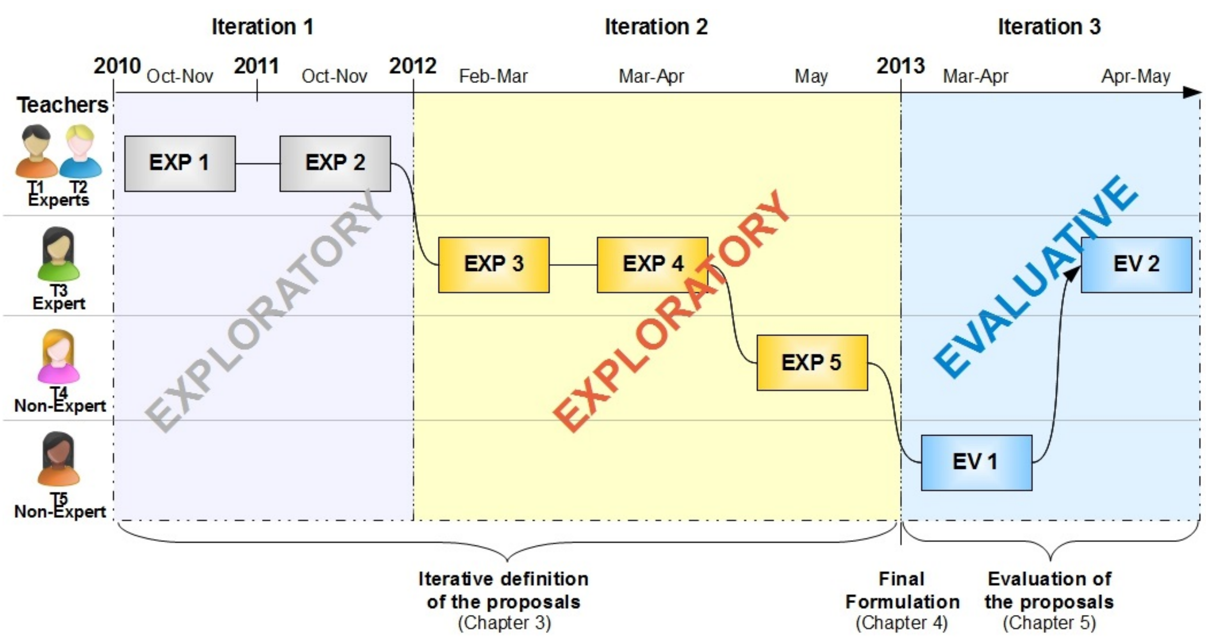


Figure 1.2: Overview of the iterations and studies carried out throughout the DBR process. The labels EXPn represent exploratory studies and EVm, the evaluative ones.

DBR, since situating the research in real educational contexts validates and ensures that the applied proposals can be effectively used to assess, inform, and improve practice in (at least) those contexts [And12]. In this dissertation, seven studies in naturalistic CSCL scenarios [Bar04], chosen by theoretical sampling [Gub81], make up our three-iteration DBR. These studies were connected to seven courses carried out at the University of Valladolid (Spain) between October 2010 and May 2013, involving five teachers and a total of 365 students from three different degrees ("Bachelor on Telecommunications Engineering", "Master's Degree for Pre-service Secondary Education Teachers" and "Bachelor on Early Childhood Education"). These scenarios present a common profile: they included blended

CSCL scenarios interleaving face-to-face and distance activities; they combined individual and collaborative learning activities (face-to-face and computer-mediated), technologically supported by DLEs; they all comprised a time frame of between two and four weeks per scenario; and they all involved participants in higher education contexts.

- **Collaborative partnership between practitioners and researchers.** The partnership in a design-based research study allows to overcome two main problems: teachers' usual lack of time to conduct rigorous research, and researchers' lack of knowledge about a specific learning context [And12]. During this DBR process, participant teachers have closely collaborated with the researcher: teachers contributed with their knowledge of the local setting and their pedagogical background, while the researcher intervened providing advice on the design decisions, monitoring reports during the enactment, and developing technological solutions that supported the emergent proposals.

  The teacher-researcher tandem favours the achievement of two DBR purposes: to have *actual impact on practice*, overcoming existing problems of the particular learning scenarios and improving the teachers' practice; and, based on the lessons learnt, to *evolve the theoretical principles* that underlay the research work. In this thesis, we expect to have an impact on practice by helping the teachers involved in our studies to foresee the awareness information that they will need, to design their learning scenarios taking into account to these needs, and to understand what is happening in the learning process, so that they can regulate the scenario towards a potentially more productive direction. Besides, we expect to contribute to the research lines that converge in this dissertation, by means of our four proposals.

- **Focus on the design and testing of a significant intervention.** According to Brown, an effective intervention should be transferable from experimental classrooms to average classrooms involving average students and teachers [Bro92]. This point of view is also aligned with Dillenbourg's perspective, which emphasizes that pedagogical methods must be adaptable to differences between teachers (both the average-skilled and the exceptional ones) [Dil10]. Thus, our selection of participant teachers was not done at random (Figure 1.2 offers an overview of the teacher associated to each study). We followed the recommendations given by Muller et al., who propose that the appropriated number of people involved in a participatory design is between 2 and 4 [Mul93]. For the first two studies of the dissertation, we involved two teachers who usually integrate CSCL in their courses. Their background in CSCL scenarios gave us the opportunity of learning from their practice and identifying the problems that expert teachers face when orchestrating a CSCL scenario. The third teacher was involved not only in the exploratory studies but also in the evaluation. There were reasons related to her background that made her suitable for the purposes of the study: a) this teacher had taught for several years in scenarios supported by ICT tools, usually including scripted CSCL scenarios during her courses; and b) she had also been involved in CSCL scenarios where interaction analysis was used to better understand the learning process. Thus, her dual expertise using scripting and monitoring (separately) could be very helpful to identify the connections between these two strategies. On the other hand, there were also methodological reasons for this choice, aligned with the DBR principles. This teacher was interested on improving her practice, and she was willing to collaborate with us on a continuous basis for two years. Therefore, her participation gave us the chance of iteratively refining the proposal with an individual who knew the context in depth. In addition, we involved teachers with relatively little experience in CSCL, one in the second exploratory iteration and one in the evaluation. With these two latter teachers, we could verify whether non-expert teachers found additional difficulties and whether our proposal was also suitable for them.

- **The use of mixed methods.** Mixed methods [Gre01] [Cre03] typically involve a variety of quantitative and qualitative techniques. This approach is generally considered to be an adequate way of exploring the different perspectives and multiple factors that affect learning situations, and it is typically used in DBR [And12] [Des02] and CSCL [Jeo10]. Furthermore, many researchers advocate for an opportunistic selection of data gathering and analysis techniques that better suit the evaluation goals [Max03] [Joh04]. In this research, qualitative and quantitative data were gathered from different sources –teachers, students, ICT tools and researchers– to obtain information about the participants' profile and background, the use of the proposed contributions, and reflections on such use. We used qualitative sources such as open questionnaires, observations, semi-structured interviews and focus groups, and quantitative sources such as closed questionnaires and automated gathering of users' interactions.

Albeit naturalistic studies have the disadvantage of not being designed to provide generalizable findings, we describe extensively the different educational context so as to increase the *transferability* [Gub81] of the thesis's artefacts to similar educational contexts. For that reason, this research tries to carefully document the context, purpose, and contingencies of each study, so that readers can judge for themselves the possibility of achieving similar results from the use of the proposals in their own contexts [Orl91]. This concern has led us to adopt the *CSCL Evaluand-Oriented Responsive Evaluation Model* (CSCL-EREM) proposed by [JA09], in order to present the studies in a structured way. The CSCL-EREM provides an action-oriented guidance to evaluate educative innovations, learning resources, teaching strategies or technological support, taking into account that CSCL scenarios may be affected by multiple variables that emerge during the process.

In order to increase the *credibility* of our results we have used mixed data gathering techniques as well as a variety of informants in order to provide multiple perspectives that allow the triangulation [Gub81] and generation of rich evaluation outcomes. In addition, we have striven to accumulate evidence from different educational contexts and to make it traceable [Gub81] (see Appendix H for a further description of the additional material attached to this document). Finally, in order to minimise the bias caused by the involvement of the researcher in the scenarios [Bar04], we relied on the participation of two external researchers, who contributed with their views to the elaboration of the proposals.

1.4 Structure of the document

In Chapter 2 we can find a literature review of the different research lines addressed in this dissertation, including Learning Design and Learning Analytics, with a special focus on scripting and monitoring. Also, the main pedagogical and technological research contexts of the thesis are described in this chapter: blended learning, CSCL and current trends in the use of DLEs. Finally, we analyse the problems that appear when we try to align scripting and monitoring in blended CSCL scenarios supported by DLEs.

Chapter 3 synthesizes the outputs of the exploratory iterations that laid the base for the formulation of the contributions, while a complete description of the exploratory studies has been included at the end of this document (Appendices C to G). We believe this split description format supports the reading styles of different readers (e.g., those wanting to go deep into the raw evidence, as well as those rapidly scanning for the main results).

Although the formulation of the contributions evolved throughout the exploratory period, Chapter 4 presents the main contributions of this thesis in their final stage (for the sake of clarity): a monitoring-aware design process of CSCL scripts, a monitoring-aware design model of CSCL scripts, a script-aware monitoring process of CSCL scenarios, and an architecture for data gathering and integration in DLEs.

The main contributions presented in Chapter 4 were evaluated in two studies carried out in CSCL scenarios. Chapter 5 describes the evaluation methodology, the evaluative studies themselves, and the evaluation results.

Finally, the dissertation's conclusions are drawn out in Chapter 6, highlighting the relevance of our findings for the CSCL and TEL research communities, as well as their implications for other educational contexts and related research areas. Furthermore, limitations of the presented work and directions for future research are outlined.

The dissertation's appendices include supplementary material such as the analysis of Collaborative Learning Flow Patterns constraints performed during the dissertation (Appendix B), the detailed descriptions of the exploratory studies (Appendices C to G), and a list with the meaning of all acronyms used in the dissertation (Appendix A).

Chapter 2

State of the art

Summary: The aim of this chapter is to present the domain problem of the dissertation, putting into focus the specific challenges that it undertakes. First, we introduce the type of learning scenarios addressed in this dissertation from the pedagogical and technological point of view: the former focused on blended learning and CSCL, the later on the use of VLEs, PLEs, and Web 2.0 tools to make up DLEs. The complexity of these scenarios leads us to review the orchestration aspects and to identify challenges for teachers. Then, we present existing LD and LA strategies, such as CSCL scripting and monitoring, that may aid teachers in this endeavour. Although these strategies have proved to be helpful in the orchestration of blended CSCL scenarios, several authors point out that even more benefits could appear if they are aligned. This chapter will help us identify problems that hinder the alignment of CSCL scripting and monitoring in DLEs. The selected problems will be explored throughout the rest of this dissertation.

2.1 Introduction

Let us imagine the following scenario: David is a computer scientist. He worked for several years as a teacher in non-formal educational settings in parallel to his research life in atmospheric optics. Recently, he has started his new job at the Université des Sciences et Technologies de Lille where he has to teach a course on "atmospheric components and optical methods" to 67 students. The course requires 6 ECTS credits[1], i.e., his students will need 150 hours of work to complete all learning activities. 33% of these activities will be *face-to-face* (e.g., lectures, seminars, and examinations) and 67,77% *distance* (e.g., projects, practical work or self-study).

Aware of the "21st Century skills" and "key competences" needed for global citizens and workers [Ana09] [Red11], David knows the important role that *collaboration* and *technological literacy* play in the learning process of his students. Thus, he has in mind to introduce these two elements in his course, promoting *computer-supported collaborative learning* (CSCL) [Kos96]. The university provides an institutional *virtual learning environment* (VLE): a Moodle platform. That is not bad, Moodle offers some features that make it suitable for CSCL [Dil02b]: it allows the definition of activities and social structures of users (e.g., groups); it supports synchronous and asynchronous interactions; it can be used both in face-to-face or distance activities; and it offers a variety of tools useful for collaborative learning (e.g., chats, fora, collaborative editors).

[1] European Credit Transfer and Accumulation System `http://ec.europa.eu/education/tools/ects_en.htm` (Last visit: 30 January 2013)

However, there are some issues that do not match exactly with David's plans. For example, there are some specific functionalities related to the course domain that the teacher is looking for [Tch13]. Certain activities will require the use of CAELIS[2], a *Web 2.0 tool* designed to analyse atmospheric components (aerosol particles, water vapour, ozone, etc.) with optical in situ and remote sensing techniques. Besides, David wants that students work in groups and, at some point, they will have to produce a joint report. If he imposes the use of the editor provided by Moodle, some students may have problems if they are not familiar with the tool [Bow11], so that he opts for a wider-spread, on-line editor such as Google Docs. This melange of technologies makes up a *distributed learning environment* (DLE) [Mac10] that better satisfies David's needs but will require him and additional effort in the setting up [AH13].

David is wondering how he can guide and assess students, deal with the technological infrastructure, cope with emerging problems during the course, etc. In other words, how to *orchestrate* the learning scenario [Dil09b]. Besides, he knows that coordinating collaborative groups is not exactly 'a piece of cake': effective collaboration, usually, does not appear by chance [Dil99], in group activities students are likely to cooperate rather that collaborate, and sometimes there are people who do not participate. More or less, David will witness the third part of the students' work (the face-to-face one). Thereby, the greatest part of the learning process will happen out of his scope (e.g., at home, at the library, or through the technological environment) [Gwe11][Fer12]. Analysing participants' computer-mediated interactions may provide him some additional hints of the students' progress [Dil11b]: Moodle gives him some clues about the students' activity within the platform; Google Docs also facilitates some data (e.g., looking at the revision history he could identify who has participated); and, dealing with CAELIS, there is no ready to use data to support the monitoring process, however the system registers some traces and he is thinking about the possibility of inferring some information from that source (he is a computer 'geek'). Hence, gathering and integrating evidence of the 67 students in such distributed learning environment will require him a lot of time [Fer12], and probably he will not be able to have the information ready to eventually intervene and adapt his plans at run-time [Gwe11][Dyc13].

Putting the situation into perspective, it is true that he is an enthusiastic of ICTs and collaborative work, and education paradigms are supposed to be shifting to include blended learning and collaborative models [The13] but ... David sets out a question: *"Should I really get into all these problems? Is it worth the effort?"*. To mitigate these concerns, there are different strategies coming from research areas such as Learning Design (LD) and Learning Analytics (LA) that try to promote and make easier the adoption of TEL among teachers [Sut12]. In the case of CSCL, *scripting* and *monitoring* are two approaches to support teachers orchestrating learning scenarios [Jer04].

As we will see in this chapter, scripting and monitoring have proved to be helpful for different orchestration aspects such as design or awareness [Pri11b]. For instance, some existing scripting proposals may help David in the design of the CSCL script and the instantiation in the DLE [Pri13]. Besides, he could use the analytics provided by Moodle and Google to partially monitor the students' actions based on the indicators provided by these tools. But *"what if he could align both strategies"*. In that case, David could monitor the students' progress according to the pedagogical decisions made at design time [Loc11] [MM11b].

[2]CAELIS `http://www.caelis.uva.es` (Last visit: 30 January 2013)

This chapter reviews the main challenges of the orchestration of blended CSCL scenarios supported by DLEs, identifying (1) how the alignment between scripting and monitoring may contribute to support teachers in this endeavour, and (2) what are the obstacles that difficult the alignment. Figure 2.1 provides an overview of the topics that are covered in this chapter. Though this dissertation addresses a very concrete domain, the following sections present a more general review, taking into account previous works in the areas of DLEs, Learning Design, and Learning Analytics, both for CSCL and TEL, that have inspired our proposal. First, we present the pedagogical and technological context of the learning scenarios addressed in this dissertation. Second, we review the different aspects and factors that must be taken into account in the orchestration of such scenarios. Then, we describe how scripting and monitoring are used in CSCL. This review will help us identify the limitations of current proposals that hinder the alignment of these two strategies in blended CSCL scenarios supported by DLEs.

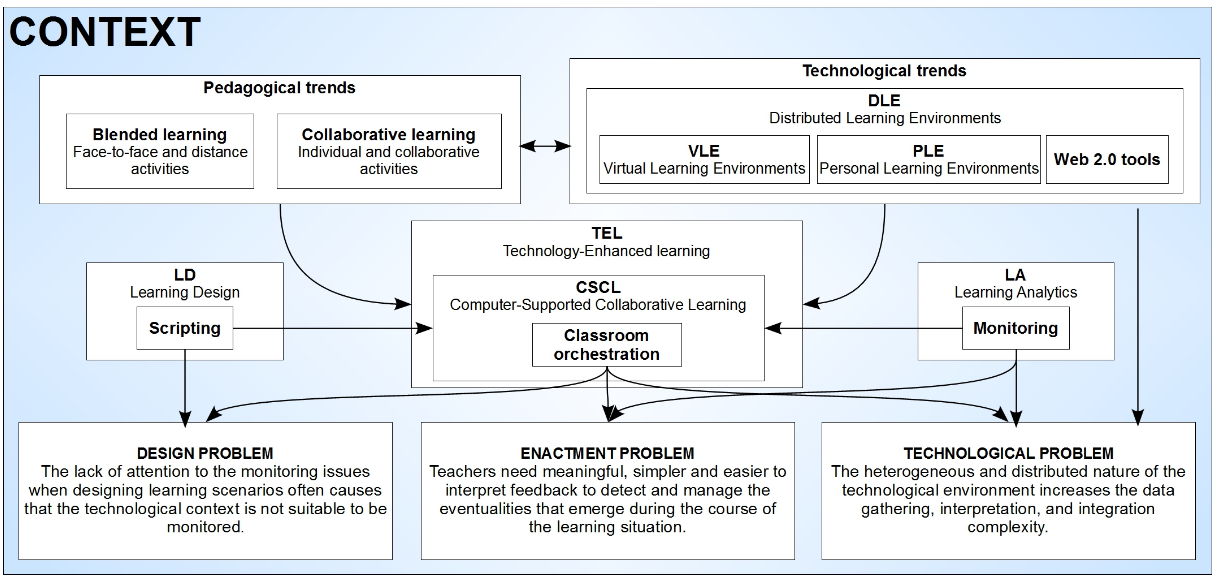


Figure 2.1: Diagram representing the research context of the dissertation, reviewed in this chapter. See also Figure 1.1

2.2 Current trends in TEL: blended CSCL scenarios and DLEs

As it has been mentioned in the previous chapter, this dissertation is framed within the wide research area of TEL. Concretely, we will mainly explore three current trends in education: those forms of TEL that try to *promote learning through collaboration* (commonly denominated Computer-Supported Collaborative Learning [Sta06]), *integrating both face-to-face and online learning activities* (i.e. blended learning [Gra05]), and combining different technological tools (i.e. *distributed learning environments* [Mac10]) for learning-teaching support. In this section we will review the most relevant concepts and bibliographic sources for blended learning and CSCL, with special emphasis on the peculiarities and challenges that blended CSCL activities pose.

2.2.1 Blended learning and CSCL

The Horizon report 2013 identifies, among the key trends in education, the shift of education paradigms to include blended learning and collaborative models [The13]. The developments in technology-supported learning offer different affordances than face-to-face learning, including opportunities for increased collaboration while equipping students with stronger digital skills.

Over the past few years, blended learning, also referred to as 'hybrid learning', has been widely adopted by institutions of all types [Dia10]. Even though blended learning has become somewhat a buzzword in TEL, there is usually quite a bit of ambiguity about what is meant when the term is used. There are some general definitions such as the one given by the Joint Information Systems Committee (JISC) -"the inclusion of multiple approaches to teaching and learning within a programme"- [BR06], or the one provided by So and Brush -"any combination of learning delivery methods"- [So08] that leave the door open to many kinds of learning. However, most commonly, blended learning refers to the combination of face-to-face with technology-supported learning activities [Kop05] [Gra05], some performed synchronously, some asynchronously [Dia10]. Rencetly, Pérez-Sanagustín proposed a wider different definition, using blend in a broad sense: blend of spaces, blend of activity types (formal and non-formal) and blend of technologies to integrate the activities [PS11a].

This dissertation will tackle a broad view considering blended scenarios that combine *face-to-face and technology-supported learning* as well as *presence and distance activities*, performed *synchronously and/or asynchronously* depending on the learning context. Besides, since our focus is to support teachers in the orchestration tasks, we will look mostly at blended learning occurring in *formal* settings (e.g., schools, universities), where teacher-centred orchestration challenges are more likely to occur.

Among the challenges of implementing blended learning scenarios, the EDUCAUSE Learning Initiative community (ELI) identified that, *teaching and learning effectiveness/faculty development* and *finding the time to research, develop, and implement blended courses* constitute the top challenges for teachers [Dia10]. Despite the benefits that the use of technologies may offer in education, there is no doubt that its integration in the classroom requires teachers an extra effort [Sel11]. As a result, some teachers are not as enthusiasm about TEL as they might be, and TEL is used less than expected [Sut12].

The current trend towards more collaborative models is represented in the TEL community by one of its core research areas: CSCL [Sut12]. This area emerged from Instructional Technology in the 1990's [Kos96], and builds on conceptual frameworks and analytic approaches of many academic fields, including education, psychology, communication, computer science and social science [Sta11]. However, the main distinctive feature of CSCL relies on its perspective concerning the implications of the social issues in the teaching and learning processes [Kos96]. That is, CSCL specifically approaches the support of social interactions among the students themselves, frequently, with a teacher playing the role of mediator or facilitator [Sta06].

Collaborative learning requires systematic efforts to work and learn together [Sta06] (as opposed to cooperation that refers to a mere assemblage of partial results corresponding to a divided task), and particular forms of interaction among people are expected to occur, triggering learning mechanisms. Since there is not guarantee that the expected interactions happen [Dil99], there are two main (complementary) strategies that may be adopted to support collaboration:

scripting (beforehand) a set of instructions that may lead to effective collaboration [Dil99]), and *monitoring* the collaboration at run-time, so that the teacher intervenes on the situation towards a more productive direction [Sol05].

If we introduce the characteristics of CSCL into the aforementioned description of our blended scenarios, a new dimension appears: a blended CSCL scenario also includes activities at various *social levels* (individual, group and class-wide activities) [Dil04]. Besides, in these scenarios, the teacher is not in the background, as in many e-learning environments. Instead the teacher is the conductor: (s)he orchestrates the sequence of activities and may change the scenario in real time [Dil07a].

These integration of CSCL in blended scenarios implies some additional complexity: both the learning flow and the technological support for the enactment have to be designed for promoting and enhancing interactions that may lead towards effective collaboration among learners [Dil07b]. Sections 2.2.2 and 2.2.3 present an overview of technological choices commonly used in blended CSCL.

2.2.2 Technological support: VLEs, PLEs, and Web 2.0 in CSCL

ICT tools are commonly employed to support teachers and students in the realization of very different tasks. Moreover, the ongoing evolution of ICTs and the capabilities of modern collaboration and communication tools open up new potential for supporting blended and collaborative learning [Sta11]. As an illustrative example, we have analysed the ICT tools that have appeared in the "Top 100 Tools for Learning" ranking[3], developed by the Centre for Learning & Performance Technologies (C4LPT), in the last few years. Table 2.1 provides an overview of the types of tools included in the rankings and Table 2.2 brings out the name of the top ten tools from 2008[4] to 2013.

Betbeder and Tchounikine group the ICT tools used in education into three categories [Bet03]: the ones devoted to specific pedagogical aims (e.g., a virtual lab for atmospheric analysis); the ones developed for educational purposes interesting in many domains (e.g., virtual learning environments); and those not specifically developed for educational purposes but can well be employed in the classroom (e.g., a text editor). If we look at Table 2.1, it shows that, according to the "Top 100 Tools for Learning', most of the voted tools were developed without educational purposes. Concretely, in 2013, the 79% were tools without educational purposes versus a 21% of educational ones.

Among the platforms developed with pedagogical purposes in mind, several studies have identified an incremental adoption of VLEs, PLEs and Web 2.0 tools in the last few years [Hug09] [Smi10a]. The "Top 100 Tools for Learning" also reflects this trend: the proportion of VLEs and PLEs among educational tools has gone from 16,67% to 33,33%, and the rise in the number of Web 2.0 tools has been 19,05% (at expense of the amount of desktop or device dependant tools). Table 2.1 shows how these values have evolved from 2008.

[3] Top 100 Tools for Learning: `http://c4lpt.co.uk/top100tools/` (Last visit: 03 January 2013). This ranking has been created based on the feedback provided by more than 500 learning professionals from 48 countries worldwide.

[4] Note that, though the survey has been carried out every year since 2007, due to the list published in 2007 is not currently available, it has not been included in the analysis.

Table 2.1: Analysis of the tools included in the ranking "Top 100 Tools for Learning". (*) Some tools are available both in Web2.0 and desktop format (e.g., Dropbox), in those cases they have been taken into account in both sets.

		2013	**2012**	**2011**	**2010**	**2009**	**2008**
Educational Purpose	Specific pedagogical purposes	2,00%	1,00%	2,00%	0,00%	0,00%	0,00%
	General educational purposes	19,00%	18,00%	18,00%	14,00%	13,00%	12,00%
	No educational purpose	79,00%	81,00%	80,00%	86,00%	87,00%	88,00%
Educational tools (*)	VLEs & PLEs	33,33%	31,58%	35,00%	42,86%	46,15%	16,67%
	Web2.0	52,38%	52,63%	40,00%	35,71%	30,77%	33,33%
	Desktop & device dependant	23,81%	26,32%	35,00%	21,43%	23,08%	50,00%
Tools not developed for educational purposes (*)	Web2.0	73,42%	71,60%	71,25%	70,93%	62,07%	53,41%
	Desktop & device dependant	35,44%	37,04%	35,00%	34,88%	42,53%	48,86%

Table 2.2: Top ten tools from 2008 to 2013 according to the ranking "Top 100 Tools for Learning". In this list, highlighted in *italic*, there are some desktop tools (PowerPoint, Evernote, Skype, Audacity and Firefox), the rest of them are Web 2.0 tools. There are also a few tools developed specifically for education purposes (Moodle and Glogster EDU), these ones appear in **bold**.

	2013	**2012**	**2011**	**2010**	**2009**	**2008**
1	Twitter	Twitter	Twitter	Twitter	Twitter	Delicious
2	Google Docs/Drive	Youtube	Youtube	Youtube	Delicious	*Firefox + addons*
3	Youtube	Google Docs/Drive	Google Docs	Google Docs	Youtube	Google Reader
4	Google Search	Google Search	*Skype*	Delicious	Google Reader	*Skype*
5	*PowerPoint*	Wordpress	Wordpress	Slideshare	Google Docs	WordPress
6	*Evernote*	Dropbox	Dropbox	*Skype*	WordPress	Google Search
7	Dropbox	*Skype*	Prezi	Google Reader	Slideshare	Google Docs
8	Wordpress	*PowerPoint*	**Moodle**	WordPress	Google Search	*PowerPoint*
9	Facebook	Facebook	Slideshare	Facebook	*Audacity*	**Moodle**
10	Google+/Hangouts	Wikipedia	**Glogster EDU**	**Moodle**	*Firefox + addons*	Blogger/Blogspot

The arrival of *VLEs, also known as Learning Management Systems (LMSs)*, is linked to the transition of Content Management Systems (CMS) towards more constructivist learning environments [Jon99]. VLEs are "designed to act as a focus for students' learning activities and their management and facilitation, along with the provision of content and resources required to help make the activities successful" [JIS06]. In the 'Top 100 Tools for Learning", the VLE best rated by learning professionals is Moodle[5], followed by Blackboard[6], Udutu[7], eFront[8], Composica[9], and Lectora[10]. Other VLEs that have been highly embraced in the educational community are LAMS[11], .LRN[12], Sakai[13] or Desire2Learn[14].

[5] `http://moodle.org` (Last visit: 03 January 2013)
[6] `http://www.blackboard.com` (Last visit: 03 January 2013)
[7] `http://www.udutu.com/` (Last visit: 03 January 2013)
[8] `http://www.efrontlearning.net/` (Last visit: 03 January 2013)
[9] `http://www.composica.com/` (Last visit: 03 January 2013)
[10] `http://lectora.com/` (Last visit: 03 January 2013)
[11] `http://www.lamsinternational.com/` (Last visit: 03 January 2013)
[12] `http://dotlrn.org` (Last visit: 03 January 2013)
[13] `http://www.sakaiproject.org/` (Last visit: 03 January 2013)
[14] `http://www.desire2learn.com/` (Last visit: 03 January 2013)

These platforms are frequently characterized by a set of features that make them suitable for blended CSCL scenarios where the teacher has a prominent role in the orchestration [Dil02b]: a) VLEs are designed information spaces co-constructed by tutors and students; b) VLEs are social spaces and most of them allow the definition of activities and social structures of users (e.g., groups); c) VLEs promote synchronous and asynchronous interactions, in a face-to-face or a computer-mediated manner; d) although these platforms were originally devoted to on-line learning [Eve07], they also support blended learning, enriching classroom activities; e) VLEs offer a variety of tools supporting multiple functions such as communication and collaborative tools (e.g., chats, fora, collaborative editors); and f) VLEs integrate heterogeneous technologies and they are usually based on web technologies, following a three-tiered client-server architectures [Eck95]. This suitability of VLEs for blended CSCL has been also posited by several studies, for instance using Moodle [Cal06] or Blackboard [Pri05].

Despite VLEs have been highly adopted -specially in schools [Smi10a], vocational training [JIS06] and higher education [Wel07]-, they are not the only widespread learning platforms. Aligned with the trends towards supporting personalised learning, lifelong learning and student-centric approaches, and in order to enhance not only formal but also informal learning, *PLEs* made their appearance in the educational landscape to help students take control of and manage their own learning. In these environments, students can access and share a range of resources, tools and services in an integrated way for supporting their own needs [ELI09]. Two PLEs, Edmodo[15] and Elgg[16], have appeared in the "Top 100 Tools for Learning" for several years. In addition, there are other well-known examples such as PLEX[17], ROLE[18] and, its successor, GRAASP[19].

Opposite to VLEs, in which educators or other staff are in charge of the selection and management of the resources and tools that students should use, PLEs directly involve learners in the access, aggregation, configuration and manipulation of lightweight tools and resources [Sev08]. In general, PLEs take a non-hierarchical approach that promotes students' self-regulation during their learning process [Zim92]. Besides, there are some additional properties that define PLEs [Gil12] [Dab12]: a) PLEs connect formal and informal learning; b) constructing the environment is part of the learning process; c) PLEs are personal but not individual, they may integrate peers, coaches, teachers or even relatives; d) each PLE is designed for a single context or purpose; e) a PLE should provide shared activity spaces (i.e. instantiation by an individual of a PLE constructed to support a dedicated learning activity), each space integrating itself people (enabling interaction), resources and tools, as well as subspaces; and f) despite the multiple differences, in technological terms, PLEs share many of the VLEs characteristics (web technology, three-tiered client-server architectures, etc). Even if PLEs are more focused on individual learning, the functionalities provided for social interaction make that PLEs may also be useful for the design and enactment of certain collaborative learning situations (e.g., ROLE and GRAASP [Gil10]).

Although PLEs are considered a very promising field in TEL, currently PLEs are less widely accepted than VLEs in formal learning. These kinds of personal technologies make difficult for a teacher to oversee, manage and adapt their practices to the progress of students

[15] `https://www.edmodo.com/` (Last visit: 15 January 2013)
[16] `http://www.elgg.org/` (Last visit: 15 January 2013)
[17] `http://www.reload.ac.uk/plex/` (Last visit: 15 January 2013)
[18] `http://www.role-project.eu/` (Last visit: 15 January 2013)
[19] `http://graasp.epfl.ch/` (Last visit: 15 January 2013)

[Bal13]. Nevertheless, the differences among them are starting to blur. On the one hand, there are some existing proposals that increase the flexibility of traditional VLEs, supporting more customization features for students, e.g., allowing students to select their own tools and to create learning resources [MnC13a]. On the other hand, there are some proposals to integrate institutions and teachers in PLEs. For instance, the Southampton Learning Environment [Whi11] extends the personal space with others spaces shared with the institution and tutors. Another example is the PLE proposed within the GO-LAB project[20], a PLE for the study of science in primary an secondary education. In GO-LAB, teachers create spaces (with guidelines, potential resources and tools that support the learning activities) and share them with the students.

Despite the widespread adoption of VLEs and PLEs, teachers and students usually criticize the reduced set of tools included in these platforms, demanding more alternatives to support the realization of their learning situations [Dag07]. Both VLEs and PLEs are developed for educational purposes and may be suitable for many domains, but sometimes users are looking for specific functionalities, or they are familiar with tools different from the ones provided in these learning environments [Bow11] [Tch13]. *Web 2.0 tools* have been increasingly used in education as an alternative or a complement to VLEs and PLEs [Scl08] [Smi10a] [Con10], even though many of these tools were not developed with learning or teaching in mind. Table 2.1 shows how, in the "Top 100 Tools for Learning", the use of Web 2.0 tools has grown around 20% for tools developed with as well as without educational purposes.

O'Reilly points out some features that usually define Web 2.0 tools [O'R07]: a) Web 2.0 tools use the web as a platform; b) users control their own data; c) Web 2.0 tools provide services instead of packaged software; d) their users are co-developers or content generators; e) tools with a cost-effective scalability; f) the software is above the level of a single device; and g) Web 2.0 tools harness collective intelligence. As Table 2.2 shows, the top 10 of the "Top 100 Tools for Learning" includes many Web 2.0 tools such as social networking sites (Twitter[21], Facebook[22]), blogs (Wordpress[23], Blogger[24]), file sharing sites (Dropbox[25], Slideshare[26], Youtube[27]), collaborative tools (Google Docs[28],Wikipedia[29]), communication tools (Skype[30], Google Hangouts[31]) and educational tools (Glogster EDU[32]).

As Table 2.3 shows, many of the Web 2.0 tools that appear in the "Top 100 Tools for Learning" provide at least one of the functionalities that Koschmann considered relevant to support CSCL [Kos96]: a) present or simulate a problem for study; b) mediate communication between participants; c) introduce new resources into the classroom that could not be otherwise available; c) store documents or other products developed by the participants; or d) enable

[20] `http://www.go-lab-project.eu/` (Last visit: 03 January 2013)
[21] `https://twitter.com` (Last visit: 17 January 2013)
[22] `https://www.facebook.com` (Last visit: 17 January 2013)
[23] `http://wordpress.org` (Last visit: 17 January 2013)
[24] `https://www.blogger.com` (Last visit: 17 January 2013)
[25] `https://www.dropbox.com` (Last visit: 17 January 2013)
[26] `http://www.slideshare.net` (Last visit: 17 January 2013)
[27] `http://www.youtube.com` (Last visit: 17 January 2013)
[28] `https://docs.google.com` (Last visit: 17 January 2013)
[29] `http://www.wikipedia.org` (Last visit: 17 January 2013)
[30] `http://www.skype.com` (Last visit: 17 January 2013)
[31] `http://www.google.com/hangouts` (Last visit: 17 January 2013)
[32] `http://edu.glogster.com` (Last visit: 17 January 2013)

Table 2.3: Classification of the Web 2.0 tools according to the categories identified in the ranking "Top 100 Tools for Learning". (*) If a tool presents several of the features listed below, the tool has been tagged according to each one of them (e.g., Google Docs is an office tool, that supports collaboration, and provides communication functionalities).

		2013	**2012**	**2011**	**2010**	**2009**	**2008**
General categories (*)	Education and training	15,94%	14,71%	12,31%	7,58%	6,90%	7,84%
	Video, audio & image	18,84%	16,18%	21,54%	22,73%	15,52%	11,76%
	Communication	17,39%	11,76%	9,23%	12,12%	13,79%	17,65%
	Networking & collaboration	37,68%	42,65%	35,38%	34,85%	37,93%	35,29%
	Web design, blogging & wikis	10,14%	13,24%	12,31%	15,15%	18,97%	23,53%
	Bookmarking & curation	11,59%	10,29%	9,23%	3,03%	3,45%	5,88%
	Office tools & ancillaries	8,70%	8,82%	13,85%	12,12%	13,79%	9,80%
	Productivity	20,29%	23,53%	20,00%	19,70%	17,24%	23,53%
	Browsers, readers & dashboards	13,04%	13,24%	9,23%	7,58%	6,90%	5,88%
	Mobile devices & synchronization	4,35%	4,41%	6,15%	7,58%	5,17%	5,88%

learners to model, represent and share their understandings of new concepts. For instance, there are works that report the use of Web 2.0 tools to support CSCL by means of wikis [Lar09] [Eck13], blogs [Alt13], communication and tools [Eng13] [Has13], social platforms [Mag09] [SF11], or educational tools [Abd13] [Eng13].

This subsection has presented different technological approaches to support blended CSCL scenarios. Taking into account that blended learning is more common in formal education, and that the main distinctive feature of CSCL is to support social interactions among students, with a teacher playing a mediator or facilitator role [Sta06], this thesis focuses mainly on VLEs and Web 2.0. Next section presents different architectures to support the integration of external tools in learning environments.

2.2.3 Distributed Learning Environments (DLEs)

As it was mentioned in the previous subsection, some of the problems that educators detect regarding the use of P/VLEs deal with the reduced set of built-in tools that these platforms provide [Dag07]. Sometimes, built-in tools do not provide the specific functionalities that teachers are looking for [Bow11] [Tch13]. Besides, every student or teacher has a legacy of habits with respect to computational tools [Dil10]: e.g., if the learning environment proposes a specific email or chat tool, it will suffer from a strong competition with the email and chats that students are using, i.e. the ones that already include all their contacts, their histories, etc. These limitations condition the amount and nature of learning situations that a teacher can propose when working with a VLE or PLE, and promote the use of external tools that comply with teachers' and students' needs.

In this context, several research initiatives have emerged lately to expand learning environments, making VLEs more customizable [Scl08] [MnC13a], connecting PLEs with the institutional community [Whi11], and integrating external tools, especially Web 2.0 ones [Dag07] [Scl08] [Liv08] [dlFV11] [AH13]. The term *Distributed Learning Environments (DLEs)*[33] has been coined to refer at those learning environments that integrate third-party tools [Mac10].

[33]The term "Distributed Learning Environments" has also been used in the field of educational technologies with the meaning of "giving students access to a wide range of resources -teachers, peers, and content such as

MacNeill and Kraan [Mac10] summarize the different integration approaches into five "models":

1. **One system in the cloud, many outlets**. In this model, a collection of services is gathered in one place, and from there they are broadcasted to a range of platforms. The platforms range from an existing VLE to a smartphone application. The Apache Wookie[34] is an example of this approach.

2. **Plug-ins to existing VLEs**. This model is oriented to extend the functionality of an existing VLE with a plug-in. The IMS Learning Tools Interoperability 2.0 specification[35] (formerly known as "Full" IMS-LTI) or the Icodeon SCORM player[36] are examples of this model.

3. **Many widgets from the web into one widget container**. This model represents the typical mash-up of a variety of sources using Software as a Service (SaaS) applications [Pap03] (e.g., Netvibes[37]). This approach is frequently followed in Personal Learning Environments, where each user has to assembly and customize the learning environment.

4. **Many providers and many clients**. As it happens with email, it is possible to federate an infrastructure out of many similar clients and servers.

5. **Both a provider and a client**. In this model, the platform does the provision and consumption of tools/content directly, and to equal degrees, following the ideal of Service Oriented Architectures (SOA) [Pap03].

Focusing on VLEs, the requirements imposed by VLE and tool providers to enable technological interoperability has been termed *integration contract* [Ghi07] (i.e. the technologies, interfaces and data models that must be employed to enable the communication between a system and its extensions). Alario-Hoyos et al. identify the main issues that should be taken into account for the definition of an integration contract [AH10a]:

1. **The restrictions on the integration interfaces**. These restrictions may impose a programming language (e.g., PHP for Moodle), a certain framework (e.g., Open ACS for .LRN), or an exchange data model (e.g., RSS-based models in most blog tools), among others. Contracts including many restrictions that are hard to be fulfilled usually allow richer, particularized interactions between VLEs and tools (e.g., the IMS LTI specification defines a complex contract, aimed to allow VLEs and tools to share information potentially useful for learning situations; however, main VLE providers have been reluctant to implement the standard due to its severe requirements). On the contrary, contracts that impose few restrictions may be easier to fulfil and may require less development effort (e.g., IMS

readings and exercises- independently of place and time" [Ala04]. This definition is focused on how learning is carried out, while MacNeill and Krann [Mac10] use the term to refer at the technological infrastructure -composed of a VLE, PLE or similar learning platform, together with other external tools such as"Web 2.0"- that supports the learning scenario.

[34] `http://wookie.apache.org/` (Last visit: 17 January 2013)

[35] `http://www.imsglobal.org/lti/` (Last visit: 17 January 2013)

[36] `http://www.icodeon.com/product.html` (Last visit: 17 January 2013)

[37] `http://www.netvibes.com` (Last visit: 17 January 2013)

Basic LTI[38] has been proposed with less restrictions aiming at reducing the development effort, engaging more VLE vendors and content publishers).

2. **The degree of adoption of the restrictions.** The less widespread the restrictions imposed by a VLE, the fewer the tools that are likely to be integrated on it, and vice versa. For example, Gridcole [BL08] is an extensible VLE that requires external tools to be developed as grid services following the WSRF specification. Since this specification never got too many adopters, the number of existing tools that can be integrated in Gridcole is very limited. On the contrary, the Apache Wookie server [39] can integrate tools based on the widespread W3C Widgets specification[40], and therefore, the number of existing tools that could benefit from this approach is much higher.

3. **The multiplicity of the integration.** A contract that promotes a one-to-one integration enables richer interactions among integrated systems, but the code generated is hardly reusable (e.g., as it happens with many Moodle modules that integrate external tools). On the contrary, contracts that promote a many-to-many integration, enables a higher code reuse among integrations, in exchange for enabling only generic functional commonalties, due to the heterogeneity of VLEs and tools (e.g., the Generic Service Integration (GSI) architecture [dlFV11] defines a many-to-many integration contract with IMS LD compliant platforms and third-party services, however, only .LRN can currently support the IMS LD specification).

4. **The degree of integration**. The integration is closely related to the interfaces and multiplicity issues: the higher the integration degree is, the more restrictions on interfaces are required. For instance, Sloodle [Liv08] enables a high control on Second Life within Moodle, but it is useful only for the VLE it was designed for. In the same proportion, a lower degree reduces the extra code needed for each new integration (e.g., IMS Basic LTI promotes a low degree of integration, by providing just a single endpoint for the access to each external tool).

Group Learning Unified Environment (GLUE!)[41] is an architecture devoted to integrate multiple third-party external tools in multiple learning environments, specially in VLEs. This service-oriented architecture aims at decreasing the average development effort that should be made to support the basic integration of several external tools, developed with multiple technologies, in different VLEs [AH13]. GLUE! defines a REST-based contract [Fie02] and follows a simple, loosely-coupled integration model of distributed services.

As Figure 2.2 depicts, GLUE! follows a three-tier architecture. On the one hand, the core is in charge of managing instances of external tools. It supports the life cycle of tools integrated in VLEs by providing the functionality to find, create, configure, update or delete tool instances. On the other hand, the learning environments and tools located on the left and right of Figure 2.2, make use of the "adapter" pattern [Gam95]. This approach enables the integration of learning environments and tools, respectively, without modifying their code, and promotes a many-to-many integration. LE adapters enable educators and students to use external tools as they

[38]`http://www.imsglobal.org/lti/` (Last visit: 17 January 2013)
[39]`http://incubator.apache.org/wookie` (Last visit: 17 January 2013)
[40]`http://www.w3.org/TR/widgets` (Last visit: 17 January 2013)
[41]`http://www.gsic.uva.es/glue/` (Last visit: 17 January 2013)

were one of the VLEs' and PLEs' built-in tools. To do so, these adapters map activities, users, groups, and roles to tool instances, as with the learning environments own tools, but delegate the creation, update and removal of these instances to the GLUElet Manager. Finally, tool adapters translate requests from the GLUElet Manager to the contracts imposed by external tools.

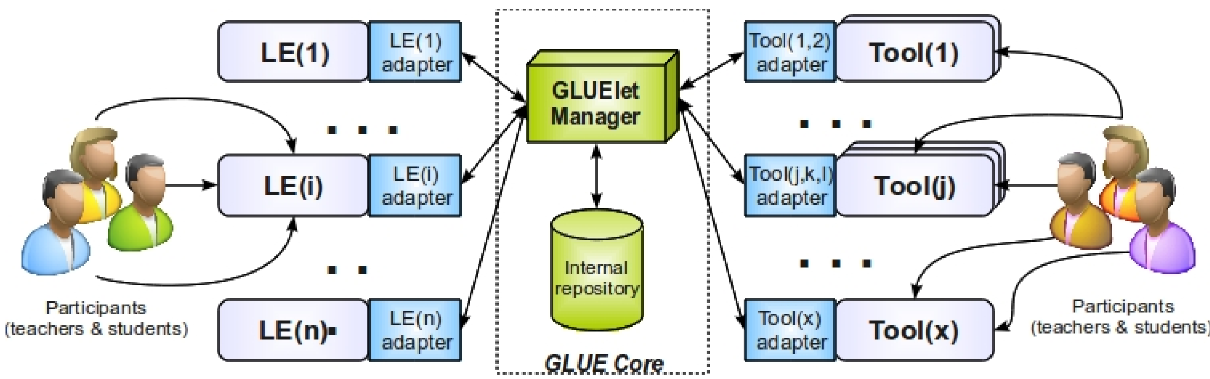


Figure 2.2: Overview of the GLUE! architecture.

GLUE! defines an integration contract for the communication between the core and the adapters. This contract imposes three mandatory features on VLEs and tools, which most providers already fulfil: they must be web-based platforms, they must offer an extension interface, and additionally VLEs must understand the concept of tool.

Besides, the adapters have to meet four restrictions based on widespread standards with a high degree of adoption, aiming at promoting the development of adapters by interested third-parties. First, to facilitate invocation of tools by the learning environment, both the VLE and tool adapters must be *RESTful* compliant. Second, in order to enable educators to configure the tools, tool adapters must follow an *XForms*[42] format, and VLE adapters have to use the *Atom*[43] syndication format, to enable the propagation of forms filled out by educators, and to provide additional information, such as which users are sharing a tool instance. Third, tool adapters must be prepared to retrieve this information from Atom feeds. Finally, tool adapters have to provide URLs representing tool instances.

Several adapters have already been developed for VLEs (e.g., Moodle, LAMS and Basic LTI) and tools such as Google Apps(Documents, Spreadsheets, Presentations and Drawings), MediaWiki, W3C widgets deployed in Apache Wookie servers, Facebook, Doodle and any URL representing a web content.

The use of architectures that support the creation of DLEs will help us to reduce the time required for teachers in the preparation of the technological setting. Besides, instead of working with the different tools as independent learning resources, these architectures accomplish the recommendation in CSCL of integrating the activities an actions of the learners into the same learning setting [Dil07b]. In the scope of this dissertation, our technological proposals and research work will focus mainly on DLEs based on the GLUE! architecture. This decision was prompted by three main reasons: a) given its ability to manage external tool instances, GLUE! can be a very useful tool for orchestrating the external tools that are part of a DLE, reducing

[42] `http://www.w3.org/MarkUp/Forms` (Last visit: 18 January 2013)
[43] `http://tools.ietf.org/html/rfc5023` (Last visit: 18 January 2013)

part of the orchestration load from the teachers or the systems that we propose; b) GLUE! was specifically designed for learning environments, while remaining VLE-agnostic, a characteristic that we also desire for our proposals, given the fragmented and confusing learning platform panorama presented above; and c) pragmatically speaking, GLUE! supported the two learning platforms in which our proposals would be first evaluated (namely, Moodle and the MediaWiki engine). It should be noted, however, that neither GLUE! nor our technological proposal (see Chapter 4) are restricted to these two learning platforms.

2.2.4 Discussion

Authentic learning contexts are undergoing a shift towards blended and collaborative learning [The13], in tandem with an increasing adoption of ICTs such as VLEs, PLEs and Web 2.0 tools [Con08]. Blended learning has been widely adopted in formal education, specially by institutions (e.g., schools, universities) [Dia10], and CSCL is frequently applied in scenarios where there is a teacher guiding and promoting effective interactions among students [Sta06]. Based on these premises, this dissertation mainly focuses on scenarios framed in formal education where teachers plays the main role conducting the learning process.

Regarding the technological context, this section has presented some ICTs frequently used in education, namely VLEs, PLEs and Web 2.0 tools. From that review we have identified that, despite the opportunities brought by VLEs and PLEs, the need of tools that provide specific functionalities together with the teachers' and students' legacy factor, claim for more open learning environments that can interact with other systems [Dil10]. To address this problem, some architectural proposals have appeared to facilitate the creation of DLEs [Dag07] [Scl08] [AH13].

Even if these contexts present multiple benefits, they also pose a set of challenges for teachers. The design and enactment of these scenarios is more complex: teachers have to design the activity flow and the technological support to promote learning in a myriad of situations (face-to-face and computer-mediated activities, combining presence and distance learning, at different social levels, and in a synchronous or asynchronous manner); besides, this higher complexity entails additional time and effort.

The potential benefits that blended CSCL supported by DLEs may report if we address the aforementioned challenges, move us to focus on this pedagogical and technological context. The following sections analyse the orchestration aspects to be taken into account in this kind of scenarios and present existing solutions in CSCL to support teachers in this endeavour.

2.3 Orchestration of blended CSCL scenarios

The metaphor of 'orchestration' has been used in education to illustrate the similarities between music and classroom: music writers and teachers both have to harmonize multiple 'voices', both need a fine-grained control of time, both translate a global message into a sequence of atomic actions. But obviously, between music and classroom there are some differences: in music, orchestration refers to writing the score that an orchestra will play, it does not refer to the activity of the conductor when the orchestra is playing; when orchestrating a classroom, the score has often to be modified on the fly; etc.

The idea of orchestrating the learning scenario has become a grand challenge in TEL and CSCL communities in the last few years [Dil09b] [Sut12]. For instance, in blended CSCL scenarios, teachers have to cope with coordinating different activities occurring at various social levels (e.g., individual, group, class), across different contexts (classroom, home, laboratory, field trips, etc.) and, often, multiple tools (technological or not) [Dil09b].

This section introduces the concept of orchestration, reviews the aspects that should be taken into account when describing, analysing and designing 'orchestrated learning', and compiles a set of factors to be considered in the design of technology for orchestration. These review will lead us to identify the difficulties that teachers face when orchestrating blended CSCL scenarios supported by DLEs.

2.3.1 Orchestration definition

Orchestration has been variously defined by researchers. As Prieto et al. describe in their review [Pri11b], multiple authors have used the orchestration metaphor in TEL. Some definitions focus on the tasks carried out at runtime: e.g., Fischer and Dillenbourg speak of 'orchestration' as the process of productively coordinating supportive interventions across multiple learning activities occurring at multiple social levels [Fis06][Dil13]. Others pay attention to the work done from the conceptualization to the enactment of the learning scenario: e.g., "the process of creating, adapting and enacting a technology-enhanced learning scenario under complex classroom conditions" [Kol13]. And some authors cover the tasks that teachers face before and while the scenario is running: e.g., defines orchestration as a combination of scripting and conducting the learning scenario [Tch13].

Even if the concept of orchestration can be stretched to apply to any learning situation, the word 'orchestration' is less fuzzy in the context of formal learning, tied very often with the concept of a 'classroom'[44] where there is a teacher who coordinates multiple constraints in terms of curriculum, assessment, time, energy, space and safety [Dil10]. Even more, in the TEL domain , Roschelle et al. (2013) highlight that there is a shared a concern about the "challenges of classroom use of technology, with a particular focus on supporting teachers' role" (p. 523) [Ros13].

In this thesis, we will adopt the definition proposed by Prieto [Pri12]. This author presents orchestration as "*the process by which teachers and other actors design, manage, adapt and assess learning activities, aligning the resources at their disposal to achieve the maximum learning effect, informed by theory while complying pragmatically with the contextual constraints of the setting*" (p. 61). This definition has been distilled to include some of the main aspects that researchers identify in the orchestration of learning [Pri11b]. In the following section, we will deepen on these aspects.

[44]The term 'classroom' is used as a flag: it does not exclude activities outside the classroom (field trips, museum visits, homework, etc.) as it happens in online and blended learning.

2.3.2 Orchestration aspects and design factors

As it happens with the definition of orchestration, there is no agreement about which aspects it entails. The preparation and design of the learning scenario [Kol13] [Tch13], the awareness in a classroom [Ala09] [Gut12], or the automation of the classroom management [PS09] [Nir10] are just some orchestration aspects that can be found in the literature.

Several attempts have been made at compiling these differing views. From an educational perspective, Hämäläinen and Vähäsantanen propose three dimensions for teacher orchestration to foster collaborative learning (pedagogical bases, teachers' pre- and real-time activities, and opportunities and challenges)[HÏ1]. Similarly, Prieto et al. (2011) gather relevant orchestration literature in TEL research, and cluster these differing views around eight aspects, frequently interrelated, regarding the questions "what is orchestrating learning?" (aspects 1-5) and "how should this orchestration be done?" (aspects 6-8) [Pri11b]:

1. *Design/planning.* An important task, often performed by the teacher beforehand, covering all the preparation of the activities and technological tools that will be used to enact them, so that the learning objectives can be achieved.

2. *Awareness/assessment.* Awareness of what is happening in the classroom and how the learning situation evolves, is crucial in order to adapt the learning process whenever needed. This information can be used for (formative or summative) assessment purposes.

3. *Regulation/management.* Another main aspect is the management of the learning process and its constraints in order to maximize outcomes. The regulation of learning activities (external or self-directed) involves the class, time, workflow, the ICT tools and group management.

4. *Adaptation/flexibility/intervention.* The orchestration includes making interventions in the learning process at run-time, in response to the emergent eventualities, in order to adapt actors' original plans.

5. *Roles of the teacher and other actors.* Despite orchestration focuses primarily on the perspective of the teacher, nothing precludes from shifting the load of orchestrating the activities from the teacher' shoulders to the students. Thus, it is necessary to identify the actors directly involved in orchestration, and their respective roles in it.

6. *Pragmatism/practice.* Pragmatic research efforts are needed in order to make TEL research available to average teachers, covering the compliance to the authentic settings' multiple constraints.

7. *Models/theories.* A deeper theoretical analysis is needed to alleviate the lack of general theories and models that can guide researchers and practitioners in orchestrating learning.

8. *Alignment/synergy.* The alignment of as many of these elements as possible, through the changing conditions of a learning situation, in order to attain the learning goals that are desired at different levels, is an essential condition of a well-orchestrated learning experience.

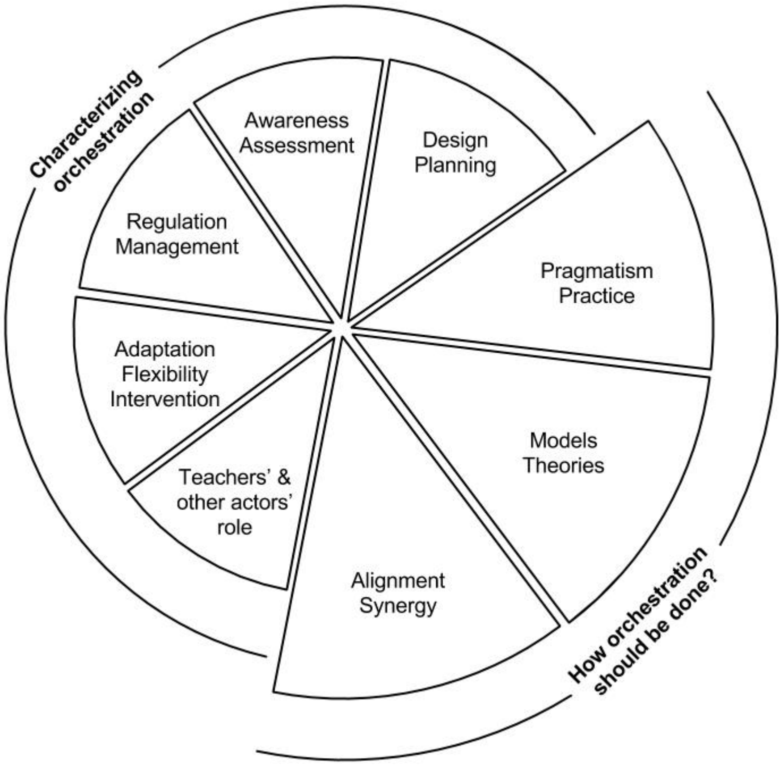


Figure 2.3: Graphical representation of the '5+3' orchestration conceptual framework (from [Pri11b]).

Aside from these efforts trying to characterize orchestration, we can also find in the literature recommendations about how to conduct research dealing with this phenomenon. Dillenbourg & Jermann compile a set of 'design factors' that technologies for orchestration should take into account in order to support teachers [Dil10]:

1. *Leadership.* Teachers act, generally, as the drivers of the scenario and lead the collective (i.e. class-wide) activities.

2. *Flexibility.* Teachers, frequently, have to change the learning scenario on the fly, adapting it to the learners' needs, or reacting to extrinsic events and constraints, without losing the pedagogical value of the scenario.

3. *Control.* Teachers need to maintain the students' level of interest and concentration necessary for the on-going activities.

4. *Integration.* Learning scenarios often combine individual, small group and class-wide activities, within and beyond the classroom.

5. *Linearity.* Usually, the sequence of activities is performed by almost all students, at almost the same period.

6. *Continuity.* The successive learning activities are articulated around shared data structures (objects, groups, assignments, etc.) that circulate via a workflow.

7. *Drama.* The emotional state of students varies across activities, with highest moments that trigger engagement for the rest of the scenario.

8. *Physicality.* Although part of the learning process happens in virtual learning spaces, another part occurs in physical spaces (as it happens in blended learning).

9. *Awareness.* Teachers need to be aware of the activity state of their students.

10. *Curriculum relevance.* The total time required to teach and prepared a subject should be proportional to the importance of this subject in the curriculum.

11. *Assessment relevance.* A successful method, tool or proposal must be compatible with the different assessments that students will have to pass.

12. *Design for all.* A successful method, tool or proposal must be feasible for most skilled teachers, not only for exceptional teachers.

13. *Minimalism.* The functionalities offered by the learning environment are only those specific to the learning scenario and that are not provided by the tools (books, software,..) already in use by the students.

14. *Sustainability.* The energy required to integrate a method, tool or proposal in the teacher practice must be affordable in order to ensure that it can be maintained over several years.

The aforementioned orchestration aspects will help us to define the scope of this dissertation as we will see throughout the following sections. Besides, the design factors will guide our efforts in the development of (conceptual and technological) tools that support teachers in the orchestration of blended CSCL scenarios. Next section illustrates some challenges that appear when orchestrating blended CSCL scenarios supported by DLEs.

2.3.3 Awareness in blended CSCL scenarios supported by DLEs

Coming back to the orchestration aspects defined by Prieto et al. [Pri11b], we can identify multiple dependences among aspects. Such is the case of awareness: once a learning scenario is running, the teacher needs to be aware of the activity performed by each actor, in order to intervene as soon as something goes wrong, adapting the learning plan or providing feedback to the students (i.e. formative assessment)[Dil10][Per10].

Awareness can be defined plainly and simply as ‘knowing what is going on’ [End95] within time and space bounds [Gut02]. There are different types of awareness: social (*who* is involved in the learning process?), action (*what* is happening?), and activity awareness (*how* are things going?) [Car03]. Frequently, to *monitor* what is happening in the learning process, teachers need to review the learning outputs verifying *what* the students have done. Indeed, in order to know *who* has been involved in the learning activities and *how* the students have participated, teachers need to inspect to the logs or the analytics that some tools offer regarding students’ interactions.

The time devoted to be aware of the learning process increases substantially the "orchestration load", i.e., the effort necessary for the teacher to conduct learning activities [Dil11a][Cue13]. This concern about time-efficiency of the tools used in the classroom is also in line with the fact that *time management is a primary concern for all teachers* [Dil09a], and that the lack of time is one of the most commonly cited barriers teachers see for innovation in the classroom [Had93] [She93] [Yan04] [Kar09b] [Dia10] [Con11]. These tasks are very time-demanding, especially in DLEs, where teachers have to visit the different resources used in the learning scenario. Moreover, in blended learning it is also necessary to include additional data sources, e.g., notes about the face-to-face sessions, and integrate this information with the computational one, to have a more realistic view of the learning process [Avo07].

Also, being properly aware of what is happening may ameliorate the 'flexibility' aspect. There are many constraints in a learning scenario that are impose by the pedagogical purposes (e.g., the students have to collaborate during the activity) or by the external context (e.g., the institution may impose a VLE), so that they are not negotiable. However, there are other constraints that are modifiable depending on the context (e.g., an activity deadline, the tool selection, or the group binding) [Dil07b]. In these situations, is critical to *receive the information as soon as possible in order to increase the time available for reacting*, especially regarding the adaptations or changes in the technological support to face unexpected events [Dil07b] [Pri11b]. Again, a teacher needing to flexibly change a DLE set-up at run-time, will very likely need to go to each of the platforms/tools that make up the DLE, and manually apply those changes (and do it without errors, so that the resulting distributed set of resources/tools is still coherent).

Despite the impact that awareness has over other aspects, it is usually a critical point in the orchestration of CSCL scenarios supported by DLEs. On the one hand, we should remember that any proposal trying to address orchestration should be acceptable and *sustainable for average teachers* [Dil09a] [Pri11b] [Ros13]. Even if the analysis of educational data offer useful insights on how the learning process unfolds, the information that current monitoring proposals provide to the teachers is not always easy to interpret [Dyc13]. Besides in-depth understanding of students is not possible when orchestrating classroom activities with several students or groups working at almost the same period [Dim04b] [Dil11a]. Thus, *teachers need simple indicators of the students' work* [Dil10] *that help them identify individual and group difficulties* [Dim04b]. On the other hand, orchestration proposals should be *complying with authentic educational settings' constraints and complexities* [Dil09a] [Pri11b] [Ros13]. This has some interesting consequences for the concrete case of CSCL practice using DLEs, since there exist multiple implementations of these environments (based on Basic LTI, based on GLUE!, based on widgets, etc.), using different learning platforms (e.g., Moodle, Blackboard, wikis) to centralize access to a set of Web 2.0 tools. Thus, *any awareness solution trying to gain acceptance in authentic classroom practice with DLEs should be able to operate within this highly fragmented technological panorama.*

In this section we have seen how, being aware of what is happening in the learning scenario, other orchestration aspects may be improved. However, we have identified that the teachers frequently lack the information they need for such purposes. The following section reflects on how we can take advantage from other orchestration aspects such as design to improve teacher's awareness.

2.3.4 Alignment of orchestration aspects: linking LD and LA strategies

One of the aspects that define how to carry out a well-orchestrated learning experience is the *alignment* of as many elements as possible in order to attain the learning goals [Pri11b].

In the previous section we have identify the need of providing teachers with meaningful information to eventually intervene and adapt their plans at run-time. According to situational approaches, one of the prerequisites to obtain relevant outputs is not to isolate the analysis of educational data from the *context* in which it is embedded [Cro00]. In addition, some research works point out that the design and deployment of any awareness system should be informed by an agreed *pedagogical strategy* [Loc11] [Sut12] [Gri13] [EM14]. In fact, Martínez-Monés et al. [MM11b] emphasised that the alignment between pedagogical and informational needs is crucial in order to integrate learning analytics into mainstream CSCL practices.

Lockyer and Dawson [Loc11] stated that the tandem between learning design and analytics offers the opportunity for better understanding the student behaviour and provide pedagogical recommendations where deviations from pedagogical intention emerge. Looney and Siemens [Loo11] considered the learning plan as an efficient learner hypothesis that may be compared with the learner on-going activity for adaptation and personalisation. In that way, the teacher could monitor the classroom, compare its state to the desirable state in the scenario, and adapt the scenario accordingly [Dil11a].

Similarly, in order to increase the effectiveness of awareness systems, CSCL practitioners should anticipate, during the design process, awareness needs that may require subsequent orchestration interventions [Dil13][Dim13], and take into account the capabilities of the awareness systems [MM11b][Gri13][EM14].

This approach of linking learning design and analytics has been already applied to support individual learning (e.g., using e-portoflios [Rei13] and on-line simulators [Lej12]) and different abstraction levels (e.g., connecting the analysis with the accomplishment of the curriculum objectives defined in a course[Glu13]).

Other works have suggested that synergies may be derived from the alignment of two specific strategies: CSCL scripting and monitoring. Although many of them are theoretical proposals that highlight the expected benefits [Dil07b] [Loc13][MM11b], there are also some practical works devoted to carry out scripting and monitoring with specific tools (e.g., a collaborative canvas [Gij13] or forums [Mag10]).

Even these works are good examples of the benefits of the aforementioned alignment approach, they have a limited applicability in the context of this thesis, being restricted to individual learning or a single learning platform. To identify the difficulties that we need to face in order to align scripting and monitoring in blended CSCL scenarios supported by DLEs, Sections 2.4 and 2.5 analyse these strategies.

2.3.5 Discussion

Among the different orchestration aspects identified by Prieto et al. [Pri11b], we have seen that awareness plays a significant role. Providing teachers with meaningful awareness information at run-time, other aspects may be benefited:

- increasing the *flexibility* of the learning scenario (the sooner teachers detect eventualities, there is more time available to modify the scenario);

- detecting situations that may need *regulation* (awareness information may reveal unknown situations that require intervention);

- gathering evidence of the learning process that may contribute to *assess* for learning (knowing how evolves the learning process, teachers may provide personalize feedback);

- decreasing the orchestration load, i.e. the time *management* (the teacher would need less time to be aware of what is happening);

However, often, current solutions do not offer teachers with the information that they need.

In order to provide suitable awareness information, we will follow the recommendation of aligning aspects. We hypothesise that linking awareness and design synergies may appear. We propose to provide awareness information related to the pedagogical decisions made at design-time. Concretely, since our focus is on CSCL scenarios, we propose to apply two specific LD and LA strategies aimed to promote effective collaboration: scripting and monitoring.

In the rest of the chapter we will review the two related areas of Learning Design and Analytics, trying to identify the challenges that hinder the alignment of scripting and monitoring in blended CSCL scenarios supported by DLEs.

2.4 Scripting CSCL scenarios

Learning Design (LD) is a research area that provides relevant resources to support teachers in the 'design' aspect of orchestration [Dil13] [Goo13]. This section introduces the concept of Learning Design and the steps that constitute a LD process. Besides, we present a LD strategy used in CSCL for enhancing collaboration, namely scripting, and how teachers may be supported in the design of CSCL scripts by means of pedagogical patterns. The section ends with the challenges of the application of scripting in CSCL scenarios supported by DLEs.

2.4.1 Learning Design

Mor and Craft define Learning Design as "*the act of devising new practices, plans of activity, resources and tools aimed at achieving particular educational aims in a given situation*" (p. 86) [Mor12]. It is informed by subject knowledge, pedagogical theory, technological know-how, and practical experience. At the same time, it can also engender innovation in all these areas and support learners in their efforts and aims.

Some authors have proposed that LD might be more accurately described as *design for learning* [Smi05] [Goo13]. The term 'learning design' can be read as meaning that it is possible to design other people's learning. However, this is not the case [Bee08], one cannot design someone else's learning, only the person who is learning can learn. Someone involved in design for learning can design things that help other people learn. Design for learning has three main components: design of tasks and design of the physical and social architectures for learning.

Research and practice of learning design have evolved along two paths in TEL [Fal11]: one concerned with the automation of workflows from conceptualization to enactment, the other with sharing design knowledge among practitioners. The first strand focuses on machine-readable representations of learning design, such as IMS-LD [Kop06] or the GLUE!-PS *lingua franca* [Pri11a]. The second focuses on design practices, tools and human-readable representations, such as design patterns, scenarios and swim lanes [Goo05][HL05b][Con13]. Koper's and Conole's definitions included below represent, respectively, the first and second trends.

- Koper (2006) states ([Kop06] p.13):
  "A 'learning design' is defined as the description of the teaching-learning process that takes place in a unit of learning (e.g., a course, a lesson or any other designed learning event). The key principle in learning design is that it represents the learning activities and the support activities that are performed by different persons (learners, teachers) in the context of a unit of learning."
- Conole (2013) defines LD as ([Con13] p.7):
  "A methodology for enabling teachers/designers to make more informed decisions in how they go about designing learning activities and interventions, which is pedagogically informed and makes effective use of appropriate resources and technologies. This includes the design of resources and individual learning activities right up to curriculum-level design. A key principle is to help make the design process more explicit and shareable. Learning design as an area of research and development includes both gathering empirical evidence to understand the design process, as well as the development of a range of Learning Design resource, tools and activities."

Goodyear and Dimitriadis (2013) describe the design lifecycle as a non-linear process, with multiple entry points and feedback loops. This lifecycle spans four main phases: configuration, orchestration, reflection and redesign, with a forward-oriented design focus [Goo13]. Such way of conceptualizing the design process hints at two different interests [EM14]: on the one hand, the teacher's inquiry and the improvement of the teacher's practice [Cla11]; and, on the other hand, the orchestration of the learning scenario.

Much of the literature in LD describes the representations or the products of design work, but not the process itself. A LD process typically begins by describing the learning context, the aims of learners, teachers and institutions, the resources at their disposal and the constraints under which they operate. The designer generates and tests conceptual models of learning activities intended to achieve those aims and the resources that would support them. The chosen models are elaborated at growing levels of detail until they are implemented in the enactment environment. Each step in this cycle – capturing context, conceptualization, elaboration and deployment – requires appropriate representations and tools. In addition to these steps, some authors also include orchestration, reflection and redesign as part of an iterative design process [Dim13].

[Emi09] describes the design of a TEL scenario as follows: the first step is to define the intentions (in terms of learning outcomes, competencies and knowledge) and the pedagogical approach (e.g., the way of teaching, the role of the teacher) in order to obtain a general idea of the learning scenario. Then, the teacher integrates the constraints of the specific context. These constraints may be: domain constraints (e.g., didactic constraints, availability and/or adaptability of existing resources), pedagogical constraints (e.g., class size, audience characteristics, roles, type of grouping), situational constraints (e.g., location, schedule, duration, tools and services available, face-to-face or hybrid), and economical or administrative constraints [Emi07]. Then, the scenario is organized iteratively into different phases and activities, which define, in an operational way, the precise organization of situations (in terms of activities, interactions, roles, tools, services, provided or produced resources, etc.). Finally this information is represented with EML for its implementation.

In this thesis we will focus on how LD, concretely by means of scripting, may help teachers in orchestrating CSCL. In the following sections, we present some works that address both branches of LD: ones concerned with the collection of good practices that may help teachers design CSCL scenarios, the others with the automation of the deployment of CSCL designs across DLEs.

2.4.2 Scripting: a LD strategy to enhance collaboration in CSCL

When the students are asked to collaborate freely, expected interactions that would lead to learning outcomes do not necessarily occur [Dil02a]. This is one of the main concerns in CSCL. To promote effective interactions, scripting has proved to be a helpful design strategy for CSCL and, therefore, a means to support teachers in the orchestration of such complex scenarios [Sut09]. This subsection presents the definition of scripting and its different types according to the granularity, the lifecycle, models and design process.

Definition and types

The term 'script' was coined by Schank to define the mental structure that represents a person's knowledge about actors, objects and actions within a specific situation [Sch77]. Later, O'Donnell introduced the idea of 'collaborative script' [O'D92], referring to the set of instructions that specify how group members should interact and collaborate in order to solve a problem. In education, scripting is a form of learning design devoted to guide the sequences of actions and activities that students should follow to achieve the learning objectives [Kol06] [Haa07] [Wei09]. In CSCL, many pedagogical decisions have to do with learner scaffolding towards effective collaboration [Dil07a]. Such learner scaffolding may be achieved through CSCL scripts, that can take the form of computationally interpretable specifications of a desired collaboration process [Wei09]. CSCL scripting can be considered a specific form of learning design, focused on pedagogical principles and techniques for collaborative learning.

Though scripts generally aim to facilitate specific socio-cognitive learning activities, they may be classified into two types depending on their purpose [Dil07a] [Kob07]. *Micro-scripts* are intended to be internalized by students from a cognitive psychologist perspective (e.g., learning how to argue) [Wei07]. They typically scaffold the interaction process per se with fine-grained actions that the participants are expected to accomplish. On the contrary, *macro-scripts* denote pedagogical methods defining flows of coarse-grained activities [Dil07a]. They aim at setting

Table 2.4: Lifecyle of CSCL scripts according to different authors

References	Phases identified in the lifecycle
[Ham06]	Design, implementation, execution and diagnosis
[HL06] [VF09a]	Design, instantiation and execution/enactment
[Dil07b]	Edition, instantiation, session set up and run-time management
[Vig08]	Design, operationalisation, enactment and evaluation
[Emi09] [GS09]	Design, enactment and evaluation
[Wei09]	Specification, formalisation and deployment
[Sob12]	Design, instantiation, monitoring and run-time management

up the conditions that elicit desired interactions potentially leading to the expected learning outcomes (e.g., understanding the key ideas of a topic by means of mutual explanation). This type of scripts support the teacher to implement CSCL scenarios within the classroom. Since we are especially interested on pedagogical issues and supporting the teachers in the orchestration of CSCL scenarios, we will focus our attention on macro-scripts and hereafter we will call them simply 'scripts'.

Scripts lifecyle

Since, in this thesis, we aim to align pedagogical and monitoring interests, we will review the phases that a CSCL script undergoes (the so-called script life-cycle) in order to identify which of them are related with making pedagogical decisions and monitoring. Though there is no clear consensus on the composition and nomenclature of this life-cycle (see Table 2.4), when analysing different proposals, the following phases can be identified:

1. The definition of the script principles (i.e. how the learning activities lead to intended learning goals, and important conditions to be accomplished). Authors have called it script design [Ham06] [HL06] [Vig08] [Emi09] [Sob12], edition [Dil07b], or specification [Wei09].
2. The script adaptation to the setting (specifying participants, groups, tools and resources and their usage by each group/participant), known as script instantiation [HL06] [Dil07b] [Sob12], formalisation [Wei09], operationalisation [Vig08] [Tch08] or implementation [Ham06].
3. While the script unfolds, teachers are also involved in script monitoring and run-time management. This phase has received the name of script management [Dil07b] [Sob12], enactment [Vig08] [Emi09], execution [HL06][Ham06], or deployment [Wei09].
4. And, eventually, the revision and refinement of those activities, that is the script evaluation [Vig08] [Emi09] or diagnosis [Ham06].

In this dissertation, we refer to the aforementioned script phases as design, instantiation, management, and evaluation (see Figure 2.4). Due to the nature of our proposal, we will focus on the *design phase*, because the pedagogical decisions are made in that moment, and on the *management phase*, because it is the phase when the learning process takes place, and therefore, when monitoring may inform the teacher about such process.

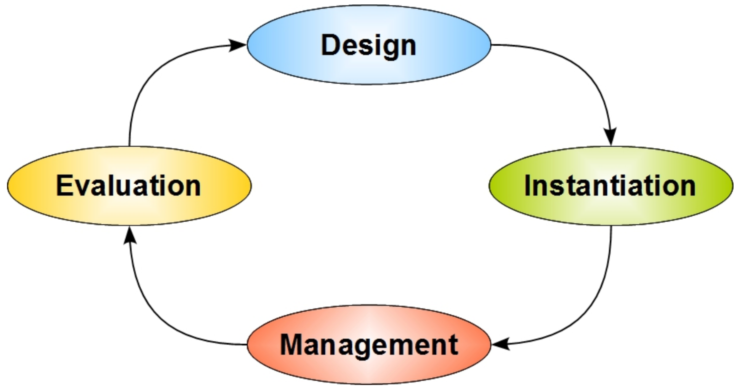


Figure 2.4: Phases of the CSCL scripts lifecyle according to the terminology used in this dissertation.

Table 2.5: Models of CSCL scripts

References	**Elements described in the models**
[Dil02a] [Dem08]	Phases, tasks, group composition, task distribution, interaction mode and timing
[Mia05]	Roles, activities, transitions (timing), artefacts, environments, participants, groups, actions, tools, contents, and conditions
[Kol06]	Specific learning objectives, activities, sequencing, role distribution and representation
[Kob07] [Dil07b] [Wei09]	Components (groups, participants, roles, activities, resources) and mechanisms (group formation, task distribution, sequencing)
[Tch08]	Structural components (phases, tasks, groups, social level, tools, interaction mode, timing) and implementation components (group formation policies and dynamics, task sequencing and articulation, data flow, work flow)
[HL10a]	Collaborative learning flow, activities, resources, roles and common collaborative learning mechanisms
[PS12]	Spaces, components, pedagogical methods, learning flow, data flow, activities, groups, participants, history and events
[Poz13]	Tasks, teams, time and technology

Models of CSCL scripts

In the field of CSCL, multiple authors have modelled the elements that conform a script (see some examples in Table 2.5). In general terms, scripts can be broken down into four main **components**: *activities* (also referred as tasks), *participants, groups, and resources*. Besides, there are some elements that frequently appear in the literature such as *roles* [Mia05] [Kol06] [HL10a], *interaction mode* [Dil02a] [Dem08] [Tch08], *timing* [Dil02a] [Dem08] [Mia05] [Tch08] [Poz13], or spaces [Mia05] [PS12]. Then, these elements are interrelated by means of **mechanisms**. The most cited are *task distribution among groups and roles, group formation, and sequencing of activities* [Dil02a] [Dil07b] [Kob07] [Wei09] [Tch08]. These concepts can even be made computer-interpretable by means of educational modeling languages such as IMS-LD [Kop06].

Depending on the specific context, the design decisions made in relation to the aforementioned components and mechanisms may vary or not at run-time. Thus, several authors [Dil07b] [Dem08] [Kar09a] [PS11b] have analyzed scripts in order to identify which features are modifiable -*extrinsic constraints* bound to contextual factors- and which ones have to be accomplished in order to maintain their pedagogical intentions -*intrinsic constraints* bound to the script's core mechanisms-. In terms of flexibility, extrinsic constraints define the space within which a script should be modifiable by teachers and/or students because the related decisions result from arbitrary or practical choices. Within this perspective, intrinsic constraints set up the limits of flexibility, i.e., what cannot be accepted in order for the script to keep its raison d'être.

Though scripts may seem simple at first glance, the design of potentially effective CSCL is a difficult task, especially for non-expert teachers [Smi79] [HÖ7]. Moreover, over-scripting the situations may be counter-productive: Dillenbourg states that while a certain degree of coercion is required for efficiency reasons (increasing the probability of fruitful interaction), excessively constraining collaboration may disturb natural interaction mechanisms [Dil02a]. This fact together with the unexpected circumstances that can appear in CSCL situations lead to a set of flexibility requirements pointed out by Dillenbourg and Tchounikine [Dil07b]. These difficulties have deserved the attention of the CSCL research community, in which several works have appeared aiming at supporting the task of script design. The use of patterns that reflect good practices in structuring collaborative learning [Con11] [Lau12] and the use of authoring and instantiation tools have proved to be helpful. Sections 2.4.3 and 2.4.4 go deeper into these topics.

Design process of CSCL scripts

Strijbos et al. proposed an iterative design process for CSCL scripts that consists of six steps [Str04]: (1) determine the learning objectives, (2) determine the expected (changes in) interaction, (3) select the task type, (4) determine whether and how much pre-structuring is needed, (5) determine group size, and (6) determine how ICT tools can be applied to support CSCL.

Based on Strijbos' proposal, Villasclaras et al. [VF09b] put forward a *pattern-based design process for CSCL scripts* that has been extensively applied in combination with a particular type of patterns: Collaborative Learning Flow Patterns (CLFPs), which capture the essence of well-accepted techniques for arranging activities in CSCL scenarios [HL06].

The process begins with the determination of learning objectives and prerequisites, in which the teacher (or designer) must consider carefully the characteristics of the learning scenario (the type of learning activity, learning objectives, and the complexity of the collaboration flow). This analysis must guide the selection of the pattern(s) that will inform the following steps of the process. Then, once the activity flow is structured, each activity should be configured attending to particularities of the learning scenario. This particularization includes the definition of the activities (tasks that the participants are expected to carry out, time constraints, etc.), and the configuration of roles and groups (for instance to indicate the maximum and minimum number of people needed for each group). Finally, the last step involves the provision of resources -creation and configuration- that support the realisation of the activities planned in the script. It is noteworthy that the pattern chosen in the second step of this process affects, not only the activity flow, but also the configuration of the activities.

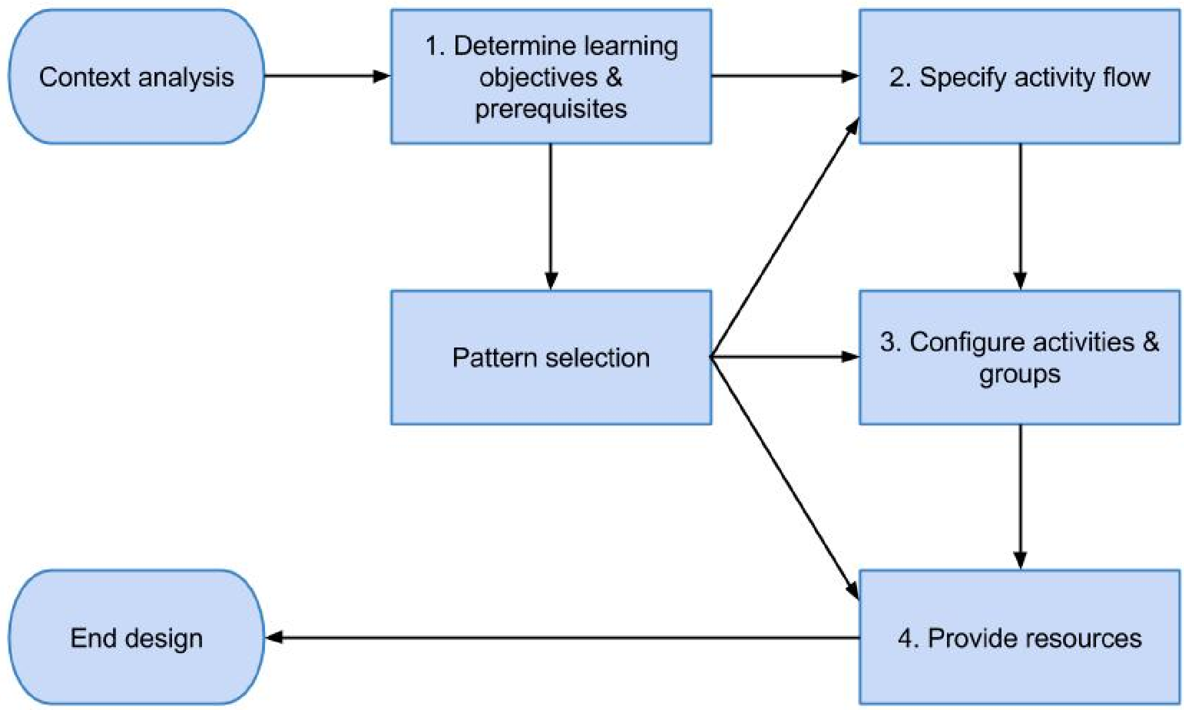


Figure 2.5: Pattern-based design process of CSCL scripts proposed by [VF09b].

2.4.3 Pedagogical patterns for CSCL

Both the conception of collaborative methods for CSCL scripts and their formulation into computational representations (e.g., IMS-LD) are complex tasks. Design patterns have been proposed in previous works to facilitate those tasks for non-expert designers. Design patterns are a way of documenting experience and knowledge about design problems that appear in a specific domain.

The term "design pattern" has been used in multiple fields such as Architecture [Ale79] and Software Engineering [Gam95]. A pattern provides a means of organizing information regarding a contextualized common problem and the essence of its broadly accepted solution, so that it can be repetitively applied [Ale79]. Other domain specific patterns have been proposed, including TEL and CSCL [Goo05] [Ret06] [Der06]. In this context, patterns reflect the knowledge of experts in a particular educational domain (e.g., CSCL), documenting and providing solutions to a wide range of recurrent problems in the design of an educational scenario. Since designing effective TEL scenarios is a complex problem, design patterns based on sound research can help guide the design process.

One of the key aspects of a pattern-based design approach deals with pattern use. Design patterns, ideally, capture the core of the solution to a given problem, i.e. the essential elements that cannot be avoided in order to solve the problem [Ale79]. Then, the complete solution to a concrete design problem, will need to be particularized for the specific context in which the problem arises [Chu04]. Another relevant feature of design patterns is that they do not only describe a problem and a solution, but also rules about when and how to apply that solution. In this way, design patterns are suitable for non-expert designers.

In general two main types of patterns can be distinguished depending on their use. Firstly, "patterns for analysis" deal with analyzing the usage of TEL systems, in order to help the implied stakeholders continually improve them [Mar01]. The patterns of interaction or behaviour are included into this group [Rad02]. Secondly, "patterns for design" are devoted to the design of TEL environments. Within this scope, patterns can be classified into those for designing learning scenarios (pedagogical patterns) [TEL05] and the ones for designing technological solutions that support these scenarios (technological patterns). Pedagogical patterns try to capture expert knowledge of the teaching/learning practice in different educational situations, including blended learning [Der05] [Smi10b] and CSCL [HL10a] [Kar10] [VF11] [Con11].

An example of pedagogical patterns for CSCL scripts are the Collaborative Learning Flow Patterns (CLFPs) proposed by Hernández-Leo et al. [HL10a]. Such patterns can guide non-expert users in the creation of (collaborative) learning scenarios in the application of potentially effective pedagogical methods. CLFPs proposed different structures of collaborative learning activities -at macro-script level- that have been validated in the practice, such as the Jigsaw, Pyramid or the Brain Storming. These structures of the learning flow can be instantiated according to the needs of different educational situations.

Part of the requirements that a pattern-based script must satisfy in order to achieve the learning objectives derive from the pattern constraints. These constraints are the conditions that should be met in a learning situation to be considered an implementation of such a pattern. Attending to the classification of the structural components of the scripts [Dil02a] [Kob05], CLFPs impose a set of (intrinsic) constraints such as group formation policies, the sequence of phases, the expected interactions, etc. The rest of the constraints of a script are the result of the particularization and instantiation of the pattern to each specific context [VF13], so they are modelled by means of elements like concrete tasks, resources, tools, participants, group composition, etc. Additional information about the description and constraints of CLFPs is available in Appendix B.

In the context of this dissertation, the constraints imposed by the pattern could be a source of pedagogical decisions to be taken into account in the analysis of educational data. Indeed, the use of patterns could support non-expert teachers to foresee their awareness needs.

2.4.4 CSCL scripting in DLEs: challenges

In order to identify the challenges that emerge from the design of CSCL scripts to be deployed in DLEs, we will illustrate the situation with an example. Let us suppose that our teacher, David, is designing a blended CSCL scenario that involves his 67 students and lasts 1 week, in the institutional Moodle at his university. In the first activity, students, individually at home, will read some documents dealing with the topic 'the atmosphere and its particles'. In the second activity, students, working in 'small groups' of dyads/triads in the class, will collect the relevant keywords related to the topic (main components, pollution indicators, analysis, etc.), putting them together in a shared document. Then, bigger groups of four-five students will review the lists generated in the previous activity by each one of the members (at home), and will draw an agreed concept map using the terms included in the list (this activity is expected to occur in the classroom but if the students do not finish they can continue at home). Finally, each 'big group' of four will present its concept map to the rest of the class in a face-to-face session[45]. Participants will have at their disposal the reference material uploaded in Moodle, a shared document (Google Docs) per 'small group' to elaborate the list, and a shared board (Google Drawing) per 'big group' to draw the concept map. Apart of describing the sequence of activities and group the students, David will have to create a course in Moodle, upload the reference material, create 33 Google Docs and assign them to the dyads (and at run-time assign them to the groups of four), create 16 canvas with Google Draw and associated them to the corresponding groups. It can be readily seen that, despite the benefits that DLEs may offer, the use of DLEs increases the difficulty of orchestrating a CSCL situation such as the one given in our example.

David has several resources at his disposal to aid him in the conceptualization of the script (e.g. patterns and authoring tools [Kop06] [Lau12] [Mor12]), however, there are not many options dealing with the gap between the conceptual design and its implementation in the ICT tools. On the one hand, he can go through the different tools and platforms that compose the DLE, and manually create, configure and link together all the resources involved in the envisioned scenario. On the other hand, there exist some technological solutions available for the transformation of his pedagogical decisions into the ICT infrastructure: some authoring tools developed for integrated environments such as LAMS [Dal03], others compatible with IMS-LD [Sus10] (but no VLEs have implemented it), and GLUE!-PS [Pri14] that allows him to deploy the designs created with several authoring tools (Pedagogical Pattern Collector[46], EdiT2 [Sob12], and IMS-LD compliant tools such as WebCollage[47] or CADMOS[48]) into Moodle and MediaWiki. Thus, he decides to use one of this tools to reduce the implementation effort, concretely, he chooses GLUE!-PS since it is the only one compatible with Moodle.

From the previous example we can realize that the solutions available to aid teachers in the creation of DLE-supported CSCL scenarios are few. Thus, many teachers will have to go through the different tools and platforms that compose the DLE, and manually create, configure and link together all the resources involved in the envisioned scenario. This manual process of building DLEs is time-consuming and error prone and constitutes a challenge for non-expert teachers.

2.5 Monitoring CSCL scenarios

This section introduces the concept of Learning Analytics and the steps that constitute a LA process. Besides, presents a LA strategy used in CSCL for enhancing collaboration: monitoring. The section ends with the challenges of the application of monitoring in CSCL scenarios supported by DLEs.

[45]Note that the this scenario implements a Pyramid pattern. See Appendix B for a detailed description of the pattern.

[46]Pedagogical Pattern Collector:`http://web.lkldev.ioe.ac.uk/PPC/live/ODC.html` (Last visit: 25 January 2013)

[47]WebCollage:`http://www.gsic.uva.es/webcollage` (Last visit: 25 January 2013)

[48]CADMOS:`http://cosy.ds.unipi.gr/cadmos` (Last visit: 25 January 2013)

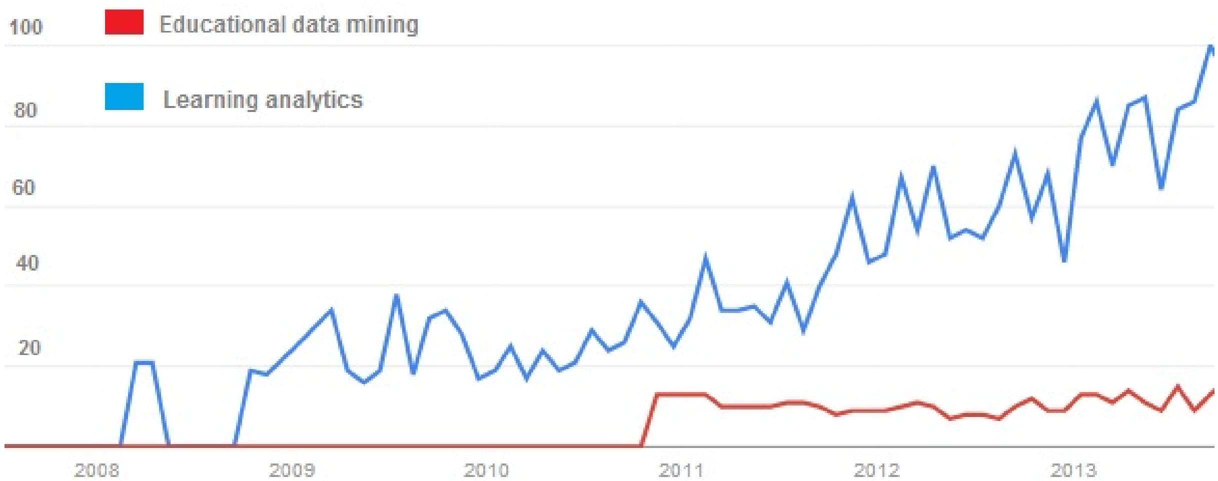


Figure 2.6: Relative levels of interest for the terms 'educational data mining' (in red) and 'learning analytics' (in blue) as revealed by Google Trends[50].

2.5.1 Learning Analytics

With the general technological advances of the recent years and the current trend in the use of ICTs, learners have at their disposal many online resources (including LMSs, VLEs, MOOCs and many other online tools) that not only facilitate the learning process, but also gather data about it. Albeit such data offer the chance of better understanding the learning process, stakeholders – learners, teachers and institutions – often need additional support to make sense of it [Dyc13] [Mac12]. The acknowledgement of these needs is at the heart of the recent emergence of Learning Analytics (LA), a research area that draws from multiple disciplines such as educational science, information and computer science, sociology, psychology, statistics and educational data mining [Buc12].

The interest on the increasing number of learners' interactions registered by the technological learning environments is not new (Ferguson, 2012). As Romero & Ventura conclude in their state of the art analysis (Romero and Ventura, 2007), there are several research approaches since 1995 dealing with the interpretation of educational data, with the main works, however, starting several years later, especially from 2008 (see Figure 2.6), with the advent of first conferences on Educational Data Mining (EDM), the Journal of EDM, and the establishment of the EDM Society[49].

Despite EDM provides researchers with relevant insights into the understanding of computer mediated learning [Bak09] [Rom10], organisations and participants keep on asking for information that raises their awareness and helps them to realise what is happening in the learning scenario [Sut12][Sie12b]. In order to save this gap between research and practice [Sie12a], LA breaks through in 2010, holding the first conference on Learning Analytics and Knowledge (LAK) and a year later setting up the Society for Learning Analytics (SoLAR).

[49] EDM Society:`http://www.educationaldatamining.org` (Last visit: 27 January 2013)

According to SoLAR, "*learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs*"[51]. Since 2011, the Horizon reports list Learning Analytics as a hot topic in higher education [Joh11], with an expected time-to-adoption of 2-3 years [The13].

Learners, teachers/educators, institutions or administrators, parents and government are the main stakeholders who can benefit from learning analytics data [Sie11] [Dra12]. However, not only individual stakeholders may benefit from LA, also the relationship between them can be influenced. As the work of [Dra12] shows, it is the relationships of teachers that are expected to be most widely affected, followed by learners, institutions, and parents at a minimal level.

In every concrete scenario where learning analytics are applied, the level or object of data analysis vary depending on the stakeholders' interests. For example, learners and educators can benefit from an analysis done at personal level (e.g., data about learning goals and resources) as well as at course-level (e.g. social network analysis or discourse analysis), whereas analysis done at higher level i.e. departmental or institutional may offer more benefits for educators and administrations.

When dealing with learning analytics, the type of data being analysed and the technological context where this data comes from play a significant role. During the last few years there have been different technological trends linked to different types of learning. VLEs and PLEs appeared to support teacher and student-centric approaches respectively. In addition, the call for specific functionalities that address users' needs often spreads learning environments over external tools (simulators, social media, forums, etc.). This myriad of VLEs, PLEs and Web 2.0 tools provides to LA the opportunity of gaining insight into online and blended learning.

Not only the technological aspects are important for learning analytics, but also in which learning scenarios they are being used. These scenarios can range from formal to informal settings, although a clear predominance of formal settings can be identified in the LA research community. In formal settings, LA approaches are being targeted for learners at any stage, starting from schools and going through higher education until university levels.

Finally, another parameter to categorise learning analytics deals with the nature of the data. A number of research works have addressed the problem of "big data". However, if we go back to the definition of learning analytics, there is no constraint in terms of the data size. As Cooper points out, doing analytics might, but does not have to, imply dealing with "big data" [Coo12]. Other problems such as the collection and analysis of distributed and heterogeneous data represent a challenge itself regardless of the size of the data sets [Fer12]. In addition, as Boyd and Crawford discuss in [Boy12], big and small data may provide different and complementary insights into the learning process.

The connection of LA with pedagogical theory and learning science need further work [Fer12]. The challenge posed by learning analytics is interpreting the resulting data against the pedagogical intents within the local context [Daw10b]. As stated by Sutherland et al., there are several open issues [Sut12]: - What real time data do teachers need for monitoring their students? And how can the data be collected and presented in an efficient and useful way?
- How can teachers adapt their teaching in order to improve their students learning after having

[51]SoLAR – Society for Learning Analytics:`http://solaresearch.org/about` (Last visit: 27 January 2013)

Table 2.6: Steps of the data analysis process

References	Steps
[Mit02]	1. Understand the application domain; 2. Extract the target data set; 3. Clean & preprocess data; 4. Integrate data; 5. Reduce data & project; 6. Choose the data mining function; 7. Choose the data mining algorithm(s); 8. Mine data; 9. Interpret; 10. Use discovered knowledge
[Sol05]	1. Collect; 2. Construct a model; 3. Compare current & desired states; 4. Advice/guide; 5. Evaluate
[Dim06]	1. Select/filter; 2. Process; 3. Present
[Cam07]	1. Capture; 2. Report; 3. Predict; 4. Act; 5. Refine
[Bra08]	1. Observe; 2. Abstract; 3. Intervene
[Dro09]	1. Gather; 2. Process; 3. Present; 4. Apply
[Har09]	1. Capture; 2. Segment; 3. Preprocess; 4. Analyse; 5. Visualize; 6. Interpret
[Eli11]	1. Capture; 2. Select; 3. Aggregate; 4. Report; 5. Predict; 5. Use; 6. Refine; 7. Share
[Cha12]	1. Collect; 2. Preprocess; 3. Analyse; 4. Postprocess
[Dia12]	1. Collect; 2. Store; 3. Clean or regularize; 4. Integrate; 5. Analyse; 6. Report & visualize; 7. Act
[Dyc12]	1. Gather; 2. Mine; 3. Visualise; 4. Interpret; 5. Conclude
[Kra13]	1. Collect; 2. Store; 3. Clean; 4. Integrate; 5. Analyse; 6. Represent & visualize; 7. Alert

received real time data?
- How can students themselves benefit from real time data collection? Can students be challenged cognitively or be provided with feedback through representations of real time data?

2.5.2 Learning Analytics processes

There are several proposals in the literature devoted to conceptualize the analysis processes of educational data (see Table 2.6). Many of them define a *data-driven approach* obtaining indicators based on the data available and trying to extract meaning from them, e.g., [Mit02] [Dim06] [Cam07] [Bra08] [Dro09] [Har09] [Eli11] [Cha12] [Dia12] [Dyc12][Kra13]. Others follow a *model-driven approach* [Sol05], in which the collected data are compared with a pre-specified model that guides the analysis. Since we aim to relate the data gathered from the learning scenario with the teacher's pedagogical intentions predefined in the scripts, we focus on the second approach, concretely in the collaboration management process proposed by Soller et al. [Sol05].

According to Soller et al., the process of collaboration management presents five steps [Sol05]: first, the collection and aggregation of interaction data; second, the construction of an interaction model, selecting and computing higher-level variables and/or termed indicators to represent the current state of interaction; third, the comparison between the current and the desired state of interaction; fourth, the advise and/or guidance in case of discrepancies between the current state of interaction; and finally, the evaluation of interaction assessment and diagnosis. Connecting this framework with the script lifecycle presented in Section 2.4.2, the four first steps of the framework belong to the management phase, whereas the fifth corresponds to the evaluation phase.

2.5.3 Monitoring: a LA strategy to enhance collaboration in CSCL

Monitoring is a well-known strategy in CSCL to enhance collaboration. Aware of how students interact with their peers and with the learning context, teachers may regulate and redirect the learning situation if needed. This section introduces this term and other related concepts such as 'interactions' and 'actions' that are relevant for this thesis. Finally, we present different categories of technological tools that may support teachers in the monitoring process.

Definitions

According to Dourish and Bellotti [Dou92], *"awareness is the understanding of the activities of others, which provides a context for your own activity"*. One way of improving such understanding is monitoring. **Monitoring** entails systematic collection of data related to specified indicators, that is provided to the manager (or the main stakeholders) of a development intervention to inform about the progress or achievement of expected goals [Mar09]. In the case of teachers, monitoring students' progress may provide an early indication of the likelihood that expected results will be attained, as well as an opportunity for making the necessary changes in programme activities and approaches. If the data generated from progress monitoring shows steady growth, then the teacher should continue with her current plan. However if there is minimal growth, no gain, or loss then the teacher can adapt the initial plan.

But monitoring is not only relevant for general orchestration purposes. Because interactions are the key to collaborative learning, monitoring students' interactions to regulate collaboration is at the heart of CSCL [Dil09b]. Thus, in orchestration of CSCL scenarios, monitoring is a crucial component of intervention.

In CSCL, the term 'interaction' refers to those happening between participants of the learning situation (mainly, students and teachers). As Crook describes [Cro94], interactions may be face-to-face or computer mediated depending on the nature of the learning scenario: in online learning, the interactions will be mainly computer-mediated; in face-to-face scenarios (e.g., in the classroom or in the lab), students' interactions tend to be face-to-face and sometimes involve technologies (e.g., groups working in front of the same computer); finally in blended scenarios, students may interact inside and outside the classroom both face-to-face or in a computer-mediated manner. What is obvious is that the information registered by the technological support is the main data source that may inform about computer-mediated interactions. Nevertheless, this information may be enriched by other data sources [Avo07] (e.g., teacher's observations or student's feedback).

In order to understand the results of a monitoring process, it is necessary to state which is the unit of analysis. According to Hilbert and Redmiles, there are different abstraction levels going from physical events (e.g., typing or mouse movement) to task-related events (e.g., writing a report) [Hil00]. In general terms, such events can be grouped in 3 categories: *activity* is a task like 'writing a report', *action* is an instruction to the computer to do something (e.g., create a new document), and *operations* are a sequence of steps to perform an action (e.g., click on the button 'new document', introduce the name, and click on the 'save' button). All related operations can be grouped into actions. In this thesis we focus on the action level, which often matches with granularity level of the information registered by many tools (e.g., accesses, editions, creation of objects, etc.).

It should be noticed that, inferring events based on lower level events can be straightforward when the user interface provides explicit indicating goals. For instance, some tools guide users through a sequence of steps in a predefined task (e.g., buying a train ticket on-line). The user's progress can be recognized in terms of simple user interface events such as button presses on the "Next" button. In other cases, inferring task and goal related events might complicated composite require more event detection (e.g., a questionnaire is filled once each one of its question has been answered). Finally, in some cases, it may be impossible to infer events at these levels based only on lower level events (e.g.,writing a report).

Focusing on CSCL, a collaborative action may be defined as "an action that affects or can affect the collaborative process. The main requirement for an action to be considered a possible interaction is that the action itself or its effect can be perceived by at least a member of the group distinct of the one that performed the action" [Mar04]. We should not forget that CSCL also involves individual learning, thus, also the actions of one student with the learning tools and the learning environment are relevant for the monitoring purposes, even if there is no reciprocity from his peers. This condition leads us to focus our study in the analysis of participants' actions.

Modeling users' actions

In the research area of computer-based interaction analysis, the need to process data by automatic means has led researchers to model users' actions and provide a computational representation. Though there is no standard, there are different proposals in the literature modelling users' actions (see Table 2.7): some of these models have been designed thinking on the information available in logs [vdA03]; others focus on the action description [Avo04]; and many authors, specially from the CSCL domain, adopt a situational approach [Mar04][Kah06][Har09].

In order to analyse participants' actions from a situated standpoint, it is necessary to consider the context in which they are taking place [Wil00][Cro00]. This is the approach followed in the DELFOS model [Mar04]. This model included the concept of *situation* (to model the general features of a learning environment, including learning objectives, number of expected participants, metaphors, etc) as well as the *users, roles, objects and groups* that intervene in the situation, and the actions. Many approaches focus on the representation of a single feature of the interaction, which hinders the desired integration of different sources of data. However, [Mar04] aim at integrating actions with no dependence to their nature (face-to-face or computer-mediated), source and data gathering system.

Another noteworthy proposal is the data format defined within the Kaleidoscope Network of Excellence in TEL, where a number of researchers collaborated to define the so-called *Common Format* [Har09]. This format had the main objective of enabling interoperability among learning and analysis tools. It therefore defines a minimum set of elements that every log event should include in order to be analysable by a computer-based interaction analysis tool. The elements defined in this Common Format are divided into two branches. The *context* is the general setup of a learning situation (users, roles of the participants, groups, resources). The second branch describes what happens during the learning activity, i.e., the *actions* carried out by participants, identifying who has done what, and when. "Who" is one user previously identified in the context

Table 2.7: User's interactions models

References	Main elements described in the models
[vdA03]	data source, task and event (user, event type, timestamp)
[Avo04]	actions (time, actors, objects and event type)
[Mar04]	situation (users, roles, groups and objects), activity and sessions (actions)
[Kah06]	context (users, roles, groups and tools) and actions
[Har09]	context (users, roles, groups and resources) and actions

branch, "what" is type of action among those allowed within the specific learning environment or tool, and "when" is the timestamp of the event.

Collaboration management systems

Collaboration management systems are those tools devoted to enrich the collaboration based on the interactions during learning process (replaying, analysing, making diagnosis, etc.). One way of classifying these tools is according to the step of the analysis process that they support [Sol05][Kra13]. For instance, Soller et al. (2005) identifies three categories attending to the collaboration management process (see Figure 2.7):

- *Mirroring tools* automatically collect and aggregate data about the students' interaction (phases 1 and 2 in Figure 2.7), and reflect this information back to the user, for example, as graphical visualizations of student actions or chat contributions. These systems are designed to raise students' awareness about their actions and behaviours. They place the locus of processing in the hands of the learners or teachers, who must compare the reflected information to their own models of desired interaction to determine what remedial actions are needed.

- *Metacognitive tools* display information about what the desired interaction might look like alongside a visualization of the current state of indicators (phases 1, 2 and 3 in Figure 2.7). These systems provide the referents needed by the learners or human coaches to diagnose the interaction. Like mirroring tools, users of metacognitive support tools are responsible for making decisions regarding diagnosis and remediation.

- *Guiding systems* perform all the phases in the collaboration management process, and propose remedial actions to help the learners. The desired model of interaction and the system's assessment of the current state are typically hidden from the students. The system uses this information to make decisions about how to moderate the group's interaction.

Another classification in terms of time-frame and purposes, is the one given by Davenport et al. [Dav10] who distinguish between more fact-based approaches (the "information" row in Figure 2.8) and approaches that are more targeted towards deeper understanding (the "insight" row in Figure 2.8) and segments these according to a temporal frame. Each approach addresses different key questions:

- Questions of information and fact:
  - *What happened?* Analytics produces reports and summarised descriptions of data (the past).

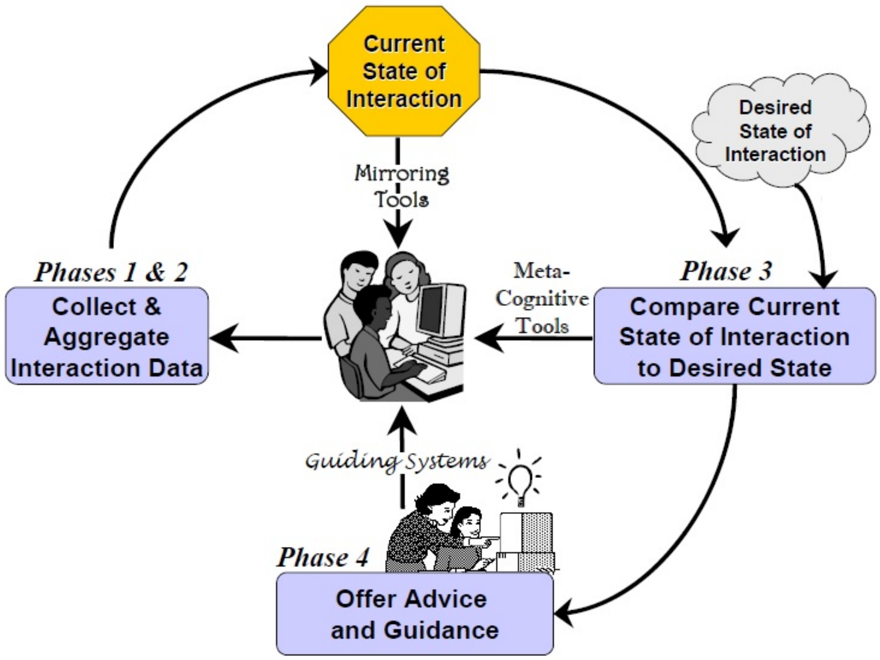


Figure 2.7: Classification of the systems according to the steps of the collaboration management process that they automatize (from [Sol05]).

  - *What is happening now?* Analytics provides alerts in near-real time (the present).
  - *Where are trends leading?* Past data is extrapolated (the future).

- Questions of understanding and insight:
  - *How and why did something happen?* Analytics builds models and explanation (the past).
  - *What is the best next action?* Analytics provides one or more recommendations (the present).
  - *What is likely to happen?* Analytics provides prediction, simulates the effect of alternative courses of action, or identifies an optimal course of action (the future).

Connecting the aforementioned classifications with teacher's information needs at runtime, in this thesis we will focus on metacognitive tools that 1) produce reports about what happened during the learning situation, 2) provide alerts about the current situation, and 3) extrapolate the impact in the future. With this information we expect to empower the teacher for regulating and adapting the learning situation.

2.5.4 Monitoring in DLEs: challenges

In Section 2.4.4 we presented by means of an example the challenges of scripting blended CSCL in DLEs. Here, we will pick up that illustrative scenario to identify the monitoring challenges.

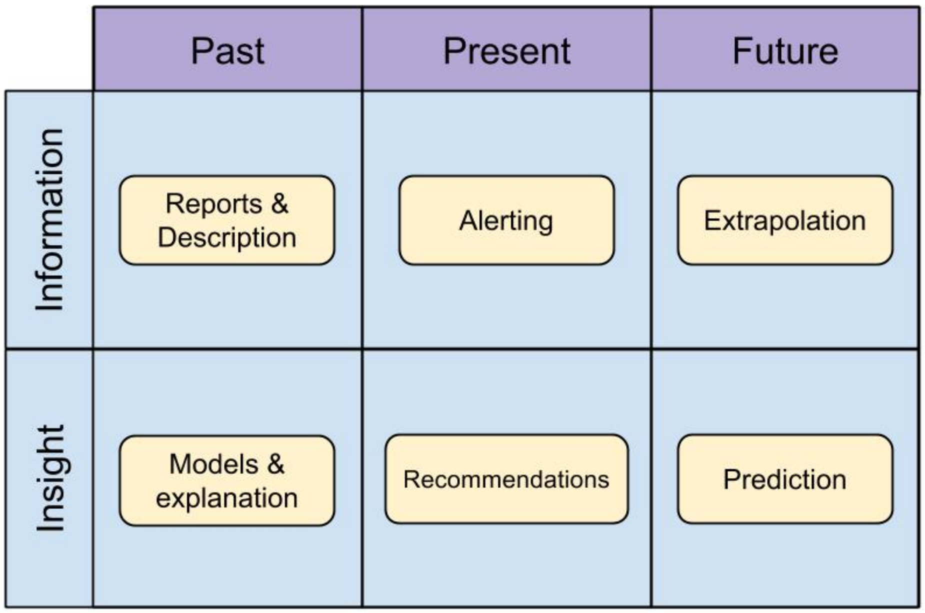


Figure 2.8: Classification of the systems according to both the time dimension of the questions and their level of insight [Dav10].

Let's get context: David has planned a one-week sequence of 4 activities with his 67 students, combining different social levels (individual, small groups, big groups, and whole class), different tools and resources (reference materials, 33 Google Docs, and 16 Google Drawings integrated in Moodle via GLUE!-PS) interleaving face-to-face and distance work. The following points bring out three simple questions that David poses about the learning process and the related tasks that he would need to do in order to answer them:

- *What if someone does not carry out the first activity? It would force me to restructure the dyads in Moodle, and it would take me too long to do it during the next session.* Since this is a distance activity, the information provided by the technological support is the only data source about the students' progress. Thus, David could use Moodle logs to verify who has accessed to the reference material. This information could be compared with the list of 67 students in order to detect who has not accessed the documents.
- *Is every group collaborating in the second activity? What if someone cannot come to the classroom and participates from home? If there are isolated students I should reorganize the groups in Moodle and reassign the documents to each new group.* The second activity combines face-to-face and computer-mediated interactions. Based on the evidence gathered just having a look to the classroom, David could know who has attend, and walking around he could have a general idea of how the students are accomplishing the activity. However, if someone carries out the activity from home, to be aware of who has participated would require writing down a list with the people attending to the class, and complete it with the evidences that the version history of each one of the 33 Google Docs the teacher could know whether the dyad has finished or not, and, looking at the history log provided by the tool, he could realize who has edited the document.

- *How can I ensure that the students review the others' work in the third activity? Otherwise, coming to an agreed version of the mindmap will take too long and they will need additional time outside the classroom.* The third activity, as the previous one, combines face-to-face and computer-mediated interactions. However in this case, before attending to the face-to-face session, each student should review the work done by their group colleagues. He could use Moodle (as in the first activity) to verify which students have accessed to their groupmate's proposals. Then, dealing with the mindmaps, Google Drawing does not provide logs, so, either David goes through the 16 mindmaps verifying what the students did, or he checks the accesses via Moodle logs.

Could we imagine the amount of time that David would need to answer just these 3 questions? Frequently, to be aware of what is happening in a DLE, teachers need to review each document verifying *what* the students have done. Indeed, in order to know *who* has collaborated and *how*, teachers need to have a look to the logs (if they exist) trying to infer some information. Obviously, addressing these tasks manually is time consuming and error-prone.

But, why existing platforms do not provide additional monitoring support? There are some problems that hinder not only monitoring but also learning analytics in DLEs:

- *Data gathering.* Records are distributed across a variety of different sites with different owners and levels of access [Scl08] [Fer12], this means that retrieving data in such technological contexts requires ad-hoc solutions for each tool. Indeed, collecting data from databases of multiple e-learning systems may not be possible if the systems are externally hosted [Scl08].

- *Data integration.* There is no standard to represent users' interactions and, for that reason, almost each tool implements its proprietary format [Scl08] [Rom10] [MM11b] [Fer12] [Kra13]. This diversity of formats causes an integration problem that requires ad-hoc solutions to deal with the myriad of languages, models and the granularity of data.

- *Data quality.* Some tools do not provide ready-to-use data (e.g., audio or video records), others store data for different purposes (such as error debugging), and there are also some cases that do not provide information at all [Avo07] [MM11b]. Registering users' interactions is a key issue to take into account in the design of CSCL environments that is often overlooked [Dil09b].

- *Tool usability.* As Romero & Ventura noted, to date, efforts to analyse educational data have been hampered by the lack of tools that may be easily use, especially for non-expert teachers [Rom10].

- *Tools interoperability.* There is a poor integration between data mining tools, analysis tools, and e-learning systems [Rom10]: the lack of standardization of data and models causes that analysis tools remain useful only for specific frameworks (or even for specific courses). Therefore, the analysis tools are often devoted to specific learning platforms [Har09].

- *Tool functionalities.* Despite VLEs amass ever-increasing amounts of interaction data, personal data, systems information and academic information [Maz04] [Rom08], the depth of extraction and aggregation, reporting and visualisation functionality of the built-in student-tracking tools has often been basic or non-existent [Daw10a].

In addition to the difficulties that appear in DLEs, if we take into account that we deal with blended scenarios, there is another problem: during the face-to-face sessions, many issues are simply invisible to these systems[Gri13], since a significant part of the learning activity takes place out of the DLE [Fer12]. Therefore, it necessary to gather and integrate information regarding the face-to-face session in order to build a thorough view of the activity [Avo07].

Thus, the use of architectures that integrate the different data sources plays a crucial role. The Tin Can API[52] and CAM [Sch10] are two solutions that may be used to this end. The Tin Can API is a specification for capturing data about a person or group's activities from multiple technologies. This specification requires that each tool implements a REST service to send statements – in the form of 'Noun, verb and object' – to a learning record store. A similar approach is followed in the CAM solution to gather data from PLEs, where each tool must offer a REST interface to provide the user's data on demand, following the CAM format. However, these architectures use their proprietary formats to store the data retrieved.

2.6 Conclusions

To wrap up the ideas presented in these chapter, we will use the '5+3 aspects' orchestration framework, as it is show in Figure 2.9:

- Context: Blended CSCL scenarios, supported by DLEs, occurring in formal education, where teachers have the main orchestration role. This chapter has started introducing the context of the dissertation (see areas surrounded by dotted lines in Figure 2.9). The main **methods and theories** that will lead the learning scenarios tackled in this thesis are the ones established by blended and collaborative learning. We have centred all our discussions around the *teacher's* **role**, trying to adopt a **pragmatic** approach: i.e., identify the challenges that they need to face in the orchestration of *authentic learning scenarios*. Since addressing every educational setting would greatly exceed the scope of the dissertation, we have focused on blended CSCL scenarios supported by DLEs, which are becoming highly adopted, even though their complexity brings out multiple challenges, and requires a lot of effort from teachers.

- Proposal: Alignment of two LD and LA strategies for enhancing collaboration: scripting and monitoring. The first challenge that we came across is *the lack of meaningful awareness information* to intervene and regulate the scenario according to the emergent needs. As we have seen in Sections 2.4 and 2.5, Learning Design and Learning Analytics support different orchestration aspects in TEL scenarios. Especially, in the case of CSCL, **design** and **awareness** aspects may be aided by means of *scripting* and *monitoring* strategies to enhance collaboration (see areas marked with dashed line in Figure 2.9).

Although scripting and monitoring help teachers in the orchestration of CSCL scenarios, there are still outstanding problems. Despite scripting the learning scenario beforehand, eventualities may emerge at run-time and jeopardize the initial plan. Furthermore, even if the analysis

[52] Tin Can API `http://tincanapi.com` (Last visit: 1 February 2014)

of the students' interactions generates useful insights on how the learning process unfolds, the information that current monitoring proposals provide to the teachers is not always easy to interpret. Thus, teachers often lack relevant information to eventually intervene and adapt their plans at run-time.

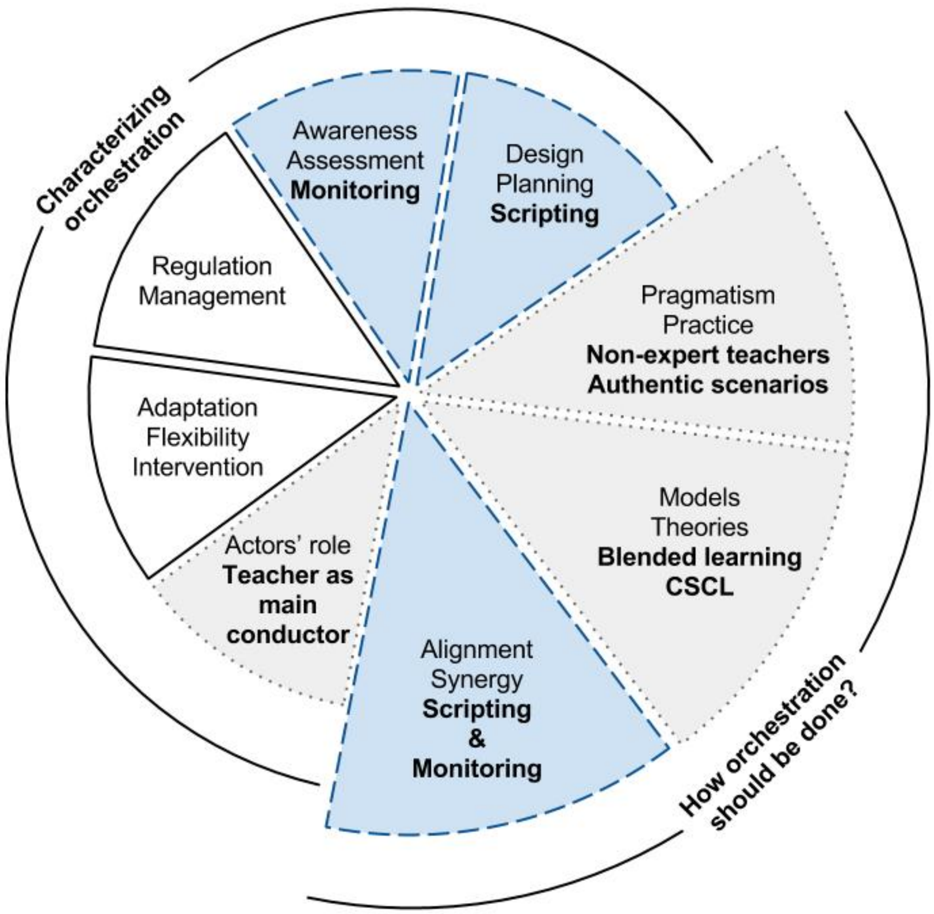


Figure 2.9: Orchestration aspects within the context of this dissertation. Green areas represent the context and blue areas highlight the aspects addressed by our proposal.

All in all, current work on CSCL orchestration recognizes the need for **aligning** *scripting and monitoring*. However, few proposals make this alignment explicit throughout lifecycle of design, instantiation, run-time management, and assessment of CSCL scenarios, and even less in the case of DLEs. Such alignment would change the way CSCL scripts are designed by educators, as well as the way learning analytics data are collected from CSCL systems and subsequently analysed for "closing the cycle".

From the review done in Sections 2.4 and 2.5 about scripting and monitoring, we can identify at least four problems that explain why the alignment is not straightforward:

- Design processes. Design processes of CSCL scripts normally do not pay attention to the awareness needs at run-time. Besides, we cannot expect that teachers can integrate these concerns by themselves. If scripting CSCL to enhance collaboration is a difficult task that frequently requires advice (e.g. by means of authoring tools or pedagogical patterns), practitioners will need additional support to anticipate during the design process which could be their awareness needs and how they can be satisfied.

- Monitoring processes. Current data gathering and analysis proposals follow mainly data-driven approaches [Mit02] [Dro09] [Cha12], that generate indicators describing the collaboration process in a bottom-up fashion, based on available data. To provide teachers with meaningful information connected to their pedagogical concerns, it is necessary to take into account the pedagogical decisions in the data analysis.

- Models. Existing models of scripting and interaction analysis fields are not suitable for guiding monitoring on the basis of pedagogical intentions. Scripting proposals cannot be applied for monitoring mainly because they do not consider the users' actions during the learning process. Regarding interaction analysis, the studied models do not take into account a core scripting concept, namely learning activities. Therefore, it is necessary to bring together both scripting and interaction analysis approaches in order to define a common ground for communication between both sides.

- Data gathering and integration architectures. Monitoring users' in DLEs represents a challenge itself: in general terms, the data to be gathered is decentralized and each tool follows its own formats and models, hampering the integration. Thus, the use of architectures for gathering and integrating data about a person or group's activities from multiple technologies plays a crucial role in order to address the aforementioned problems.

The four problems that we have emphasized here will be addressed in turn in the following chapters.

Chapter 3

Exploratory iterations

Summary: This chapter summarizes the work done in the two exploratory iterations of the DBR process. These iterations covered five studies in authentic scenarios, with four participant teachers with different backgrounds and expertise on CSCL. The first iteration focused on the use of pattern constraints to guide the monitoring process of pattern-based CSCL scenarios, and on the restrictions imposed by the DLE to collect and integrate students' actions. As a result of this iteration, we realised that certain design decisions (e.g., the selection of learning tools) influenced the monitoring results. Thus, we carried out a second iteration with a twofold purpose: a) to identify the pedagogical design decisions that affect monitoring, and b) to integrate monitoring issues in the pattern-based design process of CSCL scripts. This Chapter presents the main outputs of each iteration focusing on the most important aspects that emerged from the studies. A detailed description of the exploratory studies themselves is available in Appendices C to G.

A part of the studies and results presented in this chapter have already been published in different scientific fora. Specifically, the first exploratory study [RT11c], the third [RT12a] [RT12b] [RT13a] [RT13b] and the fourth [RT13a].

3.1 Introduction

As mentioned in Section 1.3, the DBR methodology entails both exploratory and evaluative work carried out throughout several iterations. In our case, the exploratory work contributed to the formulation of the thesis proposals (presented in Chapter 4), while the evaluative iteration (described in Chapter 5) helped to verify whether these proposals achieved our research goals. This Chapter focuses on the exploratory iterations and shows how the different research questions emerged during the DBR process, and what were the main findings obtained from the exploratory studies.

We should remember that the final goal of this dissertation is to provide teachers with monitoring information in order to help them regulate the learning situation. To achieve this goal, we propose to link monitoring with teacher's pedagogical design decisions, concretely with those described by CSCL scripts. In this exploratory work, we thus tried to identify the requirements (imposed by the teachers and the technological environments) for the integration between scripting and monitoring. Besides, we observed how the alignment between both strategies supported teachers in the orchestration of the learning scenario.

Throughout the two exploratory iterations, we carried out a total of five studies in authentic CSCL scenarios. For the sake of brevity, this Chapter presents the main outputs of the studies in each iteration. A detailed description of the exploratory studies themselves is available in Appendices C to G.

The Chapter is structured as follows: Section 3.2 describes in detail the methodological aspects of this exploratory DBR work; Sections 3.3 and 3.4 describe the first and second iterations, respectively, presenting an overview of the learning scenarios developed in each study and showing the findings that emerged from the studies; and Section 3.5 provides the conclusions obtained from these exploratory iterations.

3.2 Methodology

The exploratory phase of the dissertation involved two iterations, encompassing a total of five studies in authentic CSCL scenarios at the University of Valladolid (Spain), between October 2010 and June 2012. These five studies involved four courses and four different teachers, and a total of 185 students from three different degrees ("Bachelor on Telecommunications Engineering", "Master's Degree for Pre-service Secondary Education Teachers" and "Bachelor on Early Childhood Education"). Figure 3.1 provides a general description of the learning contexts (*EXP i* denotes EXPloratory study number *i*.).

For this exploration of the alignment between scripting and monitoring, we chose learning scenarios with a common profile: they all comprised pattern-based CSCL scenarios supported by DLEs, which lasted between two and four weeks, and combined face-to-face and distance learning (as well as face-to-face and computer-mediated interaction). We selected teachers with different expertise implementing CSCL scenarios, and different academic backgrounds (telecommunications engineering, computer science and learning sciences).

Aligned with our overall goal of providing teachers with relevant information about the learning process, the first iteration was applied to courses where the sequence of learning activities comprising the script were arranged according to pedagogical patterns. This fact enabled us to explore whether the constraints imposed by these patterns could provide some hints to monitor computer-mediated student actions. Besides, in order to collect and integrate the students' actions gathered from the DLE, we analysed which were the restrictions imposed by the technological environment. Thus, the main exploratory questions of the first iteration were:

- EXQ_MON.IT1: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?
- EXQ_DAT.IT1: What are the required conditions for collecting relevant information of the students' collaboration in a blended CSCL scenario supported by DLEs?

From the first iteration, we realised that certain design decisions (beyond the mere selection of a pedagogical pattern) had an influence on the monitoring results. For example, the monitorable actions depended on the selection of tools to be used during the activities; also, the learning evidence was gathered taking into account the activity time frames defined in the design phase. Thus, we decided to carry out a second iteration where we co-designed the CSCL scenarios with the teachers. This iteration had a twofold purpose: to identify the pedagogical decisions that affect monitoring (not only the selection of patterns), and to make monitoring issues a first-class aspect to take into account during the design process of CSCL scripts. Thus, the main exploratory questions of this second iteration were:

- EXQ_DES.IT2: How can teachers be supported to integrate monitoring concerns in the pattern-based design process of CSCL scripts?
- EXQ_MON.IT2: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?
- EXQ_DAT.IT2: What are the required conditions for collecting relevant information of the participants' actions in a blended CSCL scenario supported by DLEs?

To address the aforementioned exploratory questions, we split them into more concrete questions that inform the main ones. The specific questions addressed in the first and second iterations are presented, respectively, in Figure 3.2 and Figure 3.3. The labels used to refer at the exploratory questions are:

- **EXQ_DES.IT*i*:** main EXploratory Question related to the DESign of blended CSCL scenarios supported by DLEs, addressed during iteration number i (i=1..2)
  - **EXQ_DES.IT*i.j*:** EXploratory Question number j related to the DESign of blended CSCL scenarios supported by DLEs, addressed during iteration i (i=1..2)
- **EXQ_MON.IT*i*:** main EXploratory Question related to the MONitoring of blended CSCL scenarios supported by DLEs, addressed during iteration number i (i=1..2)
  - **EXQ_MON.IT*i.j*:** EXploratory Question number j related to the MONitoring of blended CSCL scenarios supported by DLEs, addressed during iteration i (i=1..2)
- **EXQ_DAT.IT*i*:** main EXploratory Question related to the DATa gathering and integration in DLEs, addressed during iteration number i (i=1..2)
  - **EXQ_DAT.IT*i.j*:** EXploratory Question number j related to the DATa gathering and integration in DLEs, addressed during iteration i (i=1..2)

In each study we used four main data sources to illuminate our exploratory questions: the ICT tools, the teachers, the students, and the researcher(s) involved in each scenario. Further details regarding the data sources and the data gathering techniques are presented in the Sections devoted to each iteration below, and in the Appendices C to G, where each exploratory study is described in detail.

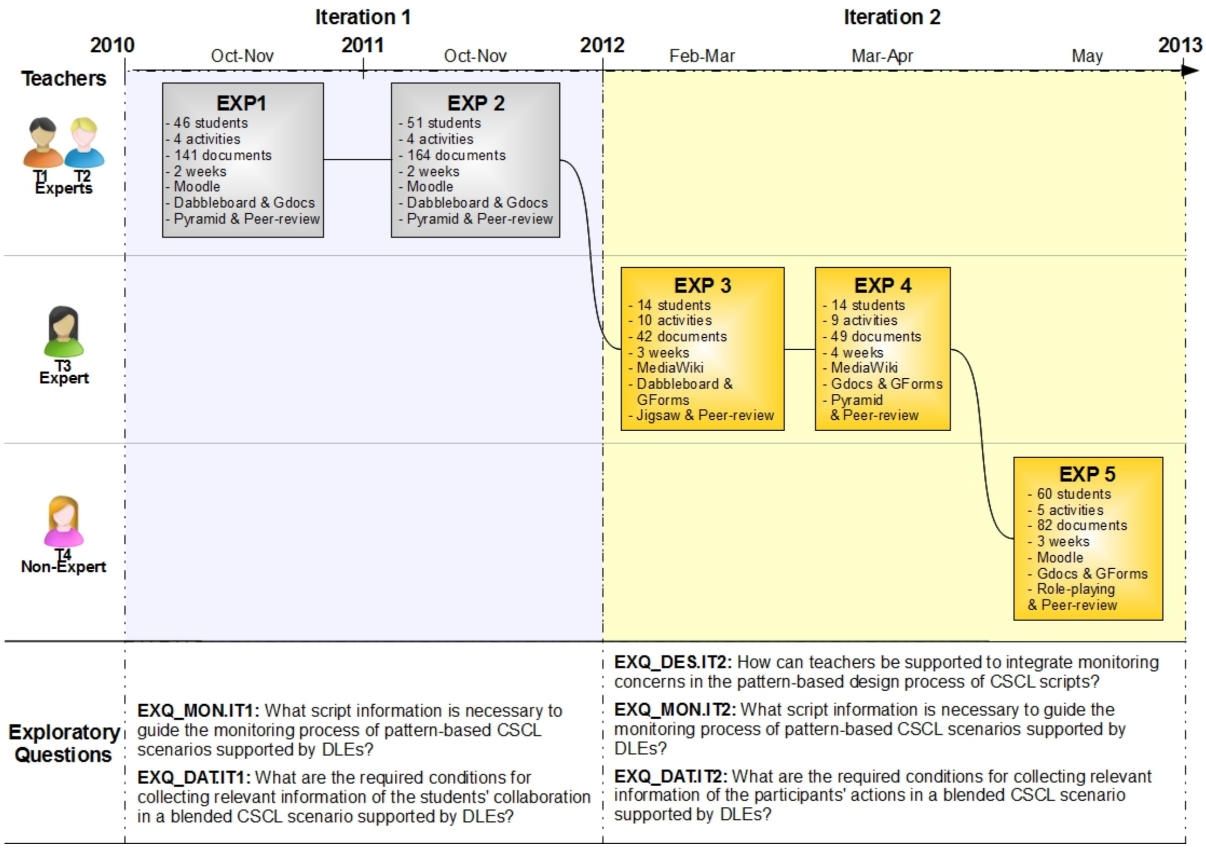


Figure 3.1: Relationship among iterations, studies and main exploratory questions.

3.3 First exploratory iteration

The first iteration was carried out between October 2010 and December 2011. In the two studies that made up this iteration, we had a twofold purpose: to identify *script parameters that could guide the monitoring process of pattern-based CSCL scenarios supported by DLEs* [EXQ_MON.IT1]; and to compile *conditions for collecting relevant information of the participants' collaboration in a blended CSCL scenario supported by DLEs* [EXQ_DAT.IT1].

To delve into the script information that could guide the monitoring process [EXQ_MON.IT1], we focused on four specific topics to be addressed in these studies (see the 'exploratory questions' area in Figure 3.2): first, we tried to figure out what script aspects teachers took into account in the design phase [EXQ_MON.IT1.1]; second, being aware of the teachers' decisions, we tried to identify what additional information could be included in the script to enable and enhance monitoring [EXQ_MON.IT1.2]; third, since we were working with pattern-based CSCL scenarios, we explored the impact of the pattern constraints on the monitoring process: concretely, we checked whether the teachers considered that being informed about the accomplishment of the pattern constraints was relevant [EXQ_MON.IT1.3]; and fourth, we analysed whether the pattern constraints were sufficient to detect the problems that emerged during the learning situation [EXQ_MON.IT1.4].

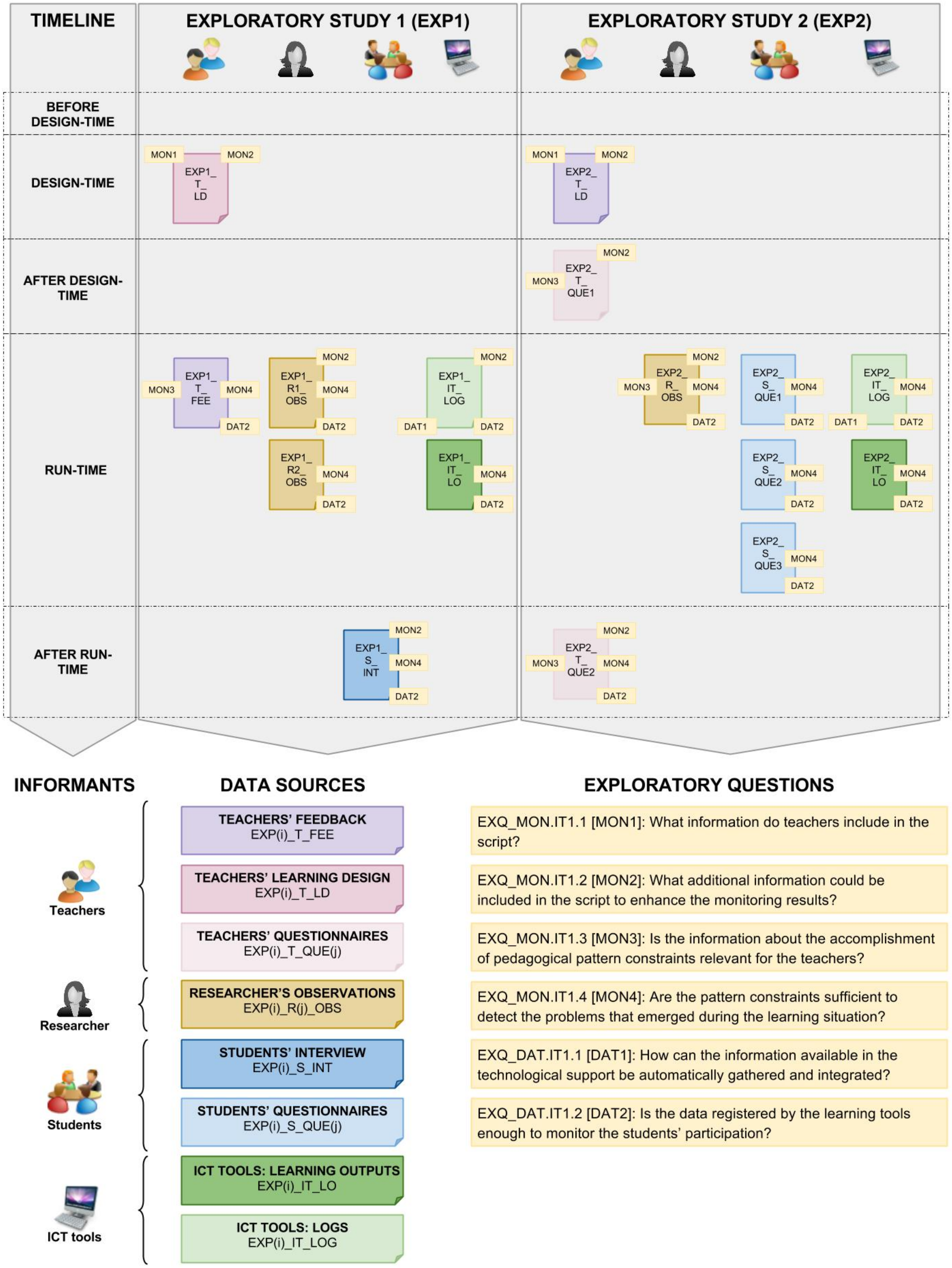


Figure 3.2: Connections between studies, exploratory questions and data sources in the first exploratory iteration.

Regarding the data sources required to monitor the learning process [EXQ_DAT.IT1], we explored two topics (formulated in Figure 3.2, area labeled 'exploratory questions'): first, what information was available in the technological learning environment and how we could automate the gathering and integration of such data [EXQ_DAT.IT1.1]; and, second, whether the computer-mediated actions registered in the DLE were enough to monitor the students' work [EXQ_DAT.IT1.2].

The rest of this section provides an overview of the exploratory studies and the main findings obtained in the first iteration of the DBR process. As noted before, the reader interested in the full description of these studies can refer to Appendices C and D.

3.3.1 Overview of the studies in this iteration

This iteration encompassed two studies carried out in two consecutive years within a course on "Network Traffic and Management" in the Telecommunications Engineering bachelors degree at the University of Valladolid (Spain). In both studies, the teachers (Daniel and Javier[1]) and the learning design of the scenario remained the same. The teachers had previous experience setting up CSCL scenarios, and they had carried out the same learning situation several times in previous years (without the support of ICT tools).

The *first exploratory study* (EXP1) took place in November 2010, with the participation of the 46 students that attended the course. During this course, students had to develop a chat tool using data network protocols. In order to help them plan and anticipate problems for a subsequent programming assignment, they were asked to elaborate a sequence diagram of their software design. To develop this diagram, students worked in a blended CSCL situation, interleaving *face-to-face* and *distance activities mediated by ICT tools*.

The collaboration script implemented a two-level *Pyramid* CLFP [HL08]. At level-1, *small groups* of two participants attended a face-to-face lab session to carry out the first activity: to draw a preliminary version of the sequence diagram, and write a report with a summary of the main decisions and open issues. At level-2, groups joined to conform *super groups* (composed of four people) that had to accomplish both a distance and a face-to-face activity. During the former, each *small group* had to review and provide feedback on the reports produced by their *super group* mates; in the latter, they had to discuss and produce a joint version of the diagram, presenting orally a common view of the main conclusions and open issues.

Regarding the technological support, teachers used *Moodle* (institutional VLE at the University of Valladolid) to centralize access to all the resources and activities. To accomplish the drawing tasks, students were provided with a shared board web application (*Dabbleboard*[2]). In order to explain, review and discuss, they had at their disposal shared documents and presentations (*Google Documents* and *Google Presentations*). Since these tools cannot be automatically integrated into Moodle, the *GLUE!* architecture [AH10b] was used to integrate them into the VLE.

[1]Throughout the dissertation, the names of the teachers have been replaced to preserve their anonymity.

[2]Despite the tool is no longer available, further information about *Dabbleboard* may be found at: `http://dabbleboard.wordpress.com/` (Last visit: 10 May 2014)

Figure 3.2 presents an overview of the data sources, the moments when evidence was collected and the exploratory questions that they aimed to answer. To describe our work below, we have divided the study into four phases:

- At design time, two researchers (R1 and R2 in Figure 3.2) observed the design sessions to collect and understand the teachers' decisions [EXP1_T_LD].
- After the design, the researchers analysed the pattern constraints. This analysis resulted in a set of indicators (e.g., participation) and conditions (e.g., $\forall$*student, student.participation* ≥ 1) that were compared with the computer-mediated actions registered in the DLE.
- During the enactment, the researchers monitored the learning process by means of the logs obtained from the ICT tools [EXP1_IT_LOG] and provided teachers with monitoring reports. Moreover, the researchers observed the face-to-face sessions [EXP1_R1_OBS, EXP1_R2_OBS], collected the teachers' feedback [EXP1_T_FEE], and revised the student-generated learning outcomes generated using the ICT tools [EXP1_IT_LO].
- Finally, after run-time, the researchers interviewed a group of volunteer students about their participation in the learning activities [EXP1_S_INT].

The *second exploratory study* (EXP2) was carried out in November 2011 with a new class of 51 students. The teachers reproduced the same design and adapted it to the particularities of the new learning context (dates, number of students, resources, etc.). However the researchers' work in this case was slightly different from that of the previous study. Figure 3.2 provides an overview of the phases, data sources, and the relationships with the exploratory questions. The main tasks carried out in each phase could be summarized as follows:

- At design time, one researcher observed the design sessions to be aware of the teachers' decisions and the implementation in the DLE [EXP2_T_LD].
- After the design process, the teachers (individually) answered a questionnaire about the flexibility of the design decisions and the potential problems they foresaw that could emerge during the enactment [EXP2_T_QUE1].
- During the enactment, in order to obtain evidence about the learning process, the researcher monitored the learning scenario by means of the logs obtained from the ICT tools [EXP2_IT_LOG]. Our monitoring results were triangulated with data coming from observations of the face-to-face activities [EXP2_R_OBS], the learning outcomes generated in the ICT tools [EXP2_IT_LO], and a questionnaire about the learning process sent to the students at the end of each activity [EXP2_S_QUE1, EXP2_S_QUE2, EXP2_S_QUE3].
- Once the learning scenario had finished, teachers answered a questionnaire about the critical situations that had emerged throughout the activities [EXP2_T_QUE2].

3.3.2 Findings

In this subsection we discuss the evidence gathered from both studies, answering the exploratory questions presented at the beginning of the section (see Figure 3.2).

EXQ_MON.IT1: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?

EXQ_MON.IT1.1: What information do teachers include in the script? In the first study, Daniel and Javier focused mainly on the following aspects of the script during the design sessions [EXP1_T_LD]: first, they built a general idea of the learning scenario, choosing the *pedagogical patterns* to be applied (i.e., the *Pyramid* and the *Peer-review*), the *activity flow*, the *ICT tools* that made up the DLE (Moodle, Dabbleboard, Google Documents, Google Presentations, and GLUE! in order to integrate the external tools into the VLE), and the group formation policies (size and number of groups). Then they provided a *description of each activity* (including the purpose and the social level), the dates of the lab sessions, and the relationship between sessions and activities. Finally, the teachers distributed the *students* into *groups* (small groups and super groups), created as many *tool instances*[3] as required to support each group throughout the learning scenario, and assigned them to the corresponding groups.

In the second study, the teachers reused the script prepared in the previous course and adapted it to the current scenario (distributing the new students into groups, creating tool instances and assigning them to the corresponding group). Moreover, since the teachers remembered that in the first study we asked them for the *time frame of each activity* (in order to filter the students' actions relevant for monitoring the student progress), they also included this information and shared it with the students [EXP2_T_LD].

EXQ_MON.IT1.2: What additional information could be included in the script to enhance the monitoring results? In the first study we realised that, in order to filter the students' actions [EXP1_IT_LOG], we needed to fix the specific moment when each activity started and ended. Though the teachers had provided some clues about the timing of the lab sessions and the deadlines for some activities [EXP1_T_LD], this information was not enough to find out in which moment each activity began or ended. Thus, we had to ask the teachers about the specific *time-frame of each activity* (date and time) [EXP1_R1_OBS].

In addition, we discovered that there were some resource-related aspects that could have contributed to provide monitoring reports closer to the teacher's needs. For instance, we saw in both studies that not all documents had the same relevance for the accomplishment of the learning activities. Albeit a drawing tool (Dabbleboard) was provided to support the creation of the sequence diagrams, some students used alternative tools such as Paint [EXP1_S_INT][EXP2_R_OBS]. Even if this change did not suppose a major problem for Daniel and Javier, they did tell students that it was mandatory to use the Google Documents and Presentations available in the DLE for the elaboration of the reports and the presentations [EXP1_R1_OBS][EXP2_R_OBS]. Additionally, during the third activity, students had at their disposal both their super group resources (Google Presentations and Dabbleboard instances) as well as their small group resources (Google Documents and Dabbleboard instances) from the previous activities. In this case the role of each resource in the learning process was different: the small group resources could be used as reference material, the super group Dabbleboard instances were optional (indeed, many groups reused the previous canvases [EXP1_R1_OBS][EXP1_S_INT][EXP2_R_OBS]), and the Google Presentations were expected to

[3] E.g., if Google Documents is a *tool*, each document created with Google Documents is a *tools instance*.

contain the learning output of the third activity. Thus, we considered that, in addition to the list of resources included in the learning design, it would be useful to specify the *expected use of each resource*. Just being aware of which *resources* were *mandatory* and which were *optional* might have contributed to reduce the amount of detected "problems" that actually had no major impact on the success of the scenario.

Finally, we detected certain learning activities (especially those that happened totally face-to-face) in which teachers were already aware of the students' progress, apparently making the monitoring information less necessary for such activities [EXP1_R1_OBS][EXP2_R_OBS]. Furthermore, some of the problems that emerged during the scenario were already expected by the teachers [EXP2_T_QUE1]. This led us to hypothesise that asking teachers beforehand about *what activities need to be monitored* and *at what moments they need the monitoring information* could help teachers to early detect and regulate potentially critical situations.

EXQ_MON.IT1.3: Is the information about the accomplishment of pedagogical pattern constraints relevant for the teachers? There were three types of evidence that supported the idea that the accomplishment of the pattern constraints was relevant for the teachers: (1) how teachers used the monitoring reports in the first study; (2) the feedback obtained from the questionnaires to the teacher in the second study; and (3) the critical situations that emerged in both learning scenarios.

Both in the first and in the second study, we generated a monitoring report to be used by teachers. First, based on the pattern constraints we defined a set of indicators (related to participation, collaboration and group formation) and conditions (extracted from the expected values of the indicators, e.g., $\forall group, \exists student1\ \&\ student2\ /\ student1.participation \geq 1\ \&\ student2.participation \geq 1$) that were used to guide the monitoring process. Then, analysing the students' actions recorded in the learning environment (computer-mediated actions obtained from the GLUE! logs in the first study [EXP1_IT_LOG], GLUE! logs and attendance to the lab session in the second study [EXP2_IT_LOG][EXP2_R_OBS]), we could have an idea of the accomplishment of the pattern constraints within a specific period of time.

During the first study the monitoring reports helped the teachers realise which pattern constraints may have been broken (potentially). Using this information, Daniel and Javier were able to infer critical situations that could have jeopardized the script's collaborative purpose [EXP1_T_FEE] (e.g., if there was an isolated group), and could have intervened on-time adapting the script and the DLE (e.g., re-structuring super groups and modifying the assignment of the resources in the DLE).

In the second study, Daniel and Javier specified in the questionnaires which design decisions were fixed and which were the critical situations that they foresaw during the enactment [EXP2_T_QUE1]. In both cases, there were several mentions to the pattern constraints. For instance, the teachers considered that, among their design decisions, the pattern constraints and the number of pyramid levels were not to be modified. Moreover, three of the four problems that the teachers envisioned were related to the pattern constraints: lack of collaboration, isolated groups, and delays in the submissions (for more information, see Table D.3).

Based on the teachers' feedback at the end of the learning situation [EXP2_T_QUE2], only two problems emerged during the enactment, both of them related to the pattern constraints.

In the first activity, none of the students had finished their reports, and thus it was necessary to postpone the deadline [EXP2_R_OBS, EXP2_T_QUE2]. Otherwise, this situation could have affected negatively both the *Peer-review* and the second level of the *Pyramid* (since the students could neither review or discuss about their proposals). In addition, during the second lab session, teachers discovered another critical situation [EXP2_T_QUE2] related to a *Pyramid* constraint (in each pyramid level there must be at least 2 groups involved from the previous level to ensure collaboration). To avoid this problem teachers intervened to adapt the scenario.

EXQ_MON.IT1.4: Are the pattern constraints sufficient to detect the problems that emerged during the learning situation? The analysis of the *Pyramid* and the *Peer-review* constraints made the identification of indicators and conditions used in the monitoring process easier. Aside from the detected problems related to pattern constraints, neither the ICT tools [EXP(i)_IT_LOG, EXP(i)_IT_LO], the researchers [EXP(i)_R1_OBS, EXP1_R2_OBS], the teachers [EXP(i)_T_FEE], or the students [EXP1_S_INT, EXP2_S_QUES(j)] reported any additional problems unconnected with the patterns constraints. However, it was necessary to ask teachers for additional constraints related to the activities, such as their time frame, in order to complement the pattern constraints. Thus, we envisioned that the list of constraints obtained from the patterns could be improved by taking into account the specific activity constraints (e.g., what is the importance of using each learning material).

EXQ_DAT.IT1: What are the required conditions for collecting relevant information of the participants' collaboration in a blended CSCL scenario supported by DLEs?

EXQ_DAT.IT1.1: How can the information available in the technological support be automatically gathered and integrated? We analysed the data provided by the tools that made up the DLEs used in the studied situations: Dabbleboard did not provide any kind of information dealing with the users' actions; Google Documents and Google Presentations provided change history logs through the user interface, but there was no application programming interface to retrieve such information automatically; Moodle offered a data base with information about the VLE and the internal tools, which could be queried; and GLUE! registered in a log file the requests related to the external tools integrated in the VLE. Since our main interest in these scenarios was on the use of the external tools (as no internal Moodle tools were used), we focused on the information provided by GLUE!.

Since GLUE! stores the registered events in log files compliant with the W3C Extended Log File Format[4], automating the analyses seemed feasible. Thus, for the second study, we developed an interpreter for GLUE! logs [EXP2_IT_LOG] that informed us about the date and time of the accesses, the user and the tool instance. With this information we could filter all those accesses originated by a participant of the learning scenario, to the resources that supported the monitored activity, within each activity time frame. Since this format is frequently used in RESTlet services (the technology used to implement GLUE!), we expected that the developed interpreter could be reused for other tools and services as well. The use of the log interpreter reduced significantly the time devoted to the log analysis (7 hours in the first study, versus 2,5 hours in the second one).

[4]W3C Extended Log File Format `http://www.w3.org/TR/WD-logfile.html` (Last visit: 10 March 2014).

Table 3.1: Validation of the monitoring reports obtained in the first exploratory study: detected problems, false positives and errors.

Data sources	Problem type	Activity 1.1	Activity 2.1	Activity 2.2	Activity 3.1
Detected problems (based on logs)	Individual participation	17	28	28	42
	Small Group participation	7	16	9	19
	Super Group participation	-	1	1	4
	Group collaboration	12	5	1	5
False positives	Individual participation	4	0	14	28
	Small Group participation	0	0	2	12
	Super Group participation	-	0	0	3
	Group collaboration	4	0	0	4
Undetected problems	Small Groups that did not complete the activity	0	1	0	0
	Super Groups that did not complete the activity	-	0	0	0

EXQ_DAT.IT1.2: Is the data registered by the learning tools enough to monitor the students participation? In the first study, to estimate the **credibility** of the monitoring process based on the logs, we compared the results of analysing such logs against the evidence of participation in the face-to-face sessions (registered by the researchers) [EXP1_R1_OBS] [EXP1_R2_OBS] and the learning outcomes of the students available in the tool instances [EXP1_IT_LO]. Table 3.1 shows that there existed few problems that went unnoticed by the log analysis, and multiple false positives (i.e., critical situations detected in the analysis that did not entail a real problem), especially in those activities were part of the interaction was face-to-face.

The problems that were not identified by the log monitoring process involved students accessing the tools [EXP1_IT_LOGS], but not completing the tasks that they were expected to do (writing the report in activity 1.1 and providing comments in activity 2.1) [EXP1_IT_LO]. In fact, finding a solution to this problem is not straightforward since it requires a detailed review of the content to decide whether the students have actually finished their work or not.

The false positives were caused by two main reasons: the lack of additional data sources (about the work done within the external tools and the face-to-face interaction) and unexpected behaviour from the students. For instance, during the first activity students were distributed in dyads sharing the same computer. Thus, in many cases, they only logged into Moodle with one of the students' accounts and developed the activity without switching usernames [EXP1_R1_OBS]. A similar situation was detected in the third activity, where the members of the super groups were working all together in front of one or two computers. In both cases, although multiple participants were involved in the activities, there was only computer-mediated evidence about a small part of the group members [EXP1_R1_OBS, EXP1_R2_OBS].

Other unexpected behaviour was identified thanks to the researchers' observations of the lab sessions and the students' feedback in the interview [EXP1_S_INT]: e.g., in the first activity, one student employed a different drawing tool (hence, the automatic logs could not register this

Table 3.2: Validation of the monitoring reports obtained in the second exploratory study: detected problems, false positives and undetected errors.

Data sources	**Problem type**	**Activity 1.1**	**Activity 2.1**	**Activity 2.2**	**Activity 3.1**
Detected problems (based on logs & attendance to the lab sessions)	Individual participation	10	24	11	11
	Small Group participation	5	11	6	6
	Super Group participation	-	0	1	1
	Group collaboration	6	1	1	1
False positives	Individual participation	0	0	0	0
	Small Group participation	0	2	0	0
	Super Group participation	-	0	0	0
	Group collaboration	0	0	0	0
Undetected problems	Small Groups that did not complete the activity	5	3	0	0
	Super Groups that did not complete the activity	-	0	0	0

work); also, in the third activity, several super groups reused the diagrams of one the small groups (i.e., adapting an existing diagram instead of drawing a new one from scratch in the super group canvases, to save time) [EXP1_R1_OBS][EXP1_S_INT].

In the second study we tried to verify whether enriching the computed-mediated log evidence [EXP2_IT_LOG] with very simple data from the face-to-face sessions (participants' attendance to the lab sessions [EXP2_R_OBS]) would decrease the number of false positives in the monitoring reports. Table 3.2 shows the number of false positives and unnoticed problems in this second study. These results were obtained comparing the monitoring reports with the researcher's observations during the face-to-face sessions [EXP2_R_OBS], the learning outcomes of the students in the tool instances [EXP2_IT_LO], the questionnaires to the students about the learning process [EXP2_S_QUE1, EXP2_S_QUE2, EXP2_S_QUE3], and the critical problems detected by the teachers [EXP2_T_QUE2].

As it happened in the first study, the unidentified problems in the monitoring report were mainly due to students accessing the tools but not finishing the tasks that they were expected to do [EXP2_IT_LO, EXP2_S_QUE1, EXP2_S_QUE2]. In this regard, although some improvement could be made by choosing ICT tools that offer monitorable data, evaluating whether the students have properly finished their work frequently requires manually reviewing the learning outcomes themselves.

Regarding false positives, their number decreased from 71 (in the previous study) to merely two in this second study. These false positives were due to unexpected behaviour in one small group, who had accessed the tool instance directly using the URL, instead of going through Moodle, where the request of resources are managed by GLUE!. Even if the number of false positives improved, we recognized a number of situations that we had not taken into account [EXP2_S_QUE1]. The student questionnaire data shows that, among the 34 respondents, 8,82% only used tools not included in the DLE, and 23,53% used both DLE and non-DLE tools. This means that our perception of the work by 32,35% of the students was only partial. In terms of monitoring, the tools that do not belong to the DLE are out of reach since we do not have access to them. One possible way to provide more accurate monitoring reports could involve discriminating between mandatory and optional resources. This approach could help teachers to better contextualize the monitoring results obtained. Another solution to increase the information available about the students' work, could be the integration of the students' feedback as an additional monitoring data source.

Thus, we can see how in the two studies there were quite a few problematic situations that we were not able to detect. However, we also envisioned several solutions to improve the evidence gathered:

- To obtain more information about computer-mediated actions, it would be advisable to help teachers in the choice of ICT tools.
- Distinguishing between optional and mandatory resources could help understand the impact that a lack of tool usage may have over the rest of the script.
- Since we are working with blended CSCL scenarios that involved not only computer-mediated but also face-to-face activities, it is necessary to include some evidence related to the face-to-face work. For instance, attendance to the lab sessions could be registered by the teachers themselves without spending too much time and effort.
- Assuming that there are parts of the students' work that cannot be registered by the DLE (e.g., off-line work), we could use the students' feedback as another monitoring data source, in order to provide additional information about the learning process.
- Identifying in advance which evidence could be obtained from the learning environment to inform about the pattern constraints, as well as looking for additional data sources in case the currently-selected ones are not sufficient to provide such information.

3.3.3 Overall discussion of the first iteration

In this section, we have covered two main topics: the use of pattern constraints to guide the monitoring process of pattern-based CSCL scenarios; and the restrictions imposed by the DLE to collect and integrate students' actions. These two studies provided evidence about the capabilities of the presented approach to generate relevant information about the evolution of the learning process. Using the monitoring reports, teachers could realise at a glance which participants seemed not to be working, which ones were isolated and which was the best way to re-distribute them. In the first study, this kind of information enabled teachers to avoid going through all the tool instances (a total of 141 considering canvases in Dabbleboard, Google Documents and Presentations) to check the activity progress, and therefore saved them a great deal of time. Then, we can state that the (pattern-based) monitoring process provided teachers with relevant feedback for regulation purposes. Besides, it is noteworthy that part of the problems that the teachers envisioned were related to the pattern constraints, and that all the detected eventualities were connected to the pattern constraints. Thus, we can also conclude that focusing the analysis on the script constraints allowed us to obtain information connected to teachers' concerns.

Another issue to take into account is that, even if the pattern constraints were used in the monitoring process, there were more design elements that had an influence over it. For instance, it was necessary to ask teachers for additional constraints related to the activities (time frames, participants, group distribution, assignment of resources) in order to contextualize the analysis. Thus, we envisioned that the list of pattern constraints should be complemented by other specific constraints derived from the activity definition.

It is interesting to note that just using GLUE! as a source of computer-mediated evidence provided a good deal of information related to the use of the third party tools (used to develop the learning activities). Despite the limitations given the reduced variety of monitored events, teachers stated that the results of such monitoring were rather close to the real facts. However, using solely ICT tools to follow the learning process made a few problems and multiple false positives to go unnoticed (especially in those activities where part of the interaction was face-to-face). Thus, in the second study we attempted to monitor, not only the computed-mediated actions, but also gather very simple evidence from the face-to-face sessions (participants' attendance to the lab sessions). Comparing the first and the second study, we found out that the integration of face-to-face evidence reduced drastically the number of false positives. This test guided us to consider that monitoring blended scenarios (in terms of learning and interaction) requires blended data sources that provide complementary evidence (e.g., coming from teachers or students), and that collecting such evidence is feasible with little effort on the part of the teacher.

Finally, we observed throughout these studies that some design decisions influenced the data available in the DLE (e.g., the selection of learning tools) and the accuracy of the monitoring results (as, e.g., the activity time frames did). Besides, involving teachers in the configuration of the monitoring process could contribute to better suit it to their needs (e.g., defining monitoring periods or choosing the activities and resources that should be monitored). This fact led us to reflect on how we could support teachers to take monitoring into account during the design of the CSCL scenario. To explore this issue we carried out the second iteration of the DBR process.

3.4 Second exploratory iteration

The second iteration took place between January and June 2012, encompassing three more studies and involving two different teachers: an expert in CSCL scenarios (in the third and fourth exploratory studies) and a teacher with little experience in CSCL (in the fifth study). This iteration covered three exploratory lines of inquiry: to find *ways of supporting teachers to include monitoring issues in the pattern-based design* of CSCL scripts [EXQ_DES.IT2]; to identify *script parameters and decisions made at design time that could focus the monitoring process* of pattern-based CSCL scenarios [EXQ_MON.IT2]; and third, to collect the *required conditions for gathering relevant monitoring data about the students' participation* in a blended scenario supported by a DLE [EXQ_DAT.IT2]. As it can be noticed, this iteration introduces new issues: while previously we had focused on the monitoring process and how it could inform about the accomplishment of design decisions, in the second iteration we also paid attention to the design process and how the design decisions could enhance the monitoring results; the second iteration took into account not only pattern constraints (as we did in the previous studies) but also additional constraints imposed by the definition of each of the activities; and finally, while the first iteration was centred on computer-mediated evidence obtained from the DLE, the second iteration also considered ways of integrating face-to-face evidence from complementary data sources (namely, teachers and students). These three exploratory lines were informed by specific questions (as it is shown in Figure 3.3).

To understand how we could help teachers integrate monitoring concerns in the design process, we defined two more specific exploratory questions: the first one aimed at identifying the influence of design decisions on the monitoring process [EXQ_DES.IT2.1] (e.g., in the data gathering or in the modelling of the desired state of the learning situation); and the second delved into the impact of the design decisions on the monitoring results [EXQ_DES.IT2.2] (e.g., the appearance of errors and 'false positives').

To understand which aspects of the script designed by the teachers could guide the monitoring process, we explored four questions during this set of studies. First, we compiled the information provided by the teachers at design-time [EXQ_MON.IT2.1] in order to identify additional parameters that could be included in the script to enable or enhance monitoring [EXQ_MON.IT2.2]. Then, we tried to verify whether the feedback obtained from the monitored data was relevant for the teacher (in order to support the regulation of the learning scenario) [EXQ_MON.IT2.3], and whether it was sufficient to detect the problems that emerged during the learning scenario [EXQ_MON.IT2.4].

Dealing with the data sources of the monitoring process, we tried to explore what information was available in different technological contexts (i.e., creating DLEs made up by tools different to the ones used in the previous iteration), [EXQ_DAT.IT2.1] and we took also into consideration how we could gather and integrate evidence from new data sources provided by teachers and students [EXQ_DAT.IT2.2]. Finally, we verified whether the monitored data sources were able to provide enough evidence about the students' participation or, on the contrary, whether it was necessary to obtain more information to provide a 'realistic' view of the learning process [EXQ_DAT.IT2.3].

Due to the mutual dependencies between design and monitoring in our proposal, we set up three pilot studies, with the intention of identifying the required conditions to integrate scripting and monitoring. The author of this dissertation worked together with each of the corresponding teachers during the whole learning scenario (from its initial design to its enactment), taking respectively the roles of 'monitoring expert' and 'learning design expert'. The rest of this section provides an overview of the exploratory studies and the main findings obtained in this second iteration of the DBR process. As usual, the full description of these studies is available in Appendices E, F, and G.

3.4.1 Overview of the studies in this iteration

This iteration encompassed three pilot studies held during in the same academic year at the University of Valladolid. The third and the fourth studies involved the same teacher and students, and took place in two courses of a "Master's degree for Pre-service Secondary Education Teachers". The fifth study was held in a course of the "Bachelor's degree in Early Childhood Education".

The learning scenario of the *third exploratory study* (EXP3) lasted from February 17th to March 9th, 2012, and took place within a course on "Learning methods", with 14 students

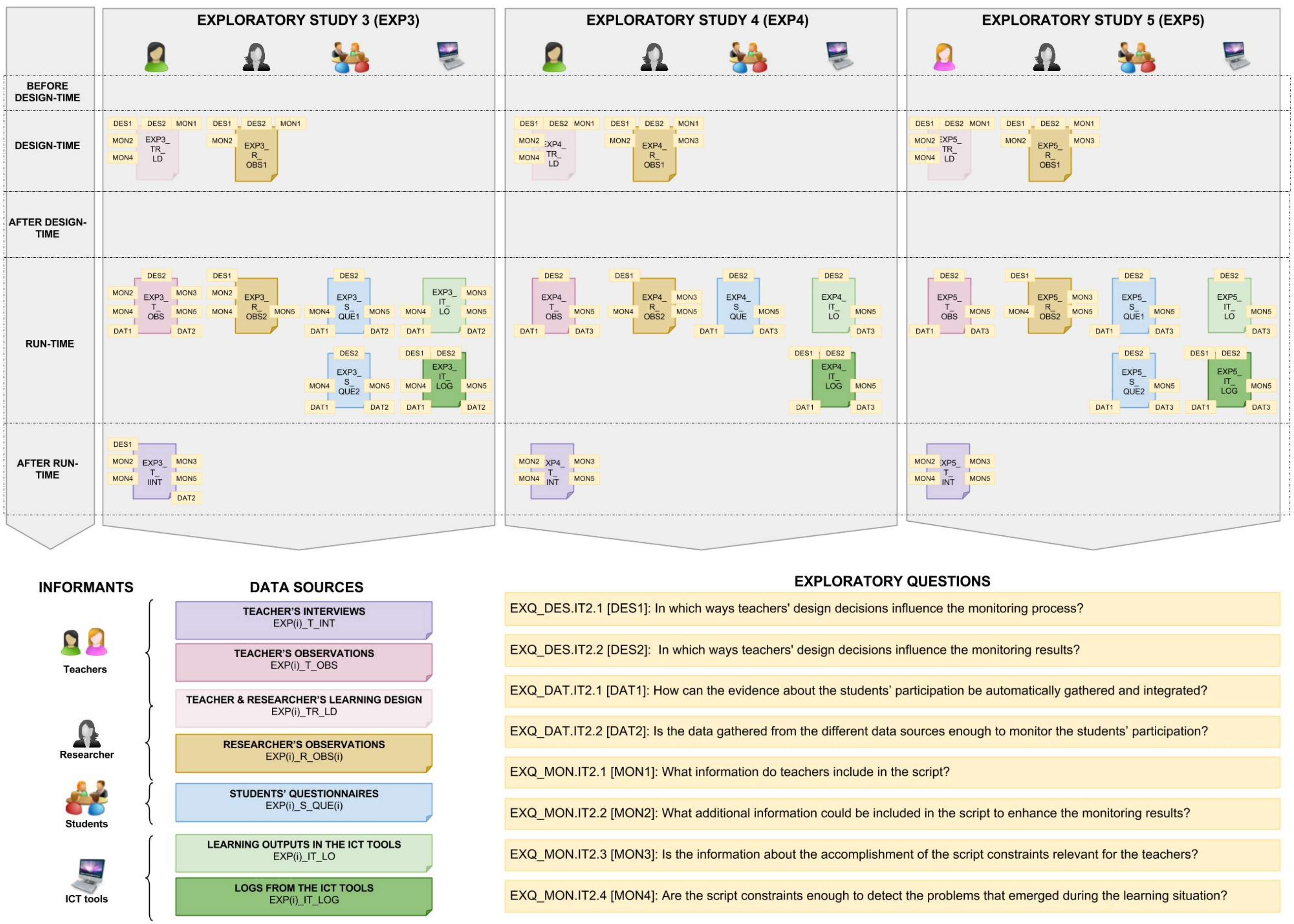


Figure 3.3: Connections between studies, exploratory questions and data sources in the second exploratory iteration.

attending the course and a teacher with several years of expertise in CSCL scenarios (Julia). During this course, students had to analyse different learning strategies applicable to secondary education (i.e., lectures, inquiry-based learning, project-based learning, cooperative learning, etc.). In order to help them in understanding and internalizing these topics, they were asked to study a specific context and decide which strategies could be the most appropriate for such a context. Once they chose the strategies, they had to create a poster where they provided an example of the application of the strategies to the context. To carry out these tasks, the students followed a CSCL script, interleaving face-to-face with distance activities mediated by ICT tools.

The script implemented two pedagogical patterns: *Jigsaw* and *Peer-review* [HL10a]. The *Jigsaw* pattern guided the students grouping, and the main structure of the activity flow. In the first phase, each student individually analysed two learning strategies assigned to each of them by the teacher. During the second phase, those students who had worked in the same strategies joined to form expert groups. Each expert group developed an individual summary of the studied strategies and a collaborative mind map with their main ideas. In the third phase, students were distributed in jigsaw groups (made up by an expert on each learning strategy). Jigsaw groups chose and justified the most suitable strategies to learn with ICT tools in Secondary Education and elaborated a poster with their proposal and some application examples. These proposals were peer-reviewed and presented orally to the whole class. Finally, the students assessed the work done by their peers.

Aside from the initial readings, the enactment of the script required ICT tools for collaborative drawing and writing as well as on-line questionnaires. *MediaWiki* was used to centralize the access to all the resources and support the collaborative writing, *Dabbleboard* to accomplish the drawing tasks, *Google Forms* for on-line questionnaires, and the *GLUE!* architecture to integrate all these external tools into MediaWiki.

The *fourth exploratory study* (EXP4) took place between March 26th and April 26th, 2012, around a learning scenario within a course on "Educational research", in the same degree and with the same participants of the third study. This course followed a project-based learning strategy, where students had to define in groups an educational research project, based on the principles of Action Research [Sus78]. To perform this task, the students followed a blended CSCL script that combined activities at different social levels (individual, group, and whole-class), with different types of learning (face-to-face, distance, and blended) and interaction (face-to-face, computer-mediated, and blended).

The script was based on a *Pyramid* CLFP and included a *Peer-review* in one of its phases. The *Pyramid* pattern guided the students' grouping, and the main structure of the activity flow which was composed of four phases, corresponding with the four levels of the *Pyramid*. At level-1, students, individually, proposed a research question suitable for a participatory research project. At level-2, small groups (of 2 or 3 participants) agreed on a research question inspired by their previous work. At level-3, small groups merged to form super groups (of 4 or 5 students) that had to agree on a research question based on the ones formulated by each small group, and propose a research plan. Then, each group's work was peer-reviewed, leading to the refinement of their proposals. Finally, at the fourth level of the *Pyramid*, super groups performed an oral presentation about their proposal and evaluated the presentations of the other super groups.

Regarding the technologies that supported the enactment, we used *MediaWiki* to centralize the access to all the resources and activities. Students had at their disposal *Google Documents* and MediaWiki pages for the writing tasks, and *Google Forms* for the on-line questionnaires. In addition, the *GLUE!* architecture allowed us to integrate the external tools into MediaWiki.

The *fifth exploratory study* (EXP5) involved a scenario taking place from May 17th to June 4th, 2012, within a course on "Guidance and mentoring for students and families", with 60 students attending the course and a teacher with little experience in CSCL scenarios (Carmen). During this course, students learnt different techniques to face controversial situations that arise in real educational practice in order to support the students and their families. To encourage the internalization of these situations, the teacher proposed the students to define a problematic situation where they had to apply the interview technique (for gathering data from parents, children and other educational experts).

The collaboration script implemented two CLFPs, namely *Role-playing* and *Peer-review*, that correspond respectively with the two phases of the script. Students worked in groups of 3 to 4 people throughout the whole learning scenario. In the first phase, each group reviewed the reference material and formulated a controversial situation that later was role played to the whole class. In the second phase, each group reviewed and provided feedback on two of their peers' performances, and finally, reflected and made a report considering the comments they had received.

The teacher chose the institutional VLE (*Moodle*), to centralize the access to all the resources and activities. She included manuals as basic readings about the interview technique, online documents (*Google Documents*) for collaborative writing, and access to the videos recorded during the role-playing presentation. GLUE! was used to integrate the third-party tools into the Moodle VLE.

In all three studies, the intervention proceeded in the same way:

- At design-time, the author of this dissertation co-designed with the teachers the learning scenarios. The design of the learning scenario consisted of several sessions, working from the conceptualisation of the learning design to its deployment in the technological environment. The design process consisted of two cycles. First, the teacher designed the learning scenario following the guidelines given by the *pattern-based design process for CSCL scripts* proposed by Villasclaras et al. [VF09b]. In this first cycle, the researcher contributed with her knowledge about the collaborative pattern, observing how the decisions taken by the teacher influenced monitoring, and intervening where necessary to ensure that the resulting technological set-up could provide data about the users' actions. In the second cycle, both the teacher and the researcher analysed the possibility of including complementary data sources that could provide information about the state of the activities. To support the design and deployment tasks, the teachers used two types of tools: *Web Collage*[5] or *Pedagogical Pattern Collector*[6] as authoring tools to produce machine-intepretable CSCL scripts (Web Collage was used in the third and fourth exploratory study and Pedagogical Pattern Collector in the fifth); and *GLUE!-PS*[7], a tool that allows practitioners to particularise and deploy CSCL scripts into DLEs.

[5]Web Collage: `http://pandora.tel.uva.es/wic` (Last visit: 16 March 2014)
[6]Pedagogical Pattern Collector: `http://web.lkldev.ioe.ac.uk/PPC/live/ODC.html` (Last visit: 16 March 2014)
[7]GLUE!-PS: `http://www.gsic.uva.es/glueps/` (Last visit: 16 March 2014)

- After design-time, the researcher elaborated a graphical representation of the monitoring report and discussed it with the teachers in order to ensure that it provided an understandable view of the learning process, and with the aim of identifying which additional features such kind of report should entail.

- At run-time, the scripts were put into practice and, throughout the different activities, we supported the teachers in monitoring the learning scenario, following the steps proposed by Soller et al. [Sol05]: collection and aggregation of learning evidence, construction of the desired model of the learning situation, comparison between current and desired states, highlighting of discrepancies between both states and, finally, evaluation and diagnosis of the learning situation. We provided teachers with monitoring reports (at the moments they had planned at design-time) to help them with the awareness and later regulation of the learning scenarios. For the generation of the monitoring reports we used the *GLIMPSE* and *GLUE!-CAS* prototypes (see Section 4.6.2 and Section 4.6.3), to partially automate the data gathering, integration and analysis tasks.

To answer the exploratory questions, we collected data from several sources throughout these three studies. Figure 3.3 presents an overview of the studies, showing the data sources, the moments when they were collected, and the exploratory questions that they aimed to answer. The co-design sessions led to CSCL scripts [EXP(i)_TR_LD[8]] that integrated pedagogical and monitoring concerns, and enabled monitoring later on. Besides, the co-design allowed the identification of dependencies between scripting and monitoring, and the detection of problems and difficulties that the teachers faced when reflecting on monitoring issues at design-time [EXP(i)_R_OBS1]. At run-time, in order to obtain evidence from the learning process, teachers provided their observations including the student attendance to the face-to-face session and the eventualities that they had detected [EXP(i)_T_OBS]; students answered questionnaires explaining how they had collaborated to perform the activities [EXP(i)_S_QUE1, EXP(i)_S_QUE2]; and the researcher obtained the logs from the ICT tools [EXP(i)_IT_LOG], reviewed the learning outcomes [EXP(i)_IT_LO], and registered the problems that emerged during the scenario, as well as the feedback provided from the teacher [EXP(i)_R_OBS2]. Finally, at the end of each learning scenario, we interviewed the teachers to collect their impressions about the design and monitoring processes [EXP(i)_T_INT]. The following subsection presents the findings about the exploratory questions, derived from all these sources.

3.4.2 Findings

This subsection presents the findings obtained from the studies in terms of the exploratory questions presented at the beginning of the section and in Figure 3.3.

EXQ_DES.IT2: How can teachers be supported to integrate monitoring concerns in the pattern-based design process of CSCL scripts?

EXQ_DES.IT2.1: In which ways teachers' design decisions influence the monitoring process? Analysing the scripts [EXP(i)_TR_LD] and taking into account the researcher's

[8]Throughout the second iteration, i may adopt three possible values -3,4 and 5- representing each one of the exploratory studies of this iteration.

observations at design and run-time [EXP(i)_R_OBS1, EXP(i)_R_OBS2], we identified a set of dimensions and parameters that influenced the monitoring process, especially regarding the data gathering and the representation of the desired state of a CSCL situation. Table 3.3 brings together these dimensions and parameters.

Table 3.3: Dimensions and parameters that guided the data gathering and representation of the desired state. These parameters have been marked from n = 1 to 5, were n represents the number of the exploratory study when they were first identified.

Dimension	**Parameter**	**Data gathering**	**Representation of the desired state**
Pattern constraints / flow dependences	Sequence dependences		1
	Resource reuse		1
	Group formation policies		1
	Collaboration		1
Activity Configuration	Time frames	1	
	Resources (tools, contents)	1	
	Expected use of resources		4
	Participants	1	
	Groups		1
	Resource assignment to participants/groups	1	1
	Participant assignment to groups		1
	Social level		3
	Interaction type		3
	Learning mode		3
	Participation		4
Teacher's monitoring decisions	Monitoring periods	3	
	Activities to be monitored	4	
	Resources to be monitored	4	
	Actions to be monitored	3	
	Constraints to be monitored		5

Firstly, certain configuration parameters of the activities guided the *data gathering of participants' actions*: the activity time frames, the resources (tools and contents), and the participants involved in each activity. These parameters allowed us to filter out actions performed out of the activity period, on resources or by users not involved in the activity. Moreover, some teachers' decisions affected the data gathering: the monitoring periods that determined when the monitoring had to be done; and activities, resources and actions to be monitored, which specified what evidence in the learning environment should be considered for the analysis.

Certain activity features also influenced *the representation of the desired state of a CSCL situation*: The interaction type determined how students were expected to participate (face-to-face, through computers, or blended); the social level (individual, group, or whole-class) defined whether the participants or groups involved in the activity should collaborate; the expected participation and the expected use of resources (optional, mandatory for individuals, or mandatory for groups) pointed out whether the lack of evidence could cause a critical situation or not.

Furthermore, the pedagogical design patterns (*Jigsaw*, *Pyramid*, *Role-playing*, and *Peer-review*) contributed to the definition of the desired state, by means of the constraints that had to be verified during the enactment in order to accomplish the pedagogical objectives these patterns represented. For instance, the activity flow provided sequencing dependencies between activities or phases (finish-to-start, start-to-start, finish-to-finish, start-to-finish), which could jeopardise the scripts' purposes. Additionally, the collaboration and group formation policies had to be satisfied in order to verify the scripts' collaborative purposes.

In order to understand how the teacher was supported to integrate the monitoring issues, below we compile the main researcher contributions in the co-design process [EXP(i)_R_OBS1]:

- When the teachers specified the learning objectives, the patterns, and the activity flow, the researcher *extracted the script constraints* that helped define the desired state and detect whether the current state of the learning situation might put future activities at risk.
- When the teachers configured the activities, the researcher *asked them for certain additional parameters that influenced monitoring* such as the activity time frames, the specification of the social level, the interactivity and the learning type. In relation to this, teachers mentioned that : "[...] it is something that you may not notice a priori, but once it is mentioned, you realise it is important" [EXP3_T_INT]; "it helps you notice about design aspects that you should anyway have in mind, such as the dates, the dependencies among activities, or what is expected of each activity" [EXP4_T_INT]; "it has helped me reflect and improve the design. In fact, I have taken into account aspects that would have otherwise gone unnoticed (e.g., who interacts and who doesn't, how the teamwork is done)"[EXP5_T_INT]. Both teachers were able to describe on their own the activity parameters that affected monitoring, by using activity forms (provided by the researcher) to support them in the collection of the monitoring-related data. Examples of these forms are available in Figure F.2 and Figure G.2.

EXQ_DES.IT2.2: In which ways teachers' design decisions influence the monitoring results? As it was observed in the co-design of the CSCL scripts [EXP(i)_TR_LD, EXP(i)_R_OBS1], teachers had a crucial role in the enhancement of the monitoring results, not only adjusting the conditions to be evaluated, but also improving and enriching the monitorable data sources. Table 3.4 summarizes how design decisions conditioned monitoring results.

In general terms, the design decisions about the participants, groups, resources and how they were distributed during the activities *focused the analysis* on the characteristics of the specific learning context. Besides, the teachers' expectations on the participation and on the resource use allowed us to *fine-tune the representation of the desired state*, making constraints more precise; also teachers' preferences *helped filter the evidence* to what was relevant for them, e.g., choosing the activities, resources and actions that should be monitored. One decision that turned out to be crucial was the definition of activity time frames. As we detected in the third and fourth studies [EXP3_R_OBS2, EXP4_R_OBS2], the dates fixed for starting and finishing an activity had an impact on the appearance of false positives (caused by the students carrying out their tasks before the expected activity time frame).

We realised that certain decisions, despite not being used in the analysis process, conditioned (indirectly) the results. For instance, in the first cycle of the design, the monitorable

Table 3.4: Dimensions and parameters that contributed to enhance the monitoring results at design-time. **"D"** means that the parameter influenced directly, and **"I"** denotes that the parameter's influence was indirect.

Dimension	**Parameter**	**Focusing the analysis**	**Filtering evidence**	**Improving monitoring data sources**
Pattern constraints / flow dependences	Sequence dependences	D		
	Resource reuse	D		
	Group formation policies	D		
	Collaboration	D		
Activity configuration	Time frames		D	
	Resources (tools, contents)	D		
	Expected use of resources	D		
	Participants	D		
	Groups	D		
	Resource assignment to participants/groups		D	
	Participant assignment to groups		D	
	Social level	D		
	Interaction type		D	I
	Learning mode			I
	Participation	D		
Teacher's monitoring decisions	Monitoring dates		D	
	Activities to be monitored		D	
	Resources to be monitored		D	
	Actions to be monitored		D	
	Constraints to be monitored		D	
ICT tools	Monitorable actions			I

actions guided the selection of ICT tools. Based on the monitoring affordances of the ICT tools, teachers adapted the selection of tools, whenever possible, in order to include those offering further information about the users' actions. This decision *improved the quantity and the quality of monitorable computer-mediated evidence*. In the second design cycle, the 'interaction type' and 'learning type' activity parameters were used to reflect on the data sources that could best inform about the activity progress (i.e., if we know about how and where learning will happen, we can think about alternative data sources). Moreover, the fact of including additional data sources coming from the students and the teachers themselves (workgroup reports and the register of attendance to the lab sessions) *enriched the variety of learning evidence* and, therefore, contributed to obtain less biased monitoring results that were not based solely on computer-mediated actions.

The selection of the pattern constraints that should be taken into account in each activity did not obey to any specific rule. Teachers were the ones who decided in which cases the pattern constraints should be applied [EXP3_R_OBS1, EXP4_R_OBS1]. In the fifth study, the researcher derived a list of constraints from both the patterns and the activity description. These constraints were shown to the teachers in order to decide which ones should be applied in each activity, and many of them were actually ignored (especially the ones related to the pattern [EXP5_R_OBS1]), as they were considered redundant or unnecessary for the specific context. In any case, the selection of constraints to be applied in each activity focused the analysis on questions relevant for the teachers and reduced the appearance of false positives in the monitoring reports. Therefore, the teachers' involvement in the monitoring decisions made the results better suited to their needs.

However, there were certain tasks that required the participation of the researcher to guide the teachers' decisions [EXP(i)_R_OBS1] [EXP(i)_T_INT]:

- *The selection of tools.* When the teachers were selecting the tools that made up the DLE, it was necessary to provide them with *the monitoring affordances of the ICT tools.* According to the teacher's feedback: "The hardest part is to know whether a tool is going to provide information or not. [...] I might want to monitor an action but I don't know if it is monitorable" [EXP3_T_INT]; "it is difficult to know which learning tool to choose and what monitoring opportunities it affords" [EXP4_T_INT]; "the hardest part is to know which tools you can use and what do they offer in terms of monitoring" [EXP5_T_INT]. This selection of tools that satisfied the pedagogical and monitoring needs, called for a list of ICT tools describing their monitoring affordances, in particular their monitorable actions.

- *The enrichment of the design to enhance monitoring.* To support this task, the researcher *identified the monitorable evidence available for each constraint* according to the script definition. Both teachers mentioned that they would not have been able to infer by themselves the situations that could require further data sources: " When you design an activity you don't know if those are the best conditions for it to be monitored" [EXP3_T_INT]; "it is difficult to know when it is necessary and/or relevant to gather data from students"[EXP4_T_INT].

EXQ_MON.IT2: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?

EXQ_MON.IT2.1: What information do teachers include in the script? According to the researcher observations [EXP(i)_R_OBS1], the teachers firstly defined the learning objectives and the pedagogical patterns, which established some guidelines about the group formation policies, the expected collaboration and the activity flow. Secondly, they described the central elements that usually appear in CSCL scripts (such as participants, groups, activities and resources [Dil02a] [Dem08]). As it is shown in Table 3.3, the parameters related to the patterns were used mainly for modelling the desired state of the learning situation, while the information related to participants and resources involved in each activity guided the data gathering.

EXQ_MON.IT2.2: What additional information could be included in the script to enhance the monitoring results? Aside from the design decisions initially defined by the teachers (patterns, activity flow, participants, groups and resources), they also included in the script certain parameters necessary to guide and enhance the monitoring process. This was done with direct support from the researcher (in the third study) or using activity forms that made such parameters explicit (in the fourth and fifth studies). For example, certain parameters were added in order to limit the data gathering to the evidence relevant for the activity constraints (e.g., activity time frames) or to obtain further details about the desired state (social level, interaction type, participation or expected use of resources); others were incorporated to adapt the results to the teachers' interests (such as monitoring dates or activities, resources and actions to be monitored). Some of these parameters had already been identified in the first iteration, while others emerged throughout the second one [EXP(i)_R_OBS1, EXP(i)_R_OBS2]. Table 3.4 summarises the information used to enhance the monitoring results across the three studies' design processes, and the role that they played [EXP(i)_TR_LD].

EXQ_MON.IT2.3: Is the information about the accomplishment of the script constraints relevant for the teachers? At the end of the three studies we interviewed the teachers and, among other issues, we reviewed the monitoring reports. Based on the obtained feedback [EXP(i)_T_INT], the monitoring reports "helped trace the learning scenario, even if some were evident"[EXP3_T_INT]. Out of the 787 evaluated conditions[9], 80,30% were considered relevant for the regulation of the scenario, and many of the remaining results turned out to be useful for assessment purposes. Although the teachers were aware of part of this information (especially in face-to-face activities), 57,94% were unknown to them before receiving the monitoring report ("when I received the reports, I had not had time to review the students' work" [EXP5_T_INT]). Besides, both teachers asserted that, independently of the number of problems detected [EXP4_T_INT], the reports contributed to save time [EXP(i)_T_INT], helping to avoid an exhaustive review of the DLE [EXP3_T_INT].

To analyse teachers' answers about the novelty of the monitoring information, we used certain script parameters that influenced the monitoring process, namely: social level, learning and interaction type of each activity, and the nature of constraints (i.e., coming from the activity or the pattern description). Table 3.5 provides an overview of these characteristics throughout the three scenarios' activity flows, and Figures 3.4, 3.5, 3.6, and 3.7 summarize the teacher's answers.

According to the teacher's perspective, in the third scenario the most useful and unknown results appeared in those activities with higher number of pattern constraints (see Figure E.5 and Figure E.6). However, in the fourth and fifth studies, the monitoring reports were considered especially relevant in those activities that involved computer-mediated interaction and distance learning (see Figures F.5 F.6 and Figures F.5 and F.6). Conversely, the monitoring reports provided less useful information in cases of face-to-face interaction during the lab sessions.

Regarding the type of constraints that prompted each evaluated condition, Figure 3.4 shows the percentages of useful and already known information based on the teachers' feedback.

[9]787 is the total quantity of conditions (inferred from the script constraints) that the teachers chose for monitoring the learning scenario. There were 113 of these conditions in the third study, 226 in the fourth, and 448 in the fifth. Examples are included in Table G.6.

Table 3.5: Analysis of the monitoring information throughout the second DBR iteration, focusing on the novelty and usefulness of monitoring reports for regulation purposes.

		Third Exploratory Study			Fourth Exploratory Study			Fifth Exploratory Study		
Parameter	**Value**	*No. of activities*	*%Known results*	*%Useful results*	*No. of activities*	*%Known results*	*%Useful results*	*No. of activities*	*%Known results*	*%Useful results*
Learning mode	Distance	7	34,43	95,08	4	6,06	93,94	3	4,44	99,60
	Blended	2	36,84	94,74	4	60,00	51,82	2	83,33	100,00
	Face-to-face	1	100,00	0,00	1	100,00	0,00	1	100,00	34,78
Interaction type	Computer-mediated	7	20,90	94,03	4	6,06	93,94	3	4,44	99,60
	Blended	2	65,63	96,88	4	60,00	51,82	2	83,33	100,00
	Face-to-face	1	100,00	0,00	1	100,00	0,00	1	100,00	34,78
Social level	Individual	4	12,50	94,64	3	6,45	93,55	0	0,00	0,00
	Group	5	65,12	95,35	5	56,90	54,31	4	28,37	99,72
	Whole-class	1	100,00	0,00	1	100,00	0,00	1	100,00	34,78
Constraint type	Activity	–	51,95	76,62	–	39,47	62,63	–	35,05	83,42
	Pattern	–	25,00	97,22	–	38,89	86,11	–	80,00	100,00

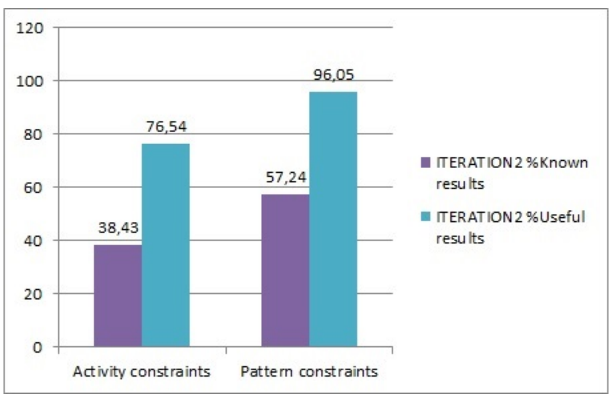


Figure 3.4: Percentage of known and useful monitoring results, classified according to the kind of script constraints that originated them (activity or pattern constraints).

Even if the number of results known by the teachers prior to the monitoring report was higher in the case of conditions related to pattern constraints (as opposed to activity constraints – 57,24% versus 38,43%), the usefulness was higher in those cases related to pattern constraints (96,05%). However, we should notice that the ratios of useful results were influenced by the decisions made by the teacher at design-time: In all three studies, the teachers decided what pattern constraints should be applied to each activity. However, only in the fifth study, the teacher filtered also the activity constraints. Another issue to take into account is that, throughout the learning scenarios, the teacher saw the students work during the face-to-face sessions and frequently received comments from the students. Therefore, when teachers looked at the monitoring reports, they often had already an idea of what was going on in the current activity. However, as one of the teachers mentioned during the interview [EXP3_T_INT], the most challenging aspect for her was to realise about the impact that the current state of the learning situation might have on the following activities.

In general terms, the analysis shows that the teachers considered most of the results (over 97%) useful, especially in cases of distance learning as well as in those activities including computer-mediated interaction (see Figure 3.5 and Figure 3.6). Conversely, in activities

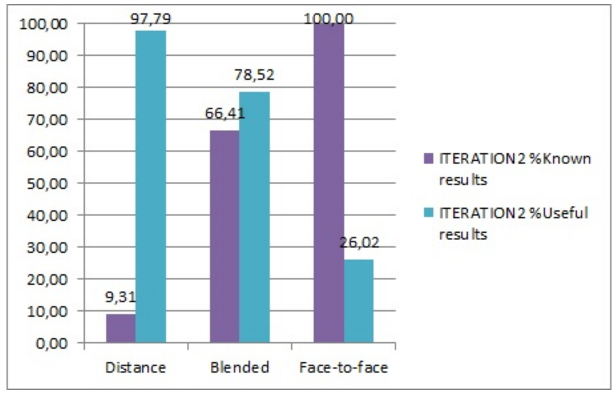


Figure 3.5: Percentage of known and useful monitoring results attending to the learning type (distance, blended, face-to-face).

with purely face-to-face learning or interaction, the teachers considered that the results were unnecessary for regulation purposes[10]. However, according to the teachers' comments during the interviews, the monitoring reports obtained from this kind of activities should not be left out, since they were very useful in order to have an overview of the students involvement over the whole scenario. The rates of useful and known information items ratify the teacher's comments during the interviews: activities held in the classroom (totally or partially) offered more awareness opportunities to the teachers (over 66% of the results were already known by the teachers?). However, in activities with some level of computer support or those performed out of the classroom, the chances of perceiving a piece of contextual information (without specialized computer support) were under 10%. From these analyses we can infer that face-to-face activities offered more awareness opportunities to the teacher. However, in activities with more computer support and performed out of the classroom, they would have received little or no contextual information.

Regarding the social level (see Figure 3.7), it seems that the monitoring results were specially useful in the individual tasks (93,96%), with their relevance decreasing as the group size increased. However, we should notice that these results were also influenced by the learning and interaction type (see Figures E.4, F.5, and G.6): all individual activities involved computer-mediated interactions and distance learning; many activities carried out in groups were blended in terms of learning and interaction; and the whole-class activities were held during a lab session and involved only face-to-face interaction (indeed, as we already mentioned, the teacher was the one who provided the information used in that of the monitoring report).

From all of the above we can deduce that the type of learning, interaction and constraints may shed some light on the teacher's monitoring needs. At least in these studies, those activities that involved distance learning and computer-mediated interaction, as well as the activities with impact on future ones tended to draw teacher's attention more. Conversely, the social level did not seem to have a clear impact since it was often conditioned by the rest of the parameters.

EXQ_MON.IT2.4: Are the script constraints enough to detect the problems that emerged during the learning situation? The list of script constraints used in the monitoring process were a subset of the constraints derived from the configuration of each activ-

[10] It is noteworthy that there was no further evidence out of the teachers' observations (the attendance registers) from these activities, and therefore they were already aware of the results.

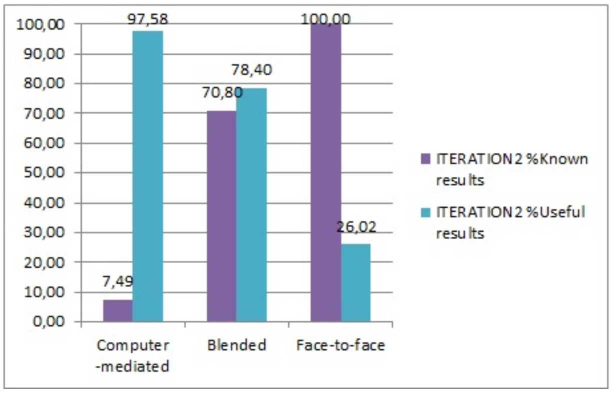


Figure 3.6: Percentage of known and useful monitoring results in terms of interaction type (computer-mediated, blended, face-to-face).

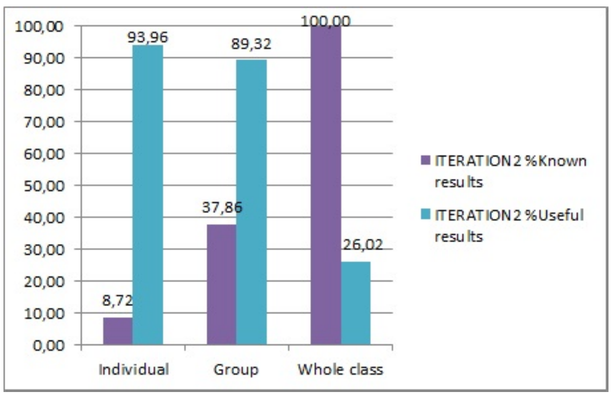


Figure 3.7: Percentage of known and useful monitoring results according to the social level (individual, expert group, jigsaw group, whole class).

ity (e.g., participants, groups, social level, resources, deadlines, etc.) and the constraints imposed by the CLFPs (e.g., group formation policies, general activity flow, dependences between phases/activities, etc.). The analysis of these constraints eased the identification of indicators that modelled the learning scenario (such as the ones presented in Tables E.5), conditions that represented the desired values (see for example Table F.4), and evaluated conditions (illustrated in Table G.6) that led us to certain problems (all of them detected, except one in the third study which was identified by the teacher) and false positives (seven in the fourth study).

Apart from the problems related to the activity and the pattern constraints, we did not identify any other critical situation from the analysis of the GLUE! logs [EXP(i)_IT_LOG], the researchers' observation [EXP(i)_R_OBS2], the learning outcomes in the ICT tools [EXP(i)_IT_LO], the teacher's feedback [EXP(i)_T_OBS, EXP(i)_T_INT], and the workgroup reports [EXP(i)_S_QUE1, EXP(i)_S_QUE2]. Thus, we can state that the script constraints were enough to detect the problems that emerged during the learning situation.

EXQ_DAT.IT2: What are the required conditions for collecting relevant information about the students participation in a blended CSCL scenario supported by DLEs?

EXQ_DAT.IT2.1: How can the evidence about the students' participation be automatically gathered and integrated? The DLEs used in the three studies were made up by a VLE (Mediawiki or Moodle), third-party tools (Dabbleboard and Google Applications), and the GLUE! architecture for supporting the integration of the third party tools in the VLEs.

Table 3.6: Validation of the monitoring reports obtained in the second iteration.

Study	Constraint type	Evaluated conditions	Real problems	Detected problems	Undetected problems	False positives
Third exp. study (EXP3)	Activity	77	13	12	1	0
	Pattern	36	3	3	0	0
	Others	0	0	0	0	0
	Total	113	16	15	1	0
Fourth exp. study (EXP4)	Activity	190	26	26	0	7
	Pattern	36	4	4	0	0
	Others	0	0	0	0	0
	Total	226	30	30	0	7
Fifth exp. study (EXP5)	Activity	368	17	17	0	0
	Pattern	80	0	0	0	0
	Others	0	0	0	0	0
	Total	448	17	17	0	0

In Mediawiki-based DLES, reviewing the monitorable data it was possible not only to see the history of changes via the user interface, but also to query the database and analyse how students had interacted through the wiki pages. In the case of Moodle, even if the platform offered a database that could be queried, it only contained information about the usage of the VLE and its internal tools. Regarding the external tools, Dabbleboard did not provide any kind of information about the users' actions and, at that moment, Google Applications offered some information exclusively through the web application's graphical user interface. Finally, GLUE! registered in a log file the requests related to the external tools integrated in the VLE. Thus, since our main interest was on the use of the external tools (as they were the ones used for performing most of the learning activities), we focused the analysis of computer-mediated actions on the information provided by Mediawiki (editions and uploads in the wiki pages) and GLUE! (accesses to the third party tools integrated in the DLEs).

Regarding face-to-face data sources, we provided teachers with a Google Spreadsheet table to register the students' attendance to the face-to-face sessions [EXP(i)_T_OBS], and to enable subsequent data gathering and interpretation. The information provided by the students in the workgroup reports [EXP(i)_S_QUE1] [EXP(i)_S_QUE2] was not integrated in the analysis, as the teacher pointed out that the purpose of these questionnaires was to gain insight into how groups had organized the work and what had been the contributions of each one of the members, not to gather information about the script constraints. In these studies, the answers to the workgroup questionnaires were delivered to the teacher separately, complementing the information presented in the monitoring reports. However, in the fifth study, we created an interpreter for the questions in the workgroup questionnaires that were specifically devoted to inform about script constraints.

A prototype of a GLUE! module named *GLUE!-CAS* (see Section 4.6.3) was used to collect the participants' actions from the technological support [EXP(i)_IT_LOG], and from the attendance registers filled out by the teacher during the activities [EXP(i)_T_OBS]. To automate the data gathering of computer-mediated actions, we developed an adaptor for the different monitorable elements that made up the DLE (the Mediawiki database and the GLUE! log files). Similarly, we created a new adaptor to collect and interpret the evidence gathered by the teacher in the attendance registers.

To facilitate the integration of the three data sources, the adaptors translated the data gathered into the *Common Format* proposed in [Har09]. This format was created to promote the data sharing between technological learning environments and analysis tools, and allowed us to represent the information required for the monitoring process (i.e., the action type, the user who performed the action, the timestamp, and the resources involved in the action).

The evidence gathered by the adaptors was analysed using *GLIMPSE* (see Section 4.6.2). This tool performed the monitoring process taking into account the indicators and conditions inferred from the script constraints. Such input was obtained by means of the script instantiation details provided by GLUE!-PS (in the form of an XML file compliant with the *Lingua Franca* defined in [Pri11a]) and the monitoring configuration (a translation of the activity form filled in by the teacher, to XML format).

Finally, the results obtained by means of *GLUE!-CAS* and *GLIMPSE* were represented manually using the graphical templates agreed with the teachers, and the monitoring reports were sent to them at the end of each activity as they had planned. It is noteworthy that the partial automation of the data gathering and analysis reduced significantly the time devoted to generate the reports from 2,5 hours (in the first iteration) to 5 minutes [EXP(i)_R_OBS2]. This drop in time costs allowed us to provide the teachers with monitoring reports whenever they needed them within a short time frame.

EXQ_DAT.IT2.2: Is the data gathered from the different data sources enough to monitor the students participation? Unlike the first and second studies, in this iteration's studies the teachers decided at design-time the data sources to be monitored. First, they adapted the list of ICT tools that made up the DLE to those that could offer more information about the students' actions, while still satisfying the pedagogical purposes. Besides, teachers also included new sources (such as the attendance registers and the work group reports) that enriched the information obtained from the technological support, involving themselves and the students in the data gathering. The integration of data sources was very well appreciated by the teachers: "Having the integrated information of the different sources is very useful [...] because it can uncover situations I was not aware of [...] and provides a general vision along the whole activity flow [EXP3_T_INT]"; "Having all the information compiled and integrated is very useful. It's magic! You manage to see things that you would not be aware of by yourself" [EXP5_T_INT].

It is noteworthy that, in the three scenarios, the students' feedback was used to gain insight on *how* the students had worked, complementing the information gathered from the ICT tools and the teachers, which was more focused on *what* the students had done. Since, in the third and fourth studies, the questionnaires addressed to the students were not designed to inform the script constraints, the answers were not integrated with the other data sources. Instead, they were directly interpreted by the teacher, complementing the information presented in the monitoring reports. In the fifth scenario some questions especially related to the script constraints were added to the questionnaires, and we created an interpreter for automatically gathering and interpreting the answers. Following the teacher's recommendation, the evidence gathered from the students was not integrated with the evidence obtained from the DLE and from the teacher, since it might be a less reliable data source. Thus, it was analysed separately and included in the monitoring reports, allowing the teacher to compare between the results obtained from both kinds of sources within the same document.

In order to estimate the *reliability* of the monitoring process based on the aforementioned data sources, the monitoring reports were compared with the learning outcomes of the students in the tool instances [EXP(i)_IT_LO], the workgroup reports [EXP3_S_QUE, EXP4_S_QUE], and the information gathered by the teacher about the problems that the students had during the learning process [EXP(i)_T_OBS]. This analysis revealed that 99,12% (out of 113), 96,90% (out of 226), and 100% (out of 448) of the conditions evaluated respectively in each study, were interpreted correctly by the system, while only one problem went unnoticed (caused by a student accessing a tool and not performing the task he was expected to), and seven other potential critical situations turned out to be false positives (due to students submitting their work sooner than expected, or using their group mates' user accounts instead of their own).

With the aim of further enhancing the monitoring data sources, the researcher and the teachers identified two main directions: a) extracting further information from the ICT tools about the user performance (e.g., more detail about the editions in Google Documents) could contribute to reduce the number of unnoticed problems [EXP3_R_OBS2][EXP4_R_OBS2][EXP5_T_INT]; and b) collecting further information from teachers and students [EXP5_T_INT] could avoid false positives and lead to more reliable results ("It would be especially useful to be able to modify the reports with my own information" [EXP4_T_INT]; "what I did was print out the reports and add my notes over them, to have a complete overview of what had happened" [EXP5_T_INT]).

3.4.3 Overall discussion of the second iteration

In this second iteration we have seen certain benefits of integrating the reflection on monitoring aspects in the design of CSCL scripts. First, according to the teachers' point of view, this integration enriched the script without a notable additional effort ([EXP(i)_T_INT], e.g., "the current design considers not only what students have to do, but also how they should do it, and how we can follow the progress of students" [EXP5_T_INT]).

This 'new' task in the design process helped teachers be aware of potential eventualities and how the apparition of problems could affect the different activities ("it helps you start thinking about what consequences such event may have" [EXP3_T_INT]) and contributed to think *a priori* about possible solutions. This knowledge guided them to configure the monitoring process to address their needs, and left them feeling more confident ("having an initial plan about what has to be monitored and what to pay attention to, gives you a greater sense of control over the activity" [EXP3_T_INT]).

Making the teachers aware of the impact that their decisions had on monitoring moved them to improve the monitorable data sources (creating a DLE that offered more information about the users' actions, and including complementary data sources). Besides, their participation in the configuration of the monitoring process (identifying the conditions to be evaluated in each activity, choosing the resources and actions to be monitored, defining the moments when they would need the information) contributed to better satisfying the teachers' monitoring needs.

Teachers emphasized that, thanks to the prior thinking about the monitoring, they had obtained much more evidence about the students' work than they would have had otherwise.

During enactment, teachers and students were actively involved in the monitoring data gathering, and we (the researchers) provided teachers with monitoring reports dealing with the script constraints. These reports helped them follow the students' performance: when monitoring reports confirmed that students were accomplishing properly the activities, teachers were not forced to review in detail the students' work to obtain the same information; and, when the report announced potential problems, it facilitated their prompt solution before they came into breakdown situations.

Among the benefits of the monitoring process, the teachers stressed that the reports saved them time, let them use such time in a more efficient manner ("monitoring reports let you focus your attention, be more efficient, and detect problems in a more timely manner" [EXP3_T_INT]). Furthermore, the reception of monitoring reports in the moments identified as 'relevant' for the monitoring (according to the teacher decisions at design-time) caused that teachers look at the students' work even if no problem was detected ("if I had not received the monitoring reports, I would not have been so watchful"[EXP3_T_INT]), increasing the teachers' awareness ("It has prompted a greater control over the evolution of the learning scenario"[EXP4_T_INT]).

One of the main purposes of the fifth study was to adapt our proposal of linking scripting and monitoring for teachers who were not expert in CSCL scenarios. Nevertheless, neither during the design or the enactment we identified special difficulties from the teacher of the fifth study (aside from those that arose in previous studies). Indeed, she highlighted the strengths of the proposal and stated that in the design of future scenarios she would take into account these new insights.

Based on the lessons learnt from this iteration, we extract below a list of considerations to be taken into account in the formulation of our proposal:

- To support teachers in the integration of monitoring concerns at design-time, it is crucial to provide them with descriptions of the ICT tools, specially regarding the user's actions that are monitorable. Such information is meaningful for pedagogical reasons since it may inform the selection of tools.

- The teacher may not realise the impact that her design decisions have on monitoring, or whether it is possible to obtain certain information from the current definition of the script. Thus, it is necessary to provide teachers with feedback on their design decisions.

- The integration of monitorable data sources from teachers and students creates a need for tools (aligned with the monitoring purposes) that support them in this endeavour and, at the same time, allow the automation of the data gathering and integration.

- In order to enhance monitoring and the consequent regulation, the teachers considered very relevant to integrate their own notes in the reports (e.g., incidents detected or comments from students). Including such notes in the monitoring reports would help to centralize the information about the learning scenario.

3.5 Conclusions

In this chapter we have summarized our exploratory work throughout two iterations that encompassed five studies in authentic CSCL scenarios. These studies provide initial evidence of the synergies that may arise with the integration of scripting and monitoring, e.g., enriching the CSCL script, providing teachers with relevant information for the regulation of the learning scenario, and saving teachers' time. Besides, these studies also provided guidelines to put the proposal into practice.

In the first iteration, we covered two main topics: the use of pattern constraints to guide the monitoring process of pattern-based CSCL scenarios, and the restrictions imposed by the DLE to collect and integrate students' actions. Taking into account the pattern constraints in the monitoring process contributed to provide teachers with relevant feedback for regulation purposes, connected to their pedagogical concerns. However, the constraints imposed by the patterns were not enough to guide the monitoring process. There were other design elements related to the activity definition (e.g., time frames, participants distribution into groups, resources) that were necessary to contextualize the monitored data. Regarding the restrictions imposed to collect students' actions, the studies showed that monitoring blended activities (in terms of learning and interaction) requires blended data sources that provide complementary evidence (e.g., combining ICTs, teachers and students).

The first iteration brought up the fact that certain pedagogical decisions made at design-time impacted on the monitorable data and the accuracy of the monitoring results. Thus, we carried out the second iteration to explore how we could support teachers to take monitoring into consideration during the design of the CSCL scenario. In this second iteration, the studies pointed out that this approach had several benefits: making teachers aware of the impact that their decisions had on monitoring moved them to improve the monitorable data sources; teacher participation in the configuration of the monitoring process contributed to better satisfying their monitoring needs; and prior thinking about the monitoring enabled teachers to obtain much more evidence about the students' work, than they would have had otherwise.

Regardless of the teachers' prior expertise on CSCL practice, both of them identified the same needs about how to support the integration of monitoring concerns at design-time. First, teachers need to be informed about the monitorable affordances of the ICT tools, in order to select tools that are adequate for their pedagogical and monitoring concerns. And, second, it is necessary to provide teachers with feedback on their design decisions, in particular about the feasibility of obtaining monitoring information, given a certain script definition.

In conclusion, this exploratory work has led to the proposal of a monitoring-aware design process (see Section 4.3) with the aim of supporting teachers in the integration of monitoring aspects in the design of CSCL scenarios. Likewise, this exploratory work also guided us towards the definition of a monitoring-aware model of CSCL scripts (see Section 4.2), which establishes the connections between the design and the monitoring processes needed to automatize the data flow between them. Moreover, we identified script parameters relevant for the data gathering and the definition of the desired model of the learning situation, which contributed to the definition of a script-aware monitoring process (see Section 4.4). Finally, the lessons learnt regarding the collection of monitoring data were used to propose an architecture for data gathering and integration in DLEs (see Section 4.5). All these proposals constitute the main contributions of this thesis and they are presented in their current form in Chapter 4.

Chapter 4

Final proposals

Summary: Based on the literature review (Chapter 2) and the lessons learnt from the exploratory studies (Chapter 3), we finally tackle the main objective of this dissertation. In order to provide teachers with design and enactment support capable of linking pedagogical intentions with monitoring needs, we formulate four interrelated proposals in this chapter: a) a *monitoring-aware scripting model* that represents the bridges between designing scripts and monitoring of users' actions in CSCL settings, facilitating the communication between the design and the monitoring process; b) a *monitoring-aware design process of CSCL scenarios* that guides teachers throughout the design to reflect on those aspects that affect monitoring, to adapt the monitoring process to their needs, and to collect the script information necessary for monitoring the learning scenario (according to the aforementioned scripting model); c) a *script-aware monitoring process* that describes the steps to be followed in order to verify whether the teachers' expectations about the learning scenario (the script) are being satisfied in light of the students' actions; and d) a *software architecture for data gathering and integration* that aims to facilitate the collection of monitoring data in CSCL DLEs. Finally, this chapter also presents *EdiT2++, GLIMPSE, and GLUE!-CAS*, three instrumental tools that have been developed to support the application of our proposals in the exploratory and evaluative scenarios presented in throughout dissertation.

Intermediate versions of these proposals have been already published in different scientific fora (the model in [RT12a] [RT13a]; the design process in [RT12b], [RT13a] and [EM14]; the monitoring process in [RT11c], [RT13b] and [EM14]; and the architecture in [RT11a] and [RT11b]). The contributions in their current state (presented here) are intended to be published in the near future.

4.1 Introduction

In Chapter 1 we formulated a list of research objectives that were addressed both in the review of the state of the art (Chapter 2) and during the exploratory studies (Chapter 3). Figure 4.1 summarizes the connections between the research problems, our objectives throughout this dissertation, and the expected contributions formulated in this chapter.

Concerning the first partial objective (the integration of monitoring issues in the design of CSCL scripts, OBJ_DES), our literature review revealed that current design proposals and scripting models do not take into account monitoring issues, hampering the alignment of both strategies. Additionally, our exploratory work showed multiple connections to be taken into account between these two strategies (script design and monitoring), as well as the need of supporting teachers to reflect and express their monitoring concerns. In response to these initial

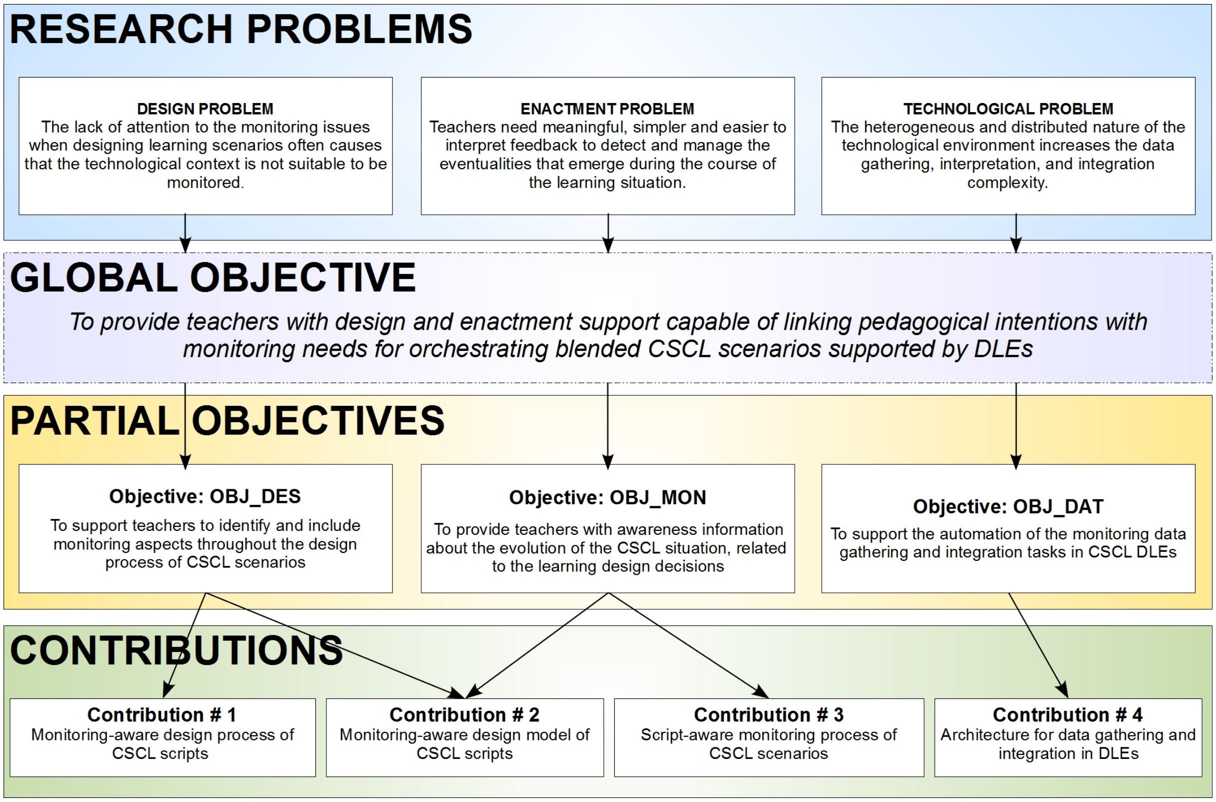


Figure 4.1: Overview of the research problems, objectives and contributions of this dissertation. See also Figure 1.1 for further details.

findings, this chapter presents a *monitoring-aware design process of CSCL scripts (C#1)* in Section 4.3. Moreover, to compile all the details that have to be addressed during the design process, and to model the dependences between both strategies, we have formulated a *monitoring-aware model of CSCL scripts (C#2)*, described in Section 4.2.

In order to link the awareness information with the teacher's design decisions (OBJ_MON), we reviewed existing Learning Analytics proposals (presented in Section 2.5.2). In this review we noted that many of these proposals follow mainly a bottom-up approach, i.e., they infer indicators based on the available data. However, this approach does not ensure the alignment between the resulting indicators and teacher awareness needs. Besides, we discovered during the exploratory studies that involving the teacher in the configuration of the monitoring process helped reduce the data gathering effort to those aspects relevant for the teachers. This teacher involvement also enabled us to offer such awareness information at those moments that the teacher considered relevant for the management of the learning scenario. In Section 4.4 we describe our proposal of a *script-aware monitoring process of CSCL scenarios (C#2)*. This monitoring process aims to inform teachers about the accomplishment of their design decisions, taking advantage of the aforementioned scripting model proposed in this dissertation.

Chapter 2 introduced certain problems that hinder data gathering and integration in CSCL scenarios supported by DLEs, due to the increasingly heterogeneous and distributed nature of such technological environments. For example, as we have seen throughout the exploratory studies, the data to be gathered is decentralized across different servers and domains, and each learning tool follows its own data formats and models. Moreover, the exploration also revealed that sometimes relevant data may be generated, not only automatically through technological means, but also manually, face-to-face, by the participants themselves. Thus, to address this challenge, we have proposed an *architecture for data gathering and integration in DLEs (C#4)* (described in Section 4.5) which is able to ease the automation of monitoring data gathering and integration in CSCL activities across DLEs.

Finally, this chapter presents three tools that have been developed during the implementation of the aforementioned proposals (see Section 4.6), namely: *EdiT2++*, *GLIMPSE*, and *GLUE!-CAS*. *EdiT2++* is an adaptation of an existing script authoring tool, modified so as to link the scripts it produces with our monitoring-aware design process of CSCL scripts; *GLIMPSE* is an analysis tool that enforces the script-aware monitoring process, taking advantage of information extracted from the script and the monitoring configuration; and *GLUE!-CAS* is a prototype of the architecture for data gathering and integration. Concretely, *GLIMPSE* and *GLUE!-CAS* were instrumental in the evaluation of the proposals, as we will see in the following chapter.

4.2 Monitoring-aware model of CSCL scripts

To establish the connections between designing scripts and monitoring users' actions in CSCL settings, it is necessary to provide a joint model that represents the elements from each domain and the connections between them. Such view of the problem can provide an idea of what additional information should be made explicit about monitoring when designing a CSCL script. From the monitoring perspective, the model can also inform about the script constraints to be verified (i.e., monitored) during the enactment.

The methodology followed in order to propose the model combines two approaches. First, a top-down approach based on a bibliographic study which analyses, on the one hand, how *CSCL scripting* has dealt with the modelling of learning scenarios in order to structure the collaborative learning process; and, on the other hand, how users' actions have been modelled, in the area of *analysis of computer-mediated interactions*, in order to process them. The second approach is a bottom-up one, based on the collection/identification of the elements required for the integration of scripting and monitoring during the *exploratory studies*. Thus, the theoretical features are complemented with the particularities that emerged from our exploratory studies, to describe what we have called a *monitoring-aware model of CSCL scripts*. The rest of this section presents the outcomes from the literature review and the exploratory studies, as well as our proposal for a model that establishes the connections between scripting and monitoring.

From the review made in Section 2.4.2 regarding existing scripting models, we identify five main elements: *activities, participants, groups, roles and resources*. These elements are interrelated, e.g., activities are distributed among groups and roles, participants make up groups, and activities are often organized in a sequence. In addition, some authors highlight the importance of taking into consideration activity aspects such as the type of interaction, the timing, or the spaces where activities will be carried out. Although we have highlighted the relevance of the aforementioned scripting elements, that does not mean that other aspects (such as the knowledge, skills and abilities – KSAs) are not relevant as well. However, computational representations of CSCL scripts (e.g., those based on IMS-LD) often do not include detailed models to capture the students' KSAs, the learning objectives, the potential benefits expected from each activity, or the specific contents dealt with throughout the script. Since these latter elements would provide little help in supporting the integration of monitoring within CSCL scripts (because they are often not modelled in the scripts), they have been put aside.

Our review of the proposals for modelling users' actions (see Section 2.5.3) brings up another issue. Despite the lack of a common standard, situational approaches include both the description of the participants' actions (specifying the users involved, the action type, the resources used, and the timestamp) and the context in which they are taking place (users, roles, resources and groups that intervene in the situation).

Figure 4.2 shows the partial overlapping between existing proposals in the scripting and interaction analysis fields. This comparison shows that, despite the multiple commonalities (both include users, roles, resources and groups), they differ on key elements: while scripting proposals do not consider the users' **actions** during the learning process, interaction analysis models do not take into account the learning **activities**. This gap between both fields lead us to think that none of the existing proposals are suitable for guiding monitoring on the basis of pedagogical intentions. Thus, in order to define a model that takes into account both scripting and monitoring, we have considered the different concepts that have been highlighted in *both* kinds of models, so that they complement each other.

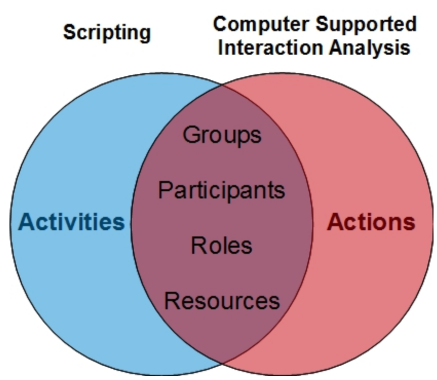


Figure 4.2: Comparison of scripting and interaction analysis models.

Throughout the exploratory studies, we identified several design aspects or parameters that influenced the monitoring process. We have classified these aspects attending to three dimensions, as it is shown in Table 4.1: a) pattern constraints and flow dependences, b) activity configuration, and c) teachers monitoring decisions. For instance, the activity flow provides sequencing dependencies between activities or phases, which may jeopardise the script's purpose. As another example, the collaboration and group formation policies must be satisfied in order to verify the script's collaborative purposes. Some details of the activity configuration (e.g., time frames, resources, and participants involved in each activity), as well as certain teacher decisions (such as monitoring periods or actions to be monitored), affect the data gathering of participants' actions. Other activity features were also useful to describe the constraints of the CSCL situation (interactivity type, social level). Additionally, there was another parameter that, despite not being used in the monitoring process, was necessary to guide the selection of resources and monitoring data sources: the monitorable actions.

Table 4.1: Exploratory work: emerging design dimensions and parameters that affected the monitoring process.

Pattern constraints or flow dependences	**Activity configuration**	**Teacher's monitoring decisions**
Sequence dependences		Monitoring periods
Resource reuse	Resources (tools, contents)	Activities to be monitored
Group formation policies	Expected use of resources	Resources to be monitored
Collaboration	Participants	Actions to be monitored
	Groups	Constraints to be monitored
	Resource assignment to participants/groups	
	Participant assignment to groups	
	Social level	
	Interaction type	
	Learning	
	Participation	

Based on the literature review and the exploratory studies, we have thus formulated the *monitoring-aware model of CSCL scripts* shown in Figure 4.3. The aim of this model is to be sufficiently descriptive in order to collect all the elements required to guide a monitoring process on the basis of a CSCL script. This proposal integrates the scripting components and the interaction analysis elements, as well as the relationships among them. The elements and attributes relevant for monitoring purposes are briefly presented below, together with illustrative examples:

- *Activity.* An activity is a collection of tasks to be carried out by the participants. In order to describe an activity is essential to know the following details:

  - *Time frame* (beginning and end): the concrete dates and times when the activity starts and finishes. In terms of monitoring, this information limits the data gathering to only the relevant time period, ignoring everything that happens out of it. Thus, these attributes prevent showing irrelevant information to the teacher, and reduce the amount of data to be processed, facilitating the generation of timely results during the enactment of the learning situation.

  - *Learning mode*: this attribute specifies whether the activity must be developed face-to-face (e.g., during a lab session), remotely, or in a blended manner (i.e., including both face-to-face and distant work). This information is useful to identify complementary data sources that may improve the monitoring results.

  - *Interaction type:* specifying the medium through which students are expected to interact (face-to-face/socially, in a computer-mediated environment, or blended – mixing both). This aspect helps to check which monitorable actions may best inform about the activity constraints. For example, if students are expected to interact face-to-face, gathering data from the VLE will not provide relevant evidence about the activity progress.

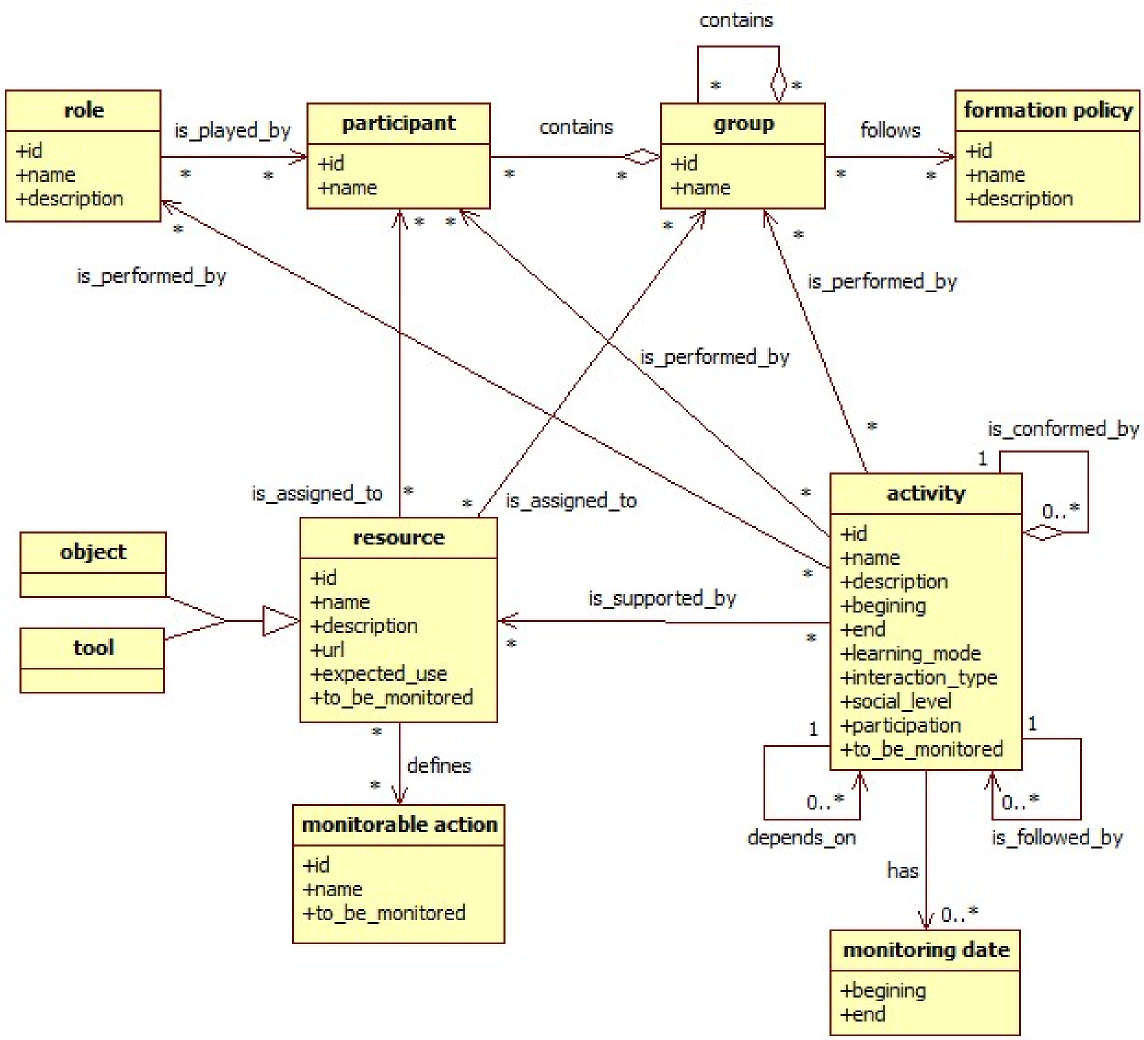


Figure 4.3: Elements and attributes of the monitoring-aware design model of CSCL scripts proposed in this dissertation.

- *Social level:* individual, group and class-wide activities are often interspersed in a learning situation. This attribute triggers different activity constraints. If an activity is individual, it will be necessary to know how each participant evolves and interacts with the context (usage of the ICT tools, attendance to the lectures, etc.). However, if the activity is carried out in groups (or by the whole class), it will be relevant to know if there is evidence of participation and collaboration among group members.

- *Participation*: this attribute represents what kind of participation is required to accomplish properly the activity. Participation in an activity can be optional, mandatory for individuals or mandatory for groups. Depending on the selected value, it will be necessary to verify whether there is evidence of individual or group participation during the enactment.

- *To be monitored*: this attribute is devoted to activate (or not) the monitoring process of the activity.

- *Monitoring dates* (beginning and end): these attributes are needed since the teacher may need to be reported at different moments about the monitoring results so far. For instance, a report might be necessary the day before the activity finishes, in order to send a reminder; or at the end of the activity, to check whether the activity has been carried out properly, and regulate the scenario if necessary.

- *Dependencies between activities:* learning activities within a CSCL scenario are usually interrelated. For example, sometimes there are dependencies due to the activity flow sequence (e.g., when one activity finishes, a related one begins). There may also exist resources that are reused among activities (e.g., the output of one activity is the input of another). Knowing about these dependencies in advance facilitates the detection of critical situations that may have a negative impact on future activities.

- *Participant.* This element represents all those people involved in the learning scenario, such as students, teachers, or observers.

- *Role.* A role is used to distinguish users who have different privileges and obligations during the activities described in the CSCL script.

- *Group.* Groups can be made up by individual participants or by subgroups. In some situations, the group configuration depends on *group formation policies*, as it happens when implementing CLFPs (e.g., *Jigsaw* , see [HL10a]). Knowing who belongs to each group defines which participant interactions are relevant for monitoring the learning activity (e.g., those between group members). Besides, being aware of the group formation policies contributes to detect the impact of the current participation on future activities. For example, let us imagine that we have an activity flow made up by an individual activity followed by a collaborative one. If the analysis of the students' participation during the first activity reveals that some of them have not been involved, we can deduce which groups may have difficulties in accomplishing their tasks later, during the collaborative activity.

- *Resource.* Resources are objects (such as a PDF file or a video) or tools (e.g., Google Documents) that support the learning activities. The description of a resource entails the definition of the following attributes:

  - *URL:* resources are usually accessible by means of an URL. In order to monitor a resource is crucial to know where it is located.

  - *Expected use of resources:* monitoring feedback may be improved by means of additional information about the way resources should be used within the learning activity (e.g. whether one resource is mandatory, as opposed to optional; whether participants are expected to use a resource individually or in groups).

  - *To be monitored*: as it happens with the activities, there are some resources that may be relevant for monitoring purposes, and others that do not require special attention. Thus, teachers may decide which ones will be taken into account in the monitoring process.

  - *Monitorable action*: another characteristic of a resource is the list of its available monitorable actions. Identifying the nature of actions that can be monitored in a tool (e.g., accesses, editions or uploads) can help teachers choose the most suitable tools for both pedagogical and monitoring reasons. Among this list, teachers can decide which actions are specifically relevant for the monitorisation of a certain learning activity.

This model represents the first step towards the integration between scripting and monitoring: a common ground for communication between both approaches. As we will see in the following sections, this model is interrelated with the proposed design and monitoring processes. On the one hand, the design process will guide the teacher to generate CSCL scripts compliant with the model, collecting the teacher's decisions about both pedagogical and monitoring issues. On the other, the monitoring process will use such scripts to guide the data gathering and analysis of the students' actions.

4.3 Monitoring-aware design process of CSCL scripts

The review presented in Section 2.4.1 points out the difficulties of designing CSCL scripts, and describes existing proposals to support teachers in this endeavour, e.g.: specifying the elements to be included in the design, structuring the design process, or using pedagogical patterns elicited from successful practice. Taking into consideration that scripting CSCL to enhance collaboration frequently requires these kinds of advice and support, we cannot expect teachers to integrate monitoring issues by themselves. We should provide practitioners with additional support to anticipate, during the design process, which could be their awareness needs and how they can be satisfied.

Instead of formulating a script design process from scratch, we have based our proposal on an existing process: the *pattern-based design process* of CSCL scripts (PBDP) [VF09b] (previously described in Subsection 2.4.2). This decision is motivated by our need of integrating monitoring in the context of the (complex) process of creating CSCL scripts.

The PBDP guides practitioners in the definition of the main elements included in CSCL scripting models (at a macro-script level), and it has been evaluated with positive results for the design of CSCL scripts [HL10b]. Additionally, the PBDP proposes the application of pedagogical design patterns. These patterns represent broadly-accepted techniques that have been repetitively used by practitioners, and are widely considered useful for guiding non-expert teachers in the design tasks [Con11]. Concretely, this design process has been extensively applied in combination with CLFPs [HL06], and to guide the integration of assessment issues in the design of CSCL scripts [VF09b].

Due to all these characteristics, the PBDP is a good candidate to support the design of our CSCL scripts, providing special support to the construction of the learning flow and the configuration of the learning activities. In this dissertation we will extend this process to take into account the dependencies identified between design decisions and monitoring, helping teachers in those tasks that turned out to be difficult for them during the exploratory studies.

The exploratory studies presented in the previous chapter showed that there were certain design-time tasks that contributed to enhance the monitoring process. Some of them were merely descriptive, and their purpose was to express teachers' expectations and to define the boundaries of the learning scenario (e.g., specifying the activity time frames and the expected

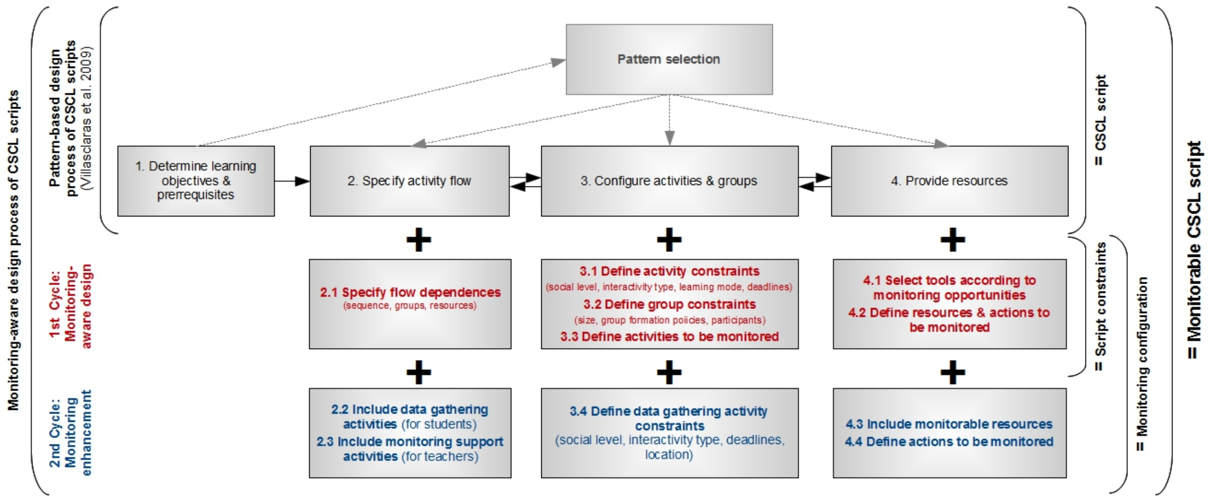


Figure 4.4: Proposal of monitoring-aware design process. In black (at the top), the phases of the original PBDP. Below, our proposed extended process, in two cycles: monitoring-aware design cycle (in red), and monitoring enhancement cycle (in blue).

use of the resources). Other design tasks focused on taking into account teachers' monitoring needs (e.g., choosing the activities and resources to be monitored, or defining when they needed the monitoring information), and yet others aimed at improving monitorable data (such as the selection of ICT tools or the identification of complementary monitoring data sources). Design dimensions and elements that affect monitoring have been summarized in Table 3.3 and Table 3.4.

Our purpose is to guide teachers in the design process of CSCL scripts to reflect on those aspects that affect monitoring, adapt the monitoring process to the teacher's needs, and collect the script information necessary for monitoring the learning scenario (according to the aforementioned monitoring-aware design model of CSCL scripts). To achieve that purpose, we propose the *monitoring-aware design process* shown in Figure 4.4. This process is based on the PBDP and the lessons learned from the exploratory studies regarding the design decisions that affect monitoring. We suggest that the process should be structured in two cycles, the first one (monitoring-aware design cycle) to collect all the details required to guide the monitoring process, and the second one (monitoring enhancement cycle) to better adequate the data sources to the monitoring purposes. These two cycles are described in more detail below:

First cycle: monitoring-aware design. This first cycle requires designers to reflect on monitoring issues while they face the steps of the PBDP. These steps are:

1. **Determine learning objectives and select pattern(s).** This first step remains identical to the one in the PBDP. It entails the specification of the learning objectives, and requires teachers to envision the learning scenario and choose, if needed, the pedagogical patterns that will guide the script definition.
2. **Specify the activity flow.** The teacher describes the concrete tasks (following the pattern guidelines, if applicable) that the students have to accomplish throughout the

learning scenario. Regarding monitoring, the teacher has to specify the dependencies of the activity flow (Phase 2.1. in Figure 4.4). Identifying these dependencies will be useful to detect during enactment whether the current state of a learning scenario can jeopardize future activities. Certain dependencies may stem from the pattern constraints (e.g., due to the group formation policies), and others may appear on account of the data flow (due to resources that are reused in different activities), or the group formation policies (as it happens when implementing the *Jigsaw* and *Pyramid* CLFPs, described in B), as we will see later.

3. Configure groups and activities. This phase is divided in two:

3.a Configure the activities. In this step the teacher has to describe the tasks to be carried out in each activity, including specific details relevant for monitoring purposes: the definition of the time frames, the social level, the interactivity type, and the learning mode. From the monitoring point of view, the time limits are used to narrow the period of the analysis, i.e., to gather evidence during the period of time representative for the development of the activities. Also, being aware of which activities have to be carried out individually or in groups –and in which groups– gives information about which evidence should be gathered (for instance, identifying collaboration is relevant in those tasks done by groups but not in the individual ones). Additionally, the combination between the interaction type and learning mode of the activity provides information about which evidence is applicable and potentially useful (e.g., attendance to the lab session in a face-to-face activity in groups, submission of a deliverable in an individual task, etc.) or not (e.g., it may not be meaningful to monitor the number of individual accesses to a tool if only a unique group submission is expected at the end of the task).

Another issue, at this point, is related to the adaptation of the monitoring process to the teachers' needs. For example, to avoid unnecessary information it is useful that the teacher decides about which activities have to be monitored. Moreover, teachers should reflect on the moments at which they need the monitoring information, in order to help them regulate the learning scenario.

3.b Configure groups. The group formation consists in distributing students in groups (sometimes, according to the group formation policies imposed by the pedagogical pattern). The way groups are structured is essential in terms of monitoring, because it informs about the expected structures of interaction in a given activity. Taking into account these constraints would, for example, help to foresee that a student may be isolated in a future activity, if her groupmates have not been involved in the previous work.

4. Provide resources. CSCL scenarios normally use ICT tools to support the learning process. This step involves the search for tools that satisfy the teacher's requirements (e.g., based on pedagogical or institutional concerns) and, at the same time, offer the possibility to store the users' actions for later analysis. This task requires informing teachers about the monitorable actions of such ICT tools, so that they can choose those tools that better suit both their pedagogical and monitoring needs. Being aware of the tools and resources required for each activity influences the data gathering (the list of resources determines where to look for learning evidence) and contributes to the definition of an activity's "desired state" (as we will see in the monitoring process described in the following section). Taking into account the expected use of the resources helps to obtain more accurate monitoring reports (avoiding unnecessary warnings in case of optional resources, and highlighting the potential problems in case of lack of use of the mandatory ones). Finally, taking into account the monitorable actions from each of the selected tools, the teacher may decide which resources and actions are relevant for monitoring each activity.

As we pointed out when describing the step *2. Specify activity flow*, it is also relevant to reflect on the dependencies that emerge from the data flow. For instance, in a *Peer-review* , if one group does not submit its report, the reviewers phase will necessarily fail, since the reviewers will not have a document to review. The identification of these dependencies contributes to the awareness about the impact that the current state of the interaction in an activity could have over the rest of the activities.

Up to this point, the design process has been driven by the pattern-based design approach, while introducing some relevant aspects for monitoring. The output of the first cycle is a script that contains all the details required for guiding the monitoring process. However, it is necessary to go one step further in order to improve the quality of the monitoring results.

Second cycle: monitoring enhancement. Once the teacher finishes the first cycle, it is necessary to extract the list of constraints to be monitored and to verify whether there exists monitorable evidence for each one of them. Based on these constraints and the monitorable data, the teacher may have to identify complementary data sources to enhance monitoring or to avoid "blind spots". Indeed, in blended learning settings, there may be many tasks that are not supported by technology, or that take place out of the classroom. If these activities are to be monitored, additional data sources that capture these actions are necessary, using teachers, students, observers, or other ICT tools as additional informants.

Thus, the main purpose of this cycle is to enrich the design, extending the activity flow with new activities or resources that provide additional monitoring information. In those activities fully or partially located in the classroom, teachers may provide their own observations (e.g., registering the attendance to the face-to-face sessions, or the interventions in a debate) in order to take into account face-to-face learning actions. We have named these observations *teachers' monitoring support activities*. Conversely, for the collaborative activities planned to happen out of the classroom, students may be involved in the monitoring process by including *students' data gathering activities*, where they are in charge of providing evidence, e.g., explaining how distribution of tasks has been done within their respective groups.

The outcome of this design process will be a script compliant with the monitoring-aware model described in the previous section. We expect that, by keeping teachers aware of the impact that their decisions have on the monitorable data, this process avoids undesired negative effects on the later monitoring [MM11b]. Furthermore, according to Bravo et al.'s suggestions [Bra08], we foresee that involving teachers in the configuration of the monitoring process will contribute to adapt it to their needs.

4.4 Script-aware monitoring process of CSCL scenarios

Learning Analytics and Educational Data Mining offer the promise of providing the instructor with information to help them analyse the learning process. However, as Dringus and Ellis stated [Dri05] (and the teachers involved in our exploratory studies pointed out), the results of the data analysis should not and cannot replace a careful review of the learning outcomes. Assuming this limitation, the scope of the monitoring process presented here is to obtain objective information that, contextualized within script constraints, may lead to meaningful feedback about the students' performance, facilitating the detection of potentially critical situations and the regulation of the learning scenario.

To build our monitoring process, we reviewed existing proposals for data analysis and chose one suited to our purposes. In addition, we used the feedback obtained from the exploratory studies to identify how the script could guide the data analysis. Both the theory-driven and the exploratory fieldwork are summarized in this section.

As we already mentioned in Subsection 2.5.2, there are several proposals in the literature devoted to conceptualize the data analysis processes, following either a data-driven or model-driven approach. Since we try to relate the data gathered from the learning scenario with the teacher's pedagogical intentions predefined in the scripts (by means of the monitoring-aware model of CSCL scripts), we focus on the second approach. Concretely, we adopt the collaboration analysis process defined by Soller et al. [Sol05] as a conceptual frame for our proposal (see Figure 4.5).

Attending to the steps that the collaboration analysis encompasses, throughout the exploratory iterations presented in the previous Chapter we identified certain parameters that guided the data analysis (see Table 3.3 and Table 3.4). This guidance occurred mainly in two ways: a) focusing the data gathering on the elements relevant for the script purposes (e.g., collecting actions timestamped within the activity time frames, done by the participants involved in the scenario, and registered by the ICT tools that support the activity) and for the teachers' concerns (e.g., activities, resources and actions to be monitored); and b) building the desired state of the learning situation (e.g., expected use of resources, participation, or social level).

Our proposal describes how to implement the four steps of the framework by [Sol05], using the script parameters to guide the data collection and build the "current" and "desired state" models. Following the recommendations given by Gutwin and Greenberg to provide awareness information [Gut02], our monitoring process aims to offer an overview of the past actions, the current state, and the potential impact on the future activities. Thus, this proposal builds an up-to-date history of the learners' actions, within the context of the learning scenario, that would serve to tailor subsequent interventions. Figure 4.5 shows the different steps that make up our script-aware monitoring process of CSCL scenarios:

Step 1: Collect data. Instead of gathering all the data available, in our proposal we select a priori the data to be included in the analysis. Table 4.2 defines a set of heuristics to relate low-level data (from now on, "actions") with the definition of the activities and the teacher's monitoring decisions (according to the monitoring-aware model of CSCL scripts proposed in this dissertation). To consider a participant's action as relevant for the analysis of one activity,

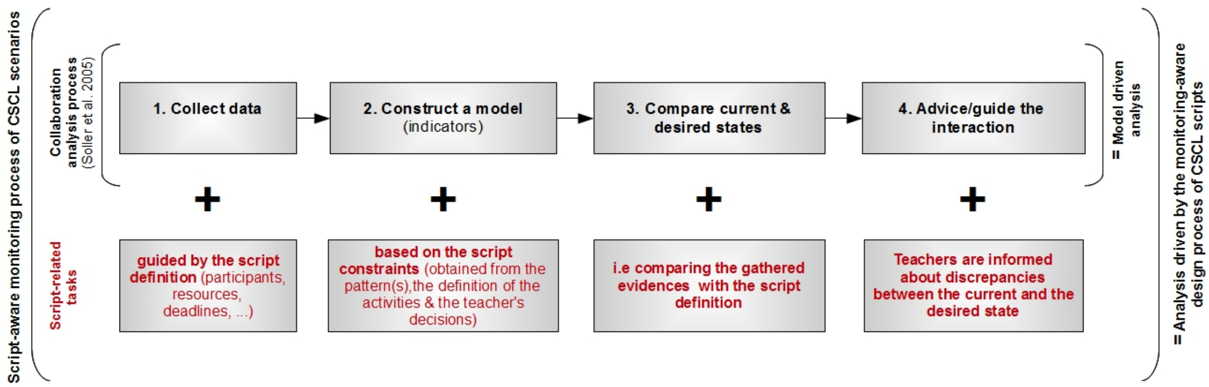


Figure 4.5: Steps of the script-aware monitoring process. In black (at the top), the phases of the original collaboration analysis process [Sol05]. In red (below), the proposed extension of this process, concerning CSCL script elements.

it should meet the following requirements: the action must be timestamped within the activity time frames, it has to be carried out on one of the resources that the teacher decided to monitor, it has to be classified as a type of action to be monitored, and has to be performed by the activity participants. In addition, if participants or groups have to work with a specific subset of resources, only their actions on these resources will be taken into account.

Table 4.2: Heuristics used to select the actions considered in the analysis.

An action is included in the analysis if:

- **The action happens within the activity deadlines:** $\{activity.begining \geq action.timestamp \leq activity.end\}$
- **The author(s) of the action belong(s) to the activity participants:** $\{action.actor \subseteq activity.participants\}$
- **The author(s) of the action is(are) supposed to use the resource:** $\{action.actor \subseteq resources.users\}$
- **The action involves a resource to be monitored during the activity:** $\{action.resource \in activity.resources\_to\_be\_monitored\}$
- **The type of interaction must be monitored in a given resource:** $\{action.type \in resource.actions.to\_be\_monitored\}$

Step 2: Construct a model. According to our proposal, the selection of the indicators is linked to the monitoring-aware model described in Section 4.2. We have identified two types of indicators presented in Table 4.3. The first type refers to low level indicators such as participation (involvement of an individual or group in the activity) and use of resources (participants' actions on the monitored resources). Based on this information, we infer more abstract indicators, that build on the previous ones, dealing with the collaboration (interactions among groups and/or group members), the group formation policies (requirements that groups should accomplish in terms of criteria such as size or type of participants), and the activity flow dependencies (activity parameters that affect other activities, e.g., reused resources, groups, or deadlines).

Table 4.3 presents indicators related to the aforementioned aspects (participation, collaboration, group formation and use of resources). Table 4.4 details how these indicators are then used to define the current and desired state of the learning situation. For instance, current participation is the sum of actions analysed at individual or group level; current collaboration is measured by the face-to-face actions and/or the actions mediated by shared resources; and current use of resources is analysed by means of the number of individual and group actions on those resources. Conversely, the desired state of the learning situation is derived from the values of the script parameters defined at design-time. For example, if the social level is individual and the participation is mandatory, there should be at least one piece of evidence of participation from each student; if the activity is collaborative, then there should be evidence of at least two participants interacting face-to-face or through shared resources; and, if the use of a resource is mandatory for groups, at least one participant of each group should interact with the resource.

Table 4.3: Definition of the *current state* of the interaction according to the indicators related to participation, collaboration, group formation and expected use of resources.

Participation: applied to individuals or groups depending on the social level of the activity.

- **Individual participation**: the involvement of each participant in the activity is measured by:
  - *The number of actions (to be monitored) that the participant performs:*
    $\{\sum \text{action}|\ (\text{action.creator.id} = \text{participant.id})\ \&(\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$
- **Group participation**: the involvement of each group in the activity is measured by:
  - *The number of actions (to be monitored) that the group members perform:*
    $\{\sum \text{action}|\ (\text{action.creator} \subseteq \text{group.participants})\ \&\ (\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$

Collaboration among group members: for each group, the collaboration is measured by the actions (performed by individuals or subgroups, depending on the social level) to be monitored according to the teacher's decisions :

- In case of groups made up by individual participants, **collaboration** is measured by
  - *The actions (to be monitored) that the group members perform:*
    $\{\sum \text{action}|\ (\text{action.creator} \subseteq \text{group.participants})\ \&\ (\text{action.type} \in \text{group.resources\_to\_be\_monitored})\}$
- In case of groups made up by subgroups, **collaboration** is measured by:
  - *The number of actions (to be monitored) that the subgroups perform:*
    $\{\sum \text{action}|\ (\text{action.creator} \subseteq \text{subgroup.participants})\ \&(\text{subgroup.id} \subseteq \text{group.subgroups})$
    $\&\ (\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$

Group involvement: for each activity, it is necessary to control the group formation policies, e.g., the group size.

- **Active members**: the size of the groups is measured by the number of group members (individuals or subgroups depending on the social level) that are participating:
  - *The number of individuals who have participated:*
    $\{\sum \text{participant}|\text{actor.id} = \text{participant.id}\ \&\ \text{action.actor} > 0\}$
  - *The number of subgroups who have participated:*
    $\{\sum \text{subgroups}|\text{group.id} = \text{subgroup.id}\ \&\ \text{action.group} > 0\}$

Use of monitored resources: for each monitored resource that supports the activity, the use that participants make of it is measured by:

- *The number of actions (to be monitored) performed by the participants of the activity*:
  $\{\sum \text{action}|\ (\text{action.creator} \subseteq \text{activity.participants})\ \&\ (\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$

The main role of the aforementioned indicators is to detect a lack of evidence of a specific

Table 4.4: Relation between the script constraints and the indicators presented in Table 4.3. The *desired state* of the learning situation is defined by means of the expected values of the indicators.

Participation: depending on the social level (individual/group), the expected participation values are:

- **Individual participation**:
  - *If the individual participation is mandatory, for each participant:*
    If activity.social_level = individual&participation = mandatory → participant.participation ≥ 1
  - *If the individual participation is optional, for each participant:*
    If activity.social_level = individual&participation = optional → participant.participation ≥ 0
- **Group participation**:
  - *If the group participation is mandatory, for each group:*
    If activity.social_level = group&participation = mandatory → group.participation ≥ 1
  - *If the group participation is optional, for each group:*
    If activity.social_level = group&participation = optional → group.participation ≥ 1

Collaboration among group members: if the activity is collaborative, for each group the expected collaboration values are:

- *At least two group members participate*:
  If (activity.social_level $\neq$ individual) → {∃participant1, participant2| (participant1.participation ≥ 1) & (participant2.participation ≥ 1)}

Group formation: the expected values are:

- *For each group there there must be at least two members (from different subgroups) actively involved*:
  {∃participant1, participant2| (participant1.participation ≥ 1) & (participant1 ∈ small_subgroupA) & (participant2.participation ≥ 1) & (participant2 ∈ small_subgroupB)}

Use of monitored resources: depending on the target users

- *If the expected use of the resource is mandatory for individuals, for each activity*:
  If activity.resource.expected_use = mandatory_for_individuals → $\forall participant, resource.individual\_use \geq 1$
- *If the expected use of the resource is mandatory for groups, for each activity*:
  If activity.resource.expected_use = mandatory_for_groups → $\forall group, resource.group\_use \geq 1$
- *If the expected use of the resource is optional, for each activity*:
  If activity.resource.expected_use = optional → $activity.resource.use \geq 0$

type of expected activity taking place (e.g., one student has not submitted its assignment). This is complemented by showing the teachers simple data (e.g. number of accesses to a tool), that they are expected to interpret in their own contexts.

The indicators we have chosen are purposefully minimalistic. This decision is based on the fact that we are dealing with DLEs and blended learning scenarios, in which the data obtained by the system often is very simple [Kru10] and incomplete: in heterogeneous, decentralized systems like DLEs we cannot ensure that we will obtain deep data; and in the case of blended scenarios, a large part of the activity happens outside the classroom, and/or outside the DLE. In our approach, we assume that the complexity of the results obtained from the analysis must be in line with the depth and reliability of the data retrievable from the scenario. Thus, we use "modest" indicators that have simple effects such as making visible things that would otherwise be invisible for teachers. However, these assumptions have to be confronted with teachers' perceptions about the usefulness of these indicators – a key issue to assess in the evaluation of this contribution (see the next Chapter).

Step 3: Compare Current and Desired States. For each monitoring period, current and desired states of the learning situation are compared, checking the constraints. In those cases where the evidence does not satisfy the expected values, warnings are triggered highlighting the problem (e.g., lack of participation, lack of collaboration, unexpected use of resources). Once the state of each activity is analysed, its impact on future activities is also checked (for instance, unavailable resources or unstructured groups).

Step 4: Advise/Guide. This step aims at informing the teacher about the commonalities/discrepancies between the current and the desired states of the learning situation. Especially we warn the teacher about the lack of evidence of expected participation, collaboration, use of resources, etc. In addition, the flow dependences help to predict the impact of unexpected situations in future activities. Taking into account that the results obtained from the analysis may be incomplete, we consider the teachers (and not the system) as the ones responsible of the regulation of the activity, since they normally have contextual information about the learning situation that may help them understand the reasons of a warning raised by the system (e.g., she knows that the internet connection is not working, and so the students cannot access to the online resources). Thus, our proposal does not take regulatory decisions, and rather provides monitoring reports to the teacher, to let him/her decide how to proceed according to the available evidence.

Following these steps, we expect that teachers may obtain relevant information to eventually intervene and adapt their plans during the enactment. By focusing the analysis on the accomplishment of design decisions, we aim to address the teachers' concerns and to make the interpretation of the results easier. Regarding the granularity of the information provided to teachers, instead of generating highly detailed accounts of the collaboration that may be difficult to handle, this monitoring process focuses on those aspects that the teacher considers relevant for each specific learning context.

4.5 Architecture for data gathering and integration in DLEs

Although CSCL scenarios may offer the possibility to store and analyse large amounts of educational data [Sie11], there exist problems that hinder data gathering and integration [MM11b]. As we have seen in the exploratory studies, some learning tools do not offer any kind of data about the users' actions (e.g., Dabbleboard). Furthermore, there is no standard format to store and model such action data, and so each tool/environment uses its approach to exposing the data (e.g., while Mediawiki provides access to the database, Google Applications provide access via an API). In addition, many applications do not provide ready-to-use data (such as audio records or low level interactions). All these obstacles are more evident when the technological context is heterogeneous and decentralized, as it happens with DLEs, or when the data is not generated automatically by the technology (e.g., as it happened during the exploratory studies when we collected ad-hoc monitoring data from teachers' observations and students' questionnaires). Due to this heterogeneity, in learning scenarios that combine different platforms, the learning process is often monitored in a fragmented manner using ad-hoc analysis tools [Ren13]. To overcome this problem, the use of architectures that integrate the different data sources available plays a crucial role.

Two architectures that may be used for this purpose are the Tin Can API[1] and CAM [Sch10]. The Tin Can API is a specification for capturing data about a person or group's activities from multiple technologies. This specification requires that each learning tool implements a REST service to send statements (in the form of "Noun, verb, object") to a learning record store. Although there exists a public learning record store (LRS), the statements stored in this public LRS are not permanent and are available for testing purposes only. To get a LRS for private and permanent testing, it is necessary to create a SCORM Cloud account with monthly costs. A similar approach is followed in the CAM solution to gather data from PLEs, where each tool must offer a REST interface to provide the user's data on demand, following the CAM format. Albeit this format is very flexible in what it can track, it has no common vocabulary to describe actions and allows each platform to define its custom vocabulary, which makes the integration among different sources difficult. Besides, the CAM specification has not been widely adopted outside research so far [Voz13]. Thus, none of the aforementioned architectures are applicable to the needs of DLE-supported scenarios outlined above.

This dissertation proposes a different architecture, a conceptual solution for gathering and integrating participants' actions in DLEs (made up of a web-based learning environment, or LE, and on-line third-party tools). This proposed architecture should address the following requirements:

- The architecture should be flexible enough to cover the specific requirements of each LE or tool (granularity, data models, storing systems, etc.).
- The architecture should reduce the development effort required to integrate a LE or third-party tool. Also, it should allow the integration of analysis tools, VLEs and web tools without imposing modifications in their source code.
- The architecture should inform about the monitorable actions of each LE and tool integrated in the architecture, so as to support teachers in the choice of ICT tools to use in a learning scenario (part of the script-aware monitoring process).
- The architecture should provide the list of monitored actions, attending to criteria such as time frames, users, action types, and LE/tool instances (to support the first step of the script-aware monitoring process).

Figure 4.6 depicts the main elements that constitute the proposed architecture. The architecture follows a three-tier structure, with loosely-coupled distributed services. Its core is made up by a *monitoring manager* and an *internal repository* where the participants' actions are stored. The monitoring manager is in charge of collecting the data from the learning tools (marked Tool(i) in the Figure) and environments (marked LE(i)). This manager stores the collected evidence in the internal repository, and answers requests coming from the collaboration analysis tools (marked CA Tool(i) in the Figure). To incorporate learning environments, learning tools, and analysis tools, we make use of the "adapter" pattern [Gam95]: an approach that

[1]Tin Can API specification:`http://tincanapi.com/` (Last visit: 9 May 2014)

enables the integration of different platforms without modifying their code, and promotes a many-to-many integration. The LE and tool adapters must include a module to answer the requests for “registered events” (filtered by users, time frames, action types, and tools instance) and “monitorable actions” made by the manager.

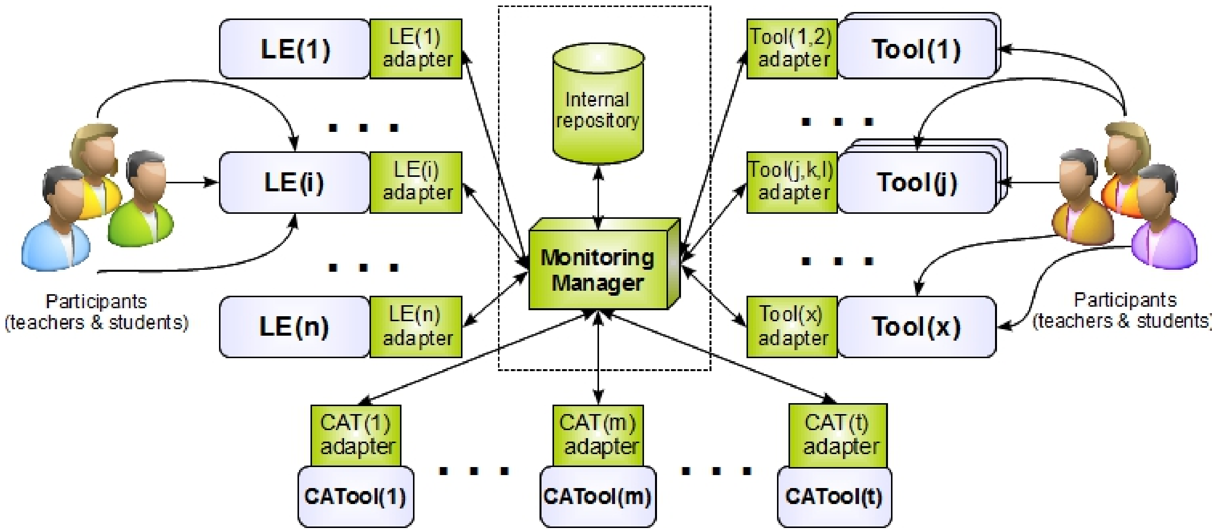


Figure 4.6: Architecture for data gathering and integration of user’s actions in DLEs

Two main approaches can be identified with regard to the data flow within the architecture: *pull* or *push*. In the first one, the request for the transmission of information is initiated by the client (i.e., the agent interested on the data). From the two aforementioned architectures, CAM follows this *pull* approach. In a *push* approach, the request for a given transaction is initiated by the publisher (i.e., the agent that provides the data), as it is done in the Tin Can API proposal. In the context of our architecture, the *pull* approach would imply that the monitoring manager asks for the monitoring data, while a *push* approach would require the learning environment and tool adapters to notify about the events to the monitoring manager.

These two strategies have advantages and disadvantages. On the one hand, the *push* model would require the LE and tool adapters to provide a publishing service that knows what information they have to provide, and when they have to send it to the monitoring manager (the manager itself would only have to store the data in the repository). In this case, the integration of new adapters would be transparent for the monitoring manager; it would just require each new adapter to be properly configured to send the feed of data to the monitoring manager). However, the implementation effort within this approach would fall on the adapters, increasing the complexity and of the adapter development (thus breaking one of the requirements described above). On the other hand, to adopt the *pull* model, the monitoring manager would be in charge of the data gathering. This task entails knowing where the data sources (i.e., the adapters) are located, and collecting the data periodically or when the CAT adapters ask for it. This option avoids the implementation of publishing services in the adapters, at the expense of more complicated development in the monitoring manager.

Taking into account the aforementioned requirements and the pros and cons of each approach, we have chosen a *pull* approach, since it minimizes the development effort in the LE and tool adapters (which often fall outside our control in a heterogeneous DLE), centralizing the complexity in the monitoring manager.

To develop the communication between the architecture components, and the monitoring manager and adapters themselves, we have chosen several widespread, loosely-coupled technologies. The main advantage of such loose coupling is the opportunity to easily reuse code from other existing components (lowering the development effort), regardless of their architectural approach or programming language used for implementation.

The adapters of our architecture act like services to invoke or to be invoked by the monitoring manager. Therefore, they must support some form of remote invocation, as well as publish the invocable interfaces. *REST* is a popular architectural style to enable simple communication among distributed elements and systems on the web [Ric07]. The main restriction of REST-based systems is its uniform interface, which must consist of a set of fixed and well-defined methods (often directly mapped to HTTP request methods). This restriction promotes the simplicity, scalability and easy development of applications on the web. Thus, designing our tool adapters as REST services enables a low degree of coupling that eases their quick and independent development.

The REST service style does not impose any specific data exchange format. However, in order to achieve interoperability among the elements of the architecture, certain common representation formats must be agreed. Here, the *Atom Syndication format*[2] and the *JavaScript Object Notation*[3](JSON) are proposed as the formats that tool adapters must support for the exchange of data, mainly due to their popularity among web applications. Thus, adapters must be prepared to process requests and responses in either Atom or JSON format.

To address the problem of the different data models followed by each tool, several works have pointed out that defining the mappings among all the different data formats is neither efficient nor scalable [Har09] [Nie13]. A more suitable solution would be to have a common data model and map the existing formats into it. The number of required mappings in that case would be far lower. Several data models have been proposed in this regard (such as the *Common Format* [Har09] and *CAM* [Sch09]) to enable the interoperability among learning and analysis tools. However, they have not been extensively adopted, and their application has been mainly in the research domain.

Instead, we propose the usage of the *ActivityStreams* specification [4] in our architecture. This specification has been designed specifically to model user interactions and enables platforms to share detailed information on user activities. ActivityStreams has a large uptake and is supported by most social media platforms (e.g., Google+ and Facebook). Many organizations have contributed to the development of the specification and have made it an open standard through the Open Web Foundation Final Specification Agreement[5], which permits its use, extension and commercialization. Indeed, ActivityStreams has been proposed as a standard for exchanging user activities among learning platforms [Man10] [Voz13]. Finally, it is worth mentioning that this specification is compliant with both Atom and JSON formats.

[2] Atom Syndication format:`http://ietf.org/rfc/rfc4287` (Last visit: 9 May 2014)
[3] JavaScript Object Notation:`http://www.json.org` (Last visit: 9 May 2014)
[4] ActivityStreams specifications:`http://activitystrea.ms` (Last visit: 9 May 2014).
[5] Open Web Foundation: `http://openwebfoundation.org/legal/the-owf-1-0-agreements/owfa-1-0` (Last visit: 9 May 2014)

An activity stream is a sequence of actions performed by a user. Such a stream models the story of a person performing an action on or with an object. Technically, an action is represented as a 5-tuple (Published, Actor, Verb, Object, Target): *Published* represents the time at which the action was published; *Actor* defines the user that performs the action; *Verb* describes which action is performed (this specification has a defined set of verbs with a corresponding meaning to describe actions, enabling better interoperability across platforms); and *Target* is intended to describe the consequences of the action. Let us consider this example action: "Luis added a figure to his report". In this example, "Luis" is an Actor, "added" a Verb, "a figure" an Object and "his report" is a Target of the action.

The proposed architecture also imposes the minimum overall behaviour that the LE and tool adapters (not the learning platforms themselves) should offer when invoked by the monitoring manager. Basically, this behaviour can be summarized as having the following functionalities:

1. To obtain the monitorable actions in the learning platform, so that the teacher can select at design-time the tools most appropriate to address both pedagogical and monitoring concerns.

2. To collect user actions from the learning platform, either as a list of all the actions registered in the platform within a time frame or, more desirably, in more concrete sets, such as the actions done in a specific tool instance, the actions done by a specific user, or one particular type of actions, etc.

3. To translate the list of actions from the LE/tool proprietary format to ActivityStream format.

The monitoring manager component, following the REST service style, defines a series of "resources" that clients of the service (such as an authoring or collaboration analysis tools) can use to access the main functionalities of the architecture. These functionalities include generalizations of the ones imposed to the adapters:

1. To obtain the monitorable actions in a learning platform, so that the teacher can select at design-time the tools most appropriate to address both pedagogical and monitoring concerns.

2. To collect user actions from the DLE, either as a list of all the registered actions within a period of time or, more concretely, all the actions performed upon a specific tool instance or by a specific user.

Using these generic functionalities, the monitoring manager can attain the desired outcomes that we set out at the beginning of this section: to provide authoring tools with the monitorable actions of a specific learning tool, and to retrieve the registered participants' actions in the DLE, which will be analysed by the CA Tools. Besides, the monitoring manager should offer the functionalities required for managing the adapters. Table 4.5 provides a resource-oriented version of these functionalities, assuming that HTTP requests (GET, PUT, POST and DELETE) on those resources are used to implement the invocations to the monitoring manager.

Table 4.5: Main services of the monitoring manager, represented as REST resources.

REST resource offered	HTTP methods offered	Information included in the HTTP request	Expected response
/learningEnvironments /{learningEnvironmentId} /monitorableActions	GET		Monitorable actions in a learning environment.
/learningEnvironments /{learningEnvironmentId} /tools/{toolId} /monitorableActions	GET		Monitorable actions in a specific tool of the learning environment.
/tools/{toolId} /monitorableActions	GET		Monitorable actions in a learning tool.
/learningEnvironments /{learningEnvironmentId} /users	GET		Users registered in a learning environment.
/tools/{toolId} /users	GET		Users registered in a learning tool.
/learningEnvironments /{learningEnvironmentId} /history	GET	Atom containing: "time frames", "users", "actionType".	Registered actions in the learning environment within the time frames, and/or carried out by a list of users, and/or corresponding to a specific action type.
/learningEnvironments /{learningEnvironmentId} /tools/{toolId}/history	GET	Atom containing: "time frames", "users", "actionType".	Registered actions in a specific tools of the learning environment within the time frames, and/or carried out by a list of users, and/or corresponding to a specific action type.
/tools/{toolId}/history	GET	Atom containing: "time frames", "users", "actionType".	Registered actions in the learning tool within the time frames, and/or carried out by a list of users, and/or corresponding to a specific action type.
/tools	GET		List of available tools.
/learningEnvironments	GET		List of available learning environments.
/tools	POST	Atom containing: "toolConfiguration".	URI of the new tool registered in the adapter.
/learningEnvironments	POST	Atom containing: "learningEnvironmentConfiguration".	URI of the new learning environment registered in the adapter.
/tools/{toolId}	DELETE	Atom containing: "toolId".	Confirmation.
/learningEnvironments /{learningEnvironmentId}	DELETE	Atom containing: "learningEnvironmentId".	Confirmation.

This section has presented our architectural proposal, in which the data to be gathered across the DLE is centralized and integrated using a single format. Applying the adapter pattern, existing learning environments and tools can be wrapped without modifying their code. Besides, the definition of a three-tier architecture with loosely-coupled distributed services, where the intermediate software layer partially undertakes the integration functionality, fosters a many-to-many integration oriented to reduce the development effort. We have used widespread web standards in the definition of the architecture, to encourage its adoption.

4.6 Implementation of the proposals

Although the software developed during the studies does not constitute a contribution in itself, it provides certain clues about the feasibility of implementing in practice the aforementioned proposals. This section presents a brief description of the prototypes[6] created to support the design process (*EdiT2++*), the monitoring process (*GLIMPSE*) and the architecture for data gathering and integration (*GLUE!-CAS*). Figure 4.7 shows how these different tools are interrelated.

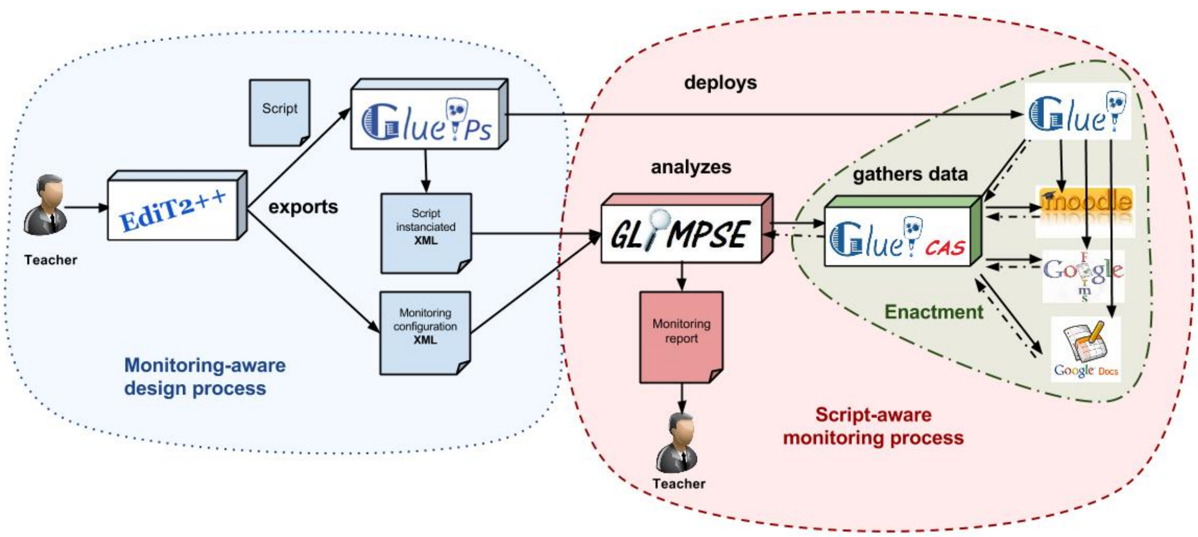


Figure 4.7: Overview of the tools used for the implementation of the proposals. *EdiT2++*, *GLIMPSE* and *GLUE!-CAS* (to support, respectively, the design process, the monitoring process and the architecture for data gathering in DLEs).

As we have already mentioned in the previous chapters, in the studies presented in this thesis the learning scenarios were supported using the *GLUE!* (Group Learning Unified Environment) and *GLUE!-PS* (GLUE!-Pedagogical Scripting) architectures (and their respective prototype implementations). GLUE! was created to support the integration of existing external tools in widespread VLEs like Moodle or LAMS (i.e., to aid practitioners in the creation of DLEs). GLUE!-PS was built to support teachers bridge the gap between the design of a script and its implementation in the technological setting. GLUE!-PS is an architecture and

[6]The source code of these prototypes is available in the additional material attached to this dissertation. See Appendix H

data model designed to deploy (and manage in run-time) learning designs specified in different languages (e.g., the IMS-LD specification), into different existing Virtual Learning Environments (e.g., Moodle and MediaWiki) and DLEs. Since both GLUE!-PS[7] and GLUE![8] were used in the exploratory and evaluative studies of this dissertation, our prototypes have been developed to interact with these technologies.

4.6.1 EdiT2++

EdiT2 [Sob12] is an editor of CSCL scripts developed in the MeTAH[9] research group at the Laboratoire d'Informatique de Grenoble. The tool has been implemented using ActionScript[10] (the programming language used in the Adobe Flash Platform), and there are several versions available to support the design of CSCL scripts according to different models, such as the one proposed by Kobbe et al. [Kob07] or the one used by GLUE!-PS [Pri13]. The main particularity of this tool is the way in which it represents the scripts: by means of a table (visually) and a tree (internally, the columns to the left side represent the root of the tree, and the columns to the right, the branches and leaves).

Designing a script with EdiT2 requires two steps: first, instantiating each 'notion' (e.g., activities, participants, resources, etc.), creating as many items as needed (e.g., an item for each activity that will be carried out in the learning scenario). Once the list of items of each notion is available, the tool provides an interface (see Figure 4.8) where scripts are visualized as a table where the columns represent the notions and, in each cell, the user can drag and drop the items previously created. The user interface offers common editing/manipulation actions conventionally offered by a table: dragging and dropping an item from one cell to another (e.g., moving a participant from one group to another); adding, removing or displacing a row (e.g., where Activity is the pivotal notion, adding a new activity or swapping two activities); splitting a cell into several cells (e.g., splitting an activity into two activities) or merging cells (e.g., regrouping participants initially spread into different groups); and adding, removing or displacing a column, modifying the levels of the tree (e.g., changing from an Activity-Group-Participant-Resource perspective to a Role-Participant-Resource perspective).

In collaboration with the MeTAH group, we developed a new version of the tool, dubbed **EdiT2++**, that unifies the previous variations of the tool. This version allows the user to edit an existing script, create a new script reusing existing models, or creating new models from scratch. The creation of new models entails the definition of the notions that make up the script, including the list of attributes. The tool also offers the functionality of predefining the possible values of such attributes.

With EdiT2++, we could create a script template that contains the list of elements, attributes, and values that appear in the monitoring-aware model of CSCL scripts. This template was designed to be also compliant with GLUE!-PS. Thus, a teacher using this template can also deploy the script in one of the technological settings supported by GLUE!-PS. Using EdiT2++,

[7] Technical details about GLUE!-PS are available in:`http://www.gsic.uva.es/glueps` (Last visit: 9 May 2014)
[8] Technical details about GLUE! are available in: `http://www.gsic.uva.es/glue` (Last visit: 9 May 2014)
[9] MeTAH - Modèles et Technologies pour l'Apprentissage Humain:`https://metah.imag.fr` (Last visit: 5 May 2014)
[10] ActionScript: `http://www.adobe.com/devnet/actionscript.html` (Last visit: 5 May 2014).

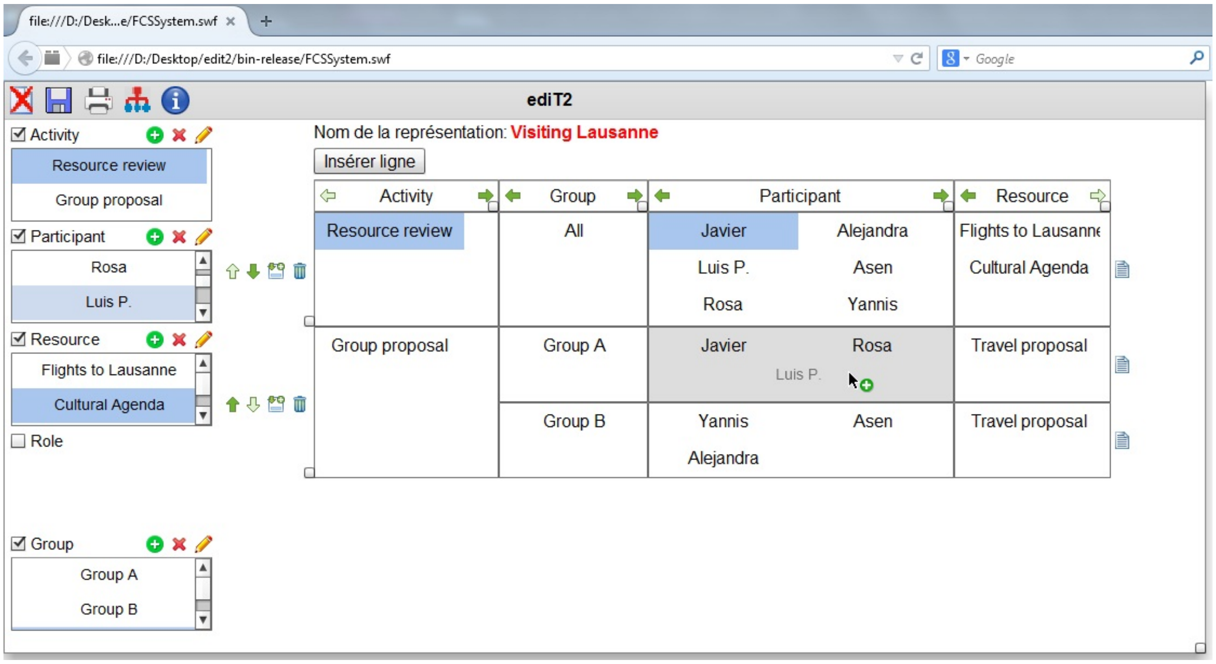


Figure 4.8: *EdiT2++*: screenshot of the design interface.

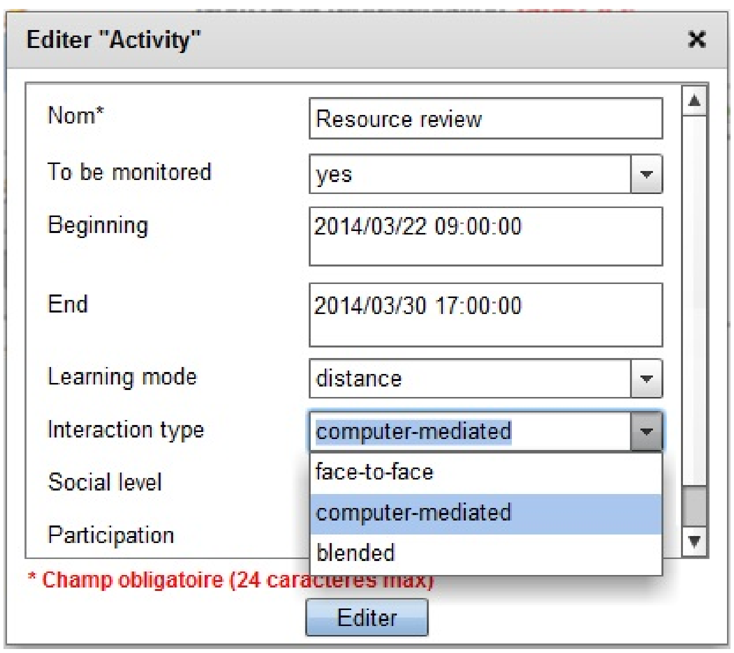


Figure 4.9: *EdiT2++*: form used for the description of a learning activity.

we were able to automatize the first cycle of the monitoring-aware design process. That is, we were able to collect the data from the design process (although the implementation currently does not offer monitoring feedback to the teacher yet). Figure 4.9 shows an example of form for the description of an activity compliant with the monitoring-aware scripting model.

Since this tool has been developed at the end of the PhD process, it has not been tested with teachers. However, we expect to use it in the near future, allowing teachers to carry out the design, instantiation and monitoring processes by themselves.

4.6.2 GLIMPSE

To support the script-aware monitoring process, we have developed *GLIMPSE* (Group Learning Interaction Monitor for Pedagogical Scripting Environments), a Java standalone tool that automatizes the first three steps of the monitoring process.

The input of this tool is a script obtained following the monitoring-aware design process of CSCL scripts. Since none of the existing authoring tools supports completely the design process proposed in this dissertation, *GLIMPSE* has been adapted to be able to take the information in two different files (see Figure 4.7): on the one hand, *GLIMPSE* takes the instantiated script as generated by GLUE!-PS (an XML file) and, on the other hand, the monitoring configuration of such script (another XML file generated manually or by means of EdiT2++). Then, *GLIMPSE* merges these files according to the monitoring-aware model of CSCL scripts, which provides the information required to execute the data gathering and analysis.

Based on the teachers decisions represented in the script (e.g., monitoring periods, participants involved in the learning process, activities and resources to be monitored, etc.), *GLIMPSE* carries out the first step of the script-aware monitoring process: in combination with the *GLUE!-CAS* prototype (see the following subsection), the tool collects the participants' actions and filters them according to the heuristics presented in Table 4.2. Once the evidence is gathered, the tool obtains the current state of the learning situation, using for that purpose the indicators shown in Table 4.3. Then, the desired state of the learning situation is obtained based on teacher's design decisions (such as learning mode, interaction type, expected use of resources or participation) as it is illustrated in Table 4.4. Finally, the tool compares the current with the desired state of the learning situation, and produces a monitoring report (in the form of an HTML web page). This monitoring report includes warnings that inform about those aspects of the desired state that are not satisfied by the current situation. An example of such a monitoring report is presented in Figure 4.10. These reports have been co-designed with the teachers involved in the exploratory studies, taking into account their feedback on how to improve the visualization, considering their needs in order to support the regulation tasks that the monitoring process might trigger.

GLIMPSE has been developed iteratively, especially during the second exploratory iteration. This prototype has also been used in the third (evaluative) iteration, as we will see in the following chapter.

Activity: Actividad 2.1 - Propuesta de proyecto de investigación-acción en grupo pequeño

- **Begining:** Tue May 07 16:00:00 CEST 2013
- **End:** Wed May 08 13:00:00 CEST 2013
- **Participation:** mandatory-individuals
- **Presenciality:** blended
- **Social level:** group

Groups	Participants	Informe del trabajo en grupo pequeño		Propuesta Individual (Estudiante 1)		Propuesta Individual (Estudiante 2)		Propuesta Individual (Estudiante 3)		Propuesta de grupo pequeño (Grupo pequeño 1)			Descripción de la Actividad: Propuesta de investigación-acción en grupo pequeño		Control de asistencia y participación				Warnings
		link	access	link	access	link	access	link	access	link	access	edition	link	access	link	attendance	submission	comment	
Grupo pequeño 1	Alberto		3		1		1		2		5			2		1			** There is no evidence of **Celina** using **Propuesta Individual (Estudiante 2)**. This resource must be used by each group member.
	Alvaro		3		0		1		1		6	5		2		1	1		** There is no evidence of **Alvaro** using **Propuesta Individual (Estudiante 1)**. This resource must be used by each group member.
	Celina		3		0		0		1		5			1		1			** There is no evidence of **Celina** using **Propuesta Individual (Estudiante 1)**. This resource must be used by each group member.

Figure 4.10: *GLIMPSE*: piece of monitoring report generated by the tool.

4.6.3 GLUE!-CAS

The *GLUE!-CAS* (Collaboration Analysis Support for GLUE!) prototype facilitates the data gathering and integration in DLEs created using the GLUE! architecture. *GLUE!-CAS* is implemented using Java, following the guidelines of the proposed architecture for data gathering and integration in DLEs (presented in Section 4.5). The current prototype (see Figure 4.11) includes adapters for MediaWiki, Google Applications, and tools that store their data according to the W3C Extended Log File Format[11] (e.g., GLUE!). Since this format is frequently used in RESTlet services, we expect that this last adapter will be reusable by other tools. In addition, to include in the monitoring process data provided by students and teachers, we created two additional adapters to collect and interpret the evidence gathered by them (via questionnaires, attendance registers, and observations). In the case of the data provided manually by teachers and students, we created ad-hoc Google Spreadsheet and Google Form files that helped them in this endeavour (see Figure 4.12). The adapters developed to gather these data were adapted to interpret the content of the files according to a specific template.

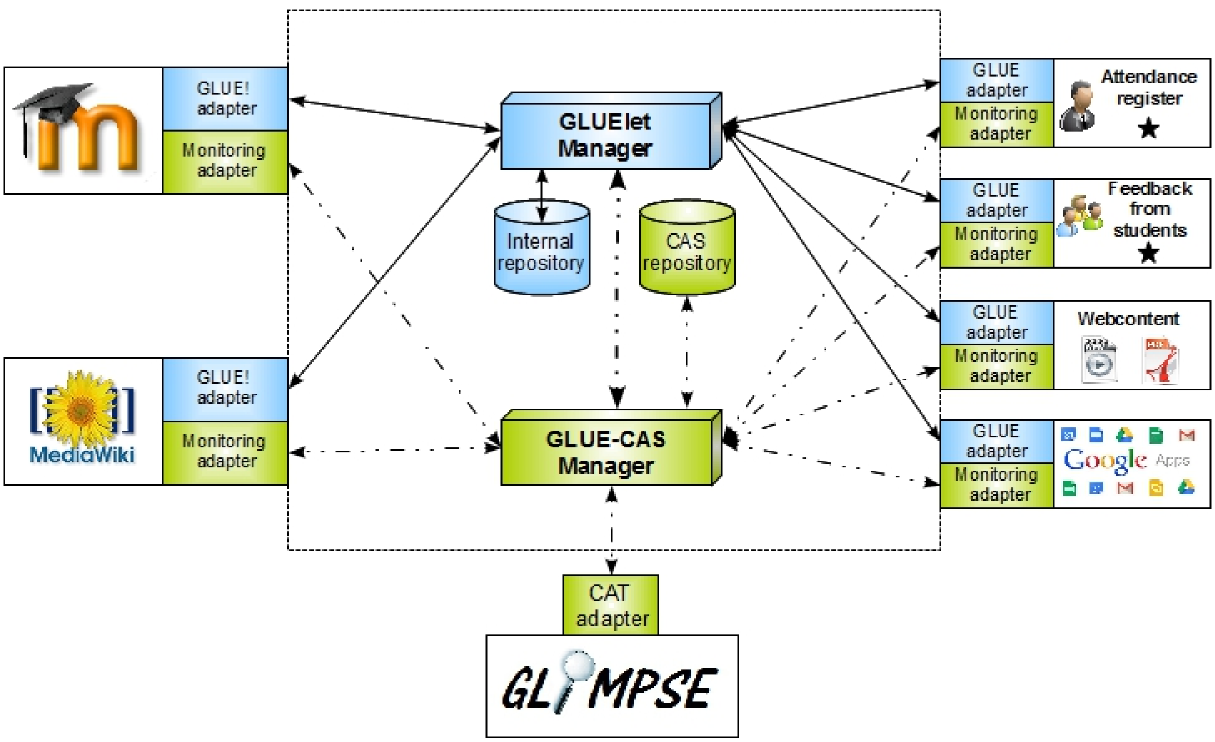


Figure 4.11: *GLUE!-CAS*: overview of the prototype and the existing adapters.

As it is shown in Figure 4.11, our proposal is compatible with GLUE!, which also follows an architectural design based on adapters. Since the data formats used in both architectures are also compliant, and GLUE! tool adapters often will coexist with GLUE-CAS tool monitoring adapters, both kinds of services could be merged into a single implementation.

GLUE!-CAS has been iteratively developed, starting during the second exploratory study, up until the fifth study. Afterwards, it has been used during the evaluative iteration studies to

[11]W3C Extended Log File Format:`http://www.w3.org/TR/WD-logfile.html` (Last visit: 10 May 2014)

support the automation of data gathering and integration, as it is described in the following chapter.

4.7 Conclusions

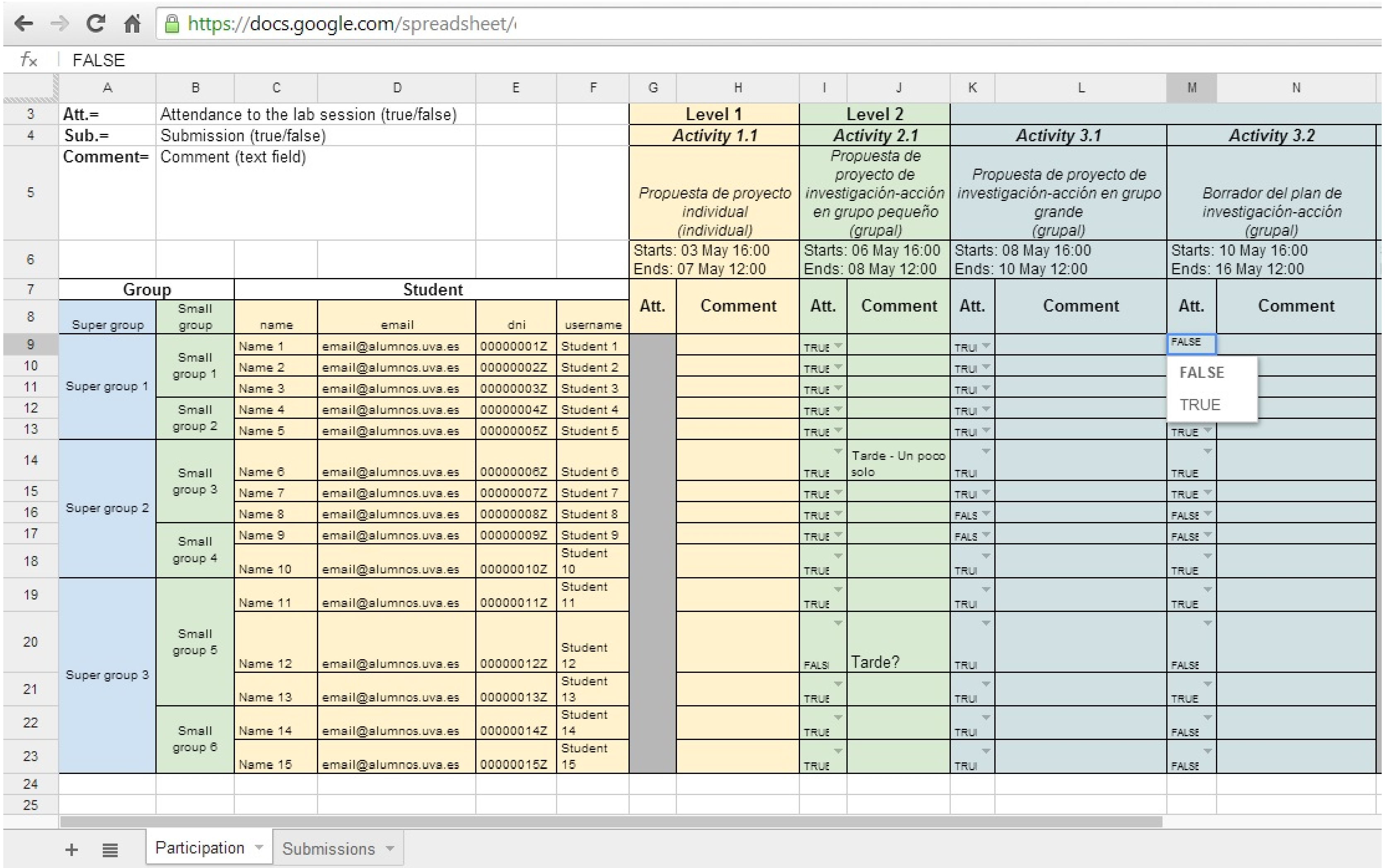
Based on our literature review (Chapter 2) and exploratory work (Chapter 3), this Chapter has presented four proposals that aim to address the main objective of this thesis, i.e., to provide teachers with design and enactment support capable of linking pedagogical intentions with monitoring needs for orchestrating blended CSCL scenarios supported by DLEs.

To support teachers to identify and include monitoring aspects throughout the design process of CSCL scenarios (OBJ_DES), we have proposed the monitoring-aware design process of CSCL scripts (C#1). With this design process we expect to overcome the problems that the lack of attention to monitoring issues often causes on the monitorable data. Part of this design process –its first cycle– may be supported by *EdiT2++*, an authoring tool adapted to collect teachers' monitoring-related decisions.

To provide teachers with awareness information about the evolution of the CSCL situation, in relation to their learning design decisions (OBJ_MON), we have formulated the script-aware monitoring process of CSCL scenarios (C#3). Following this process, we expect to inform teachers about the accomplishment of their design decisions, contributing to the detection and regulation of emerging eventualities during the course of the learning situation. To automate this monitoring process, we have developed *GLIMPSE*, a tool that monitors CSCL scenarios deployed by means of GLUE!-PS.

To enable the connection between the design and the monitoring process, we have defined the monitoring-aware model of CSCL scripts (C#2). This model describes the decisions to be made at design-time that will guide the monitoring process. And finally, to support the automation of the monitoring data gathering and integration tasks (OBJ_DAT), we have proposed an architecture for CSCL scenarios supported by DLEs (C#4), which deals with the heterogeneous and distributed nature of that technological environment. A prototype of this architecture, GLUE!-CAS, has been implemented for DLEs built using GLUE!.

In the following chapter we will evaluate these proposals in two authentic CSCL scenarios.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
3	Att.=	Attendance to the lab session (true/false)					Level 1		Level 2					
4	Sub.=	Submission (true/false)					Activity 1.1		Activity 2.1		Activity 3.1		Activity 3.2	
5	Comment=	Comment (text field)					Propuesta de proyecto individual (individual)		Propuesta de proyecto de investigación-acción en grupo pequeño (grupal)		Propuesta de proyecto de investigación-acción en grupo grande (grupal)		Borrador del plan de investigación-acción (grupal)	
6							Starts: 03 May 16:00 Ends: 07 May 12:00		Starts: 06 May 16:00 Ends: 08 May 12:00		Starts: 08 May 16:00 Ends: 10 May 12:00		Starts: 10 May 16:00 Ends: 16 May 12:00	
7	Group		Student				Att.	Comment	Att.	Comment	Att.	Comment	Att.	Comment
8	Super group	Small group	name	email	dni	username								
9	Super group 1	Small group 1	Name 1	email@alumnos.uva.es	00000001Z	Student 1			TRUE		TRUI		FALSE	
10			Name 2	email@alumnos.uva.es	00000002Z	Student 2			TRUE		TRUI			
11			Name 3	email@alumnos.uva.es	00000003Z	Student 3			TRUE		TRUI			
12		Small group 2	Name 4	email@alumnos.uva.es	00000004Z	Student 4			TRUE		TRUI			
13			Name 5	email@alumnos.uva.es	00000005Z	Student 5			TRUE		TRUI		TRUE	
14	Super group 2	Small group 3	Name 6	email@alumnos.uva.es	00000006Z	Student 6			TRUE	Tarde - Un poco solo	TRUI		TRUE	
15			Name 7	email@alumnos.uva.es	00000007Z	Student 7			TRUE		TRUI		TRUE	
16			Name 8	email@alumnos.uva.es	00000008Z	Student 8			TRUE		FALS		FALSE	
17		Small group 4	Name 9	email@alumnos.uva.es	00000009Z	Student 9			TRUE		FALS		FALSE	
18			Name 10	email@alumnos.uva.es	00000010Z	Student 10			TRUE		TRUI		TRUE	
19	Super group 3	Small group 5	Name 11	email@alumnos.uva.es	00000011Z	Student 11			TRUE		TRUI		TRUE	
20			Name 12	email@alumnos.uva.es	00000012Z	Student 12			FALSI	Tarde?	TRUI		FALSE	
21			Name 13	email@alumnos.uva.es	00000013Z	Student 13			TRUE		TRUI		TRUE	
22		Small group 6	Name 14	email@alumnos.uva.es	00000014Z	Student 14			TRUE		TRUI		FALSE	
23			Name 15	email@alumnos.uva.es	00000015Z	Student 15			TRUE		TRUI		FALSE	
24														
25														

Figure 4.12: Example of attendance and submission register used by the teachers.

Chapter 5

Evaluative iteration

Summary: This chapter delves into the evaluation of the proposals presented in the previous chapter. This evaluation is intended to assess whether the proposals meet the teachers requirements, and thus overcomes the limitations found in previous related works and in the exploratory iterations. This chapter explains the methodology that has been followed for the evaluation (guided by the CSCL-EREM evaluation framework), describes the authentic learning scenarios where the proposals were tested, and discusses findings that came out during the realization of the studies. Finally, the chapter wraps up the partial conclusions stated in each happening and combines them to enunciate the global conclusions of the evaluation.

The evaluation of the proposals, including the methodology employed and the two evaluative studies, will be published in [RT14].

5.1 Introduction

This thesis dissertation tackles the synergies and problems that emerge from the integration between scripting and monitoring in CSCL scenarios supported by DLEs. The problems that hinder the alignment between scripting and monitoring were discussed in Chapter 2 and the requirements that emerged from the exploratory iterations were presented in Chapter 3. These problems and requirements were distilled as guidelines for the formulation of the proposals detailed in Chapter 4. In order to complete the research work, our proposals towards the alignment of scripting and monitoring in CSCL DLEs must be evaluated.

According to the overall methodology followed in this dissertation (see Section 1.3), Design-Based Research [Bar04], the iterations that make up the research process address exploratory and evaluative purposes. In this thesis, while the first and second iterations pursued, mainly, exploratory purposes, the third iteration was devoted to assess whether the proposals meet the objectives they were designed for; that is to say, the compliance to the teachers' requirements and the overcoming of the limitations found in previous related works. This chapter focuses on the aforementioned evaluative iteration.

The design of the third iteration has been supported by the CSCL-EREM (Computer Supported Collaborative Learning Evaluand - oriented Responsive Evaluation Model) framework [JA09], which is especially indicated for the evaluation of CSCL strategies and tools. This framework has guided us in the definition of the evaluand, and in the formalization of the authentic studies [Dew01] aimed at assessing this evaluand. In the context of this thesis, the evaluation goal is to analyse whether the proposals presented in Chapter 4 support teachers in the orchestration of blended CSCL scenarios supported by DLEs. For this reason, the evaluands of the present evaluation are the monitoring-aware scripting model, the monitoring-aware design process of CSCL scripts, the script-aware monitoring process of CSCL scenarios, and the architecture for data gathering and integration.

The evaluation consists of *two happenings [JA09] carried out in authentic CSCL scenarios.* These scenarios presented different characteristics that made them good candidates for the evaluation of the proposal: the first one involved a *non-expert teacher on CSCL scenarios* and a *high number of students and resources*; the second one was led by an *expert teacher on CSCL scenarios*, previously involved in the exploratory studies, who proposed a *complex design, with many interrelated activities* occurring in a short period of time. Figure 5.1 frames the evaluation studies within the DBR-process followed in this dissertation.

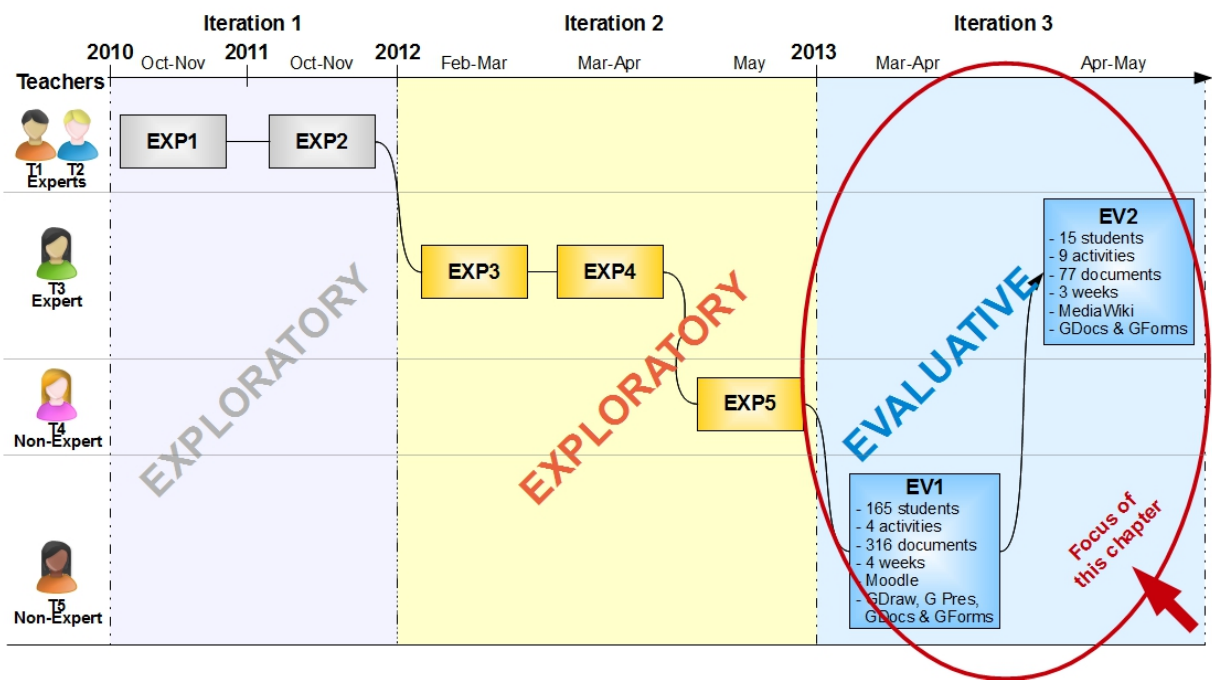


Figure 5.1: Overview of teachers and studies involved in the evaluative iteration.

Another important characteristic of the evaluation presented is the use of *mixed methods* [Gre01] [Cre03] that involve a variety of quantitative and qualitative techniques. This approach is generally considered to be an adequate way of exploring the different perspectives and multiple factors that affect learning situations, and it is typically used in DBR [And12][Des02] and CSCL [Str07] [Jeo10]. In addition, we have involved a variety of informants and data sources that provide multiple perspectives and allow for the triangulation of data and techniques, assuring the quality and creditibilty of the research [Gub81].

The rest of the chapter is structured as follows. Section 5.2 presents the evaluation framework and states the evaluation objectives. Then, Section 5.3 briefly describes the evaluative studies and presents the main findings obtained. Finally, Section 5.4 includes a discussion and the main conclusions stemming from the evaluation.

5.2 Evaluation methodology

5.2.1 Evaluation framework

Due to the intrinsic difficulty of evaluation itself and the complexity of CSCL scenarios, it is convenient to use a theoretical framework to guide the collection of evaluation data, its analysis and its interpretation. Specifically, the evaluation of this thesis dissertation follows the CSCL-EREM (Computer Supported Collaborative Learning Evaluand - oriented Responsive Evaluation Model), a framework proposed to guide researchers and practitioners in the formal evaluation of courses, resources, teaching strategies and software systems in CSCL settings [JA09]. Indeed, the CSCL-EREM has already been successfully employed in other PhD thesis related to CSCL (e.g., [VF10] [AH12] [MG12] [Pri12] [RC13]).

One of the distinctive characteristics of CSCL-EREM is that it is centred in the phenomena to be evaluated (*evaluand*) rather than in the field of expertise of the evaluators (e.g., social network analysis, didactics, etc). In the context of this thesis, the evaluation explores if the alignment between scripting and monitoring supports teachers in the orchestration of blended CSCL scenarios in DLEs, by assessing the proposals presented in Chapter 4. Therefore, this evaluation has a fourfold evaluand that includes the proposed monitoring-aware scripting model, the monitoring-aware design process of CSCL scripts, the script-aware monitoring process of CSCL scenarios, and the architecture for data gathering and integration in DLEs.

Around the evaluand concept, the framework structures the evaluation design into three different facets: *perspective* (why the evaluand is evaluated), covering the main goal pursued and other significant open questions; *ground* (where the evaluand is evaluated), gathering the information about the context and the participants; and *method* (how the evaluand is evaluated), indicating the data gathering techniques and the documents that support the conclusions. Figure 5.2 shows a generic representation of the CSCL-EREM framework including the evaluand (in the center of the figure) and the three different facets around the evaluand. This graphical representation has been obtained using the CSCL-EREM web tool[1].

The *perspective* facet is organized around the definition of *issues*. An issue can be understood as a troubling choice, a tension, an organizational perplexity or a problem. Four issues naturally arise from the objectives of the present evaluation. They are stated as follows:

- Issue 1 (I1): Does the monitoring-aware design process of CSCL scripts help teachers to align pedagogical and monitoring issues?
- Issue 2 (I2): Does the monitoring-aware model of CSCL scripts allow expressing the scripting and monitoring aspects required to guide the monitoring process?
- Issue 3 (I3): Does the script-aware monitoring process provide teachers with relevant information for the management of the CSCL scenario?

[1] CSCL-EREM web tool:`http://pandora.tel.uva.es/cscl-erem` (Last visit: 17 May 2014)

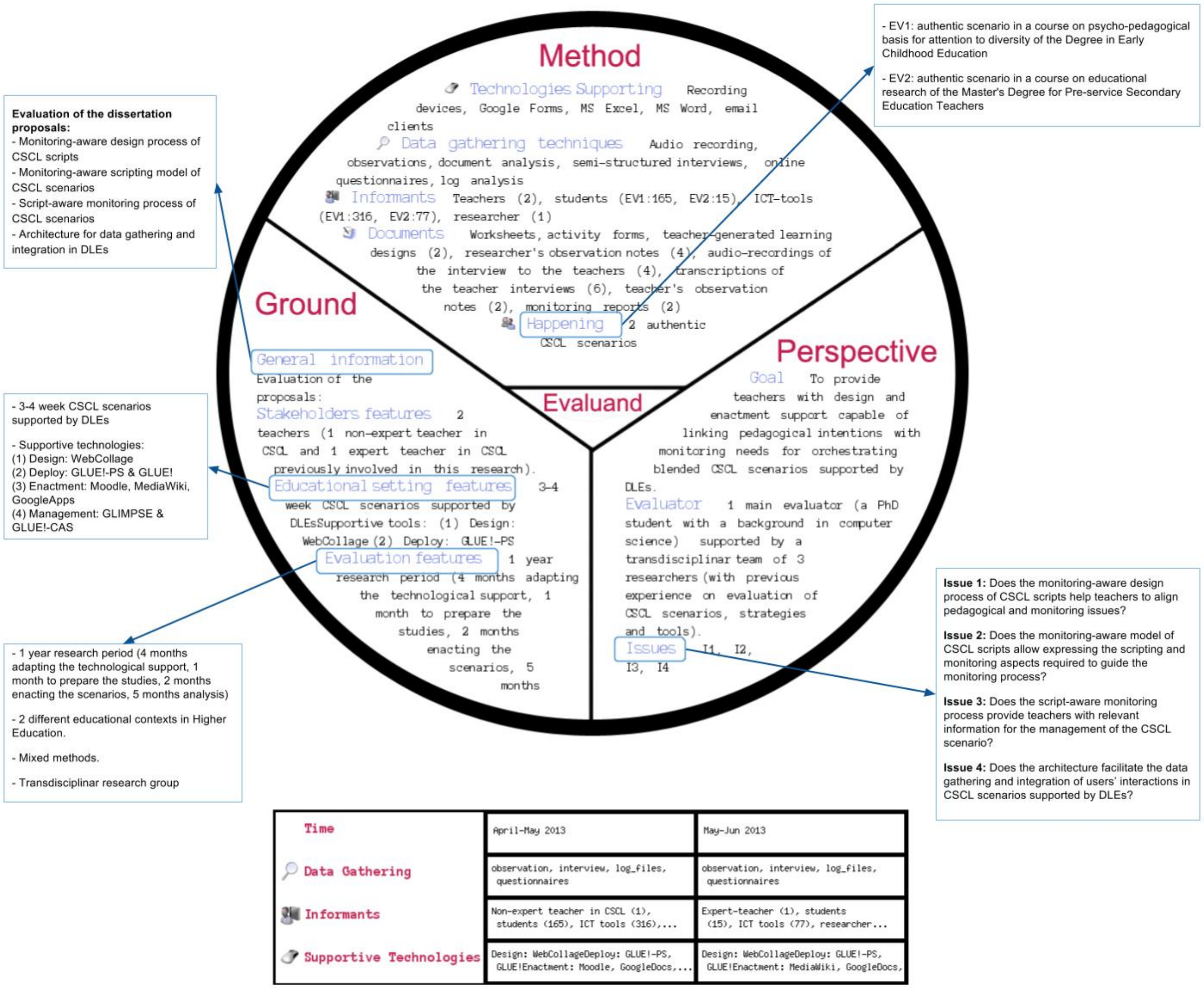


Figure 5.2: Graphical representation of this thesis evaluation design.

- Issue 4 (I4): Does the architecture facilitate the data gathering and integration of users' interactions in CSCL scenarios supported by DLEs?

With the aim of assessing the evaluand, two studies in authentic CSCL scenarios [Dew01] were defined. These studies were formalized using the CSCL-EREM, and involved real end-users, like educators and students as suggested in [Dew01]. This evaluation method follows an interpretive research perspective [Orl91] that does not pursue statistically significant results or generalizations. Rather, it aims to a deeper understanding of the concrete phenomena under study [Gub81], in our case, the orchestration support provided by the proposals for teachers performing blended CSCL scenarios in DLEs. Besides, application of the thesis proposals to authentic scenarios shows that they can be used by real educators and students to support learning activities, and allows to detect the benefits and limitations.

Finally, the CSCL-EREM highly encourages to use mixed data gathering techniques and multiple informants in order to obtain different perspectives about the evaluand, thus enriching the evaluation process. In this regard, the researcher is encouraged to gather and analyze data about the evaluand using a *mixed methods approach* [Gre01] [Cre03], which are commonly used in DBR [And12][Des02], TEL [Joh04] and CSCL research [Sut06] [Jeo10]. Specifically, this dissertation combines quantitative and qualitative data coming from four types of informants (2 teachers, 180 students, 1 researcher, and 2 DLEs) using different data gathering techniques such as questionnaires, interviews, logfile analysis, observations, audio recordings, and document analysis. Then, the evidence collected from different sources is comparatively analysed in a process called *triangulation* [Gub81], in order to reach the global conclusions of this evaluation, increasing the trustworthiness of the findings. The following section describes the connections between the aforementioned issues and the data gathered throughout the studies.

5.2.2 Data sources and evaluation goals

The aforementioned issues can be explored through informative questions grouped into several topics, both defined by us at the start of the evaluation, but also emergent while gathering and analysing data, in a "progressive in-focus" approach [Sta10]. These topics can be exemplified by the following questions:

Issue 1: *Does the monitoring-aware design process of CSCL scripts (MADP) help teachers to align pedagogical and monitoring issues?*

Topic 1 (teachers' background/experience). How do the participants' background and prior practice scripting CSCL affect their perception of the MADP? How do these factors affect the participants' perception of the MADP? Is the MADP compliant with the teacher's design previous practice?

Topic 2 (process's coherence). Is the MADP reasonable and understandable?

Topic 3 (process's pedagogical relevance). Are the monitoring decisions relevant for the pedagogical purposes? Does the MADP enrich/improve the CSCL script?

Topic 4 (impact on monitoring). Does the MADP help teachers better adapt the monitoring process? Does the MADP improve the monitoring results?

Topic 5 (teachers' effort). Does the MADP require an affordable effort (e.g., in terms of time, data required, ...)?

Topic 6 (process's perceived usefulness). Would teachers use the MADP in their practice? Would they recommend the MADP to other teachers?

Issue 2: *Does the monitoring-aware model of CSCL scripts (MAM) allow expressing the scripting and monitoring aspects required to guide the monitoring process?*

Topic 1 (model's expressiveness). Is the MAM expressive enough to describe the design decisions? Is the MAM able to represent all the dependences that appear in the design? Does the MAM provide the information required to launch the monitoring process?

Issue 3: *Does the script-aware monitoring process (SAMP) provide teachers with relevant information for the management of the CSCL scenario?*

Topic 1 (teachers' background). How does the teachers' background and prior practice in monitoring CSCL scenarios affect their perception of the SAMP?

Topic 2 (results' representativeness). Does the SAMP provide results that represent the real facts?

Topic 3 (results' novelty and relevance). Does the SAMP provide awareness information unnoticed by the teacher? Does the SAMP provide teachers with relevant information for the orchestration purposes (regulation, assessment, ...)?

Topic 4 (teachers' effort). Does the SAMP reduce the time required to manage the learning scenario?

Topic 5 (process's perceived usefulness). Would teachers use the SAMP in their practice? Would they recommend the SAMP to other teachers?

Issue 4: *Does the architecture facilitate the data gathering and integration of users' actions in CSCL scenarios supported by DLEs?*

Topic 1 (impact on the design process). Does the architecture provide teachers with relevant information for the design process?

Topic 2 (data gathering). Does the architecture allow the data gathering of the user' actions registered in the learning scenario? Is the architecture flexible enough to conform to the data sources (teachers/students/ICT tools) restrictions?

Topic 3 (data gathering and integration time cost). Is the time required to gather and integrate the data acceptable for teachers?

Each of these topics is in turn informed by several informative questions that try to probe for information. This conceptual organization of the data from the evaluation is adapted from the anticipated data reduction procedure typically used in qualitative data analysis [Mil94].

During the evaluation, a profuse set of data gathering techniques and data sources were used to address the aforementioned issues and topics. Figure 5.3 presents an overview of the two studies, showing the data sources, the moments when the evidence was collected, and the issues that they aim to answer. The data sources have been classified according to the informant: namely, teachers, researcher, students, and ICT tools. We followed the same schema of data gathering in both studies: an initial interview to the teachers [EV(i)_T_INT1], before the design phase, dealing with their usual CSCL design and management practices; the researcher's observations during the design process [EV(i)_R_OBS1] where she controlled the time devoted by the teachers and registered their doubts; teacher-generated artefacts such as the designs of the CSCL scenarios (e.g., activity forms, and computational representations of the designs in the authoring and deployment tools)[EV(i)_TR_LD]; a second interview to the teachers, after the design phase, to gather their impressions regarding the monitoring-aware design process and model [EV(i)_T_INT2]; the teachers' observations during the enactment [EV(i)_T_OBS], where they daily annotated all the eventualities that emerged during the learning scenarios, expressed their expectations about the monitoring reports before checking them, and registered the errors

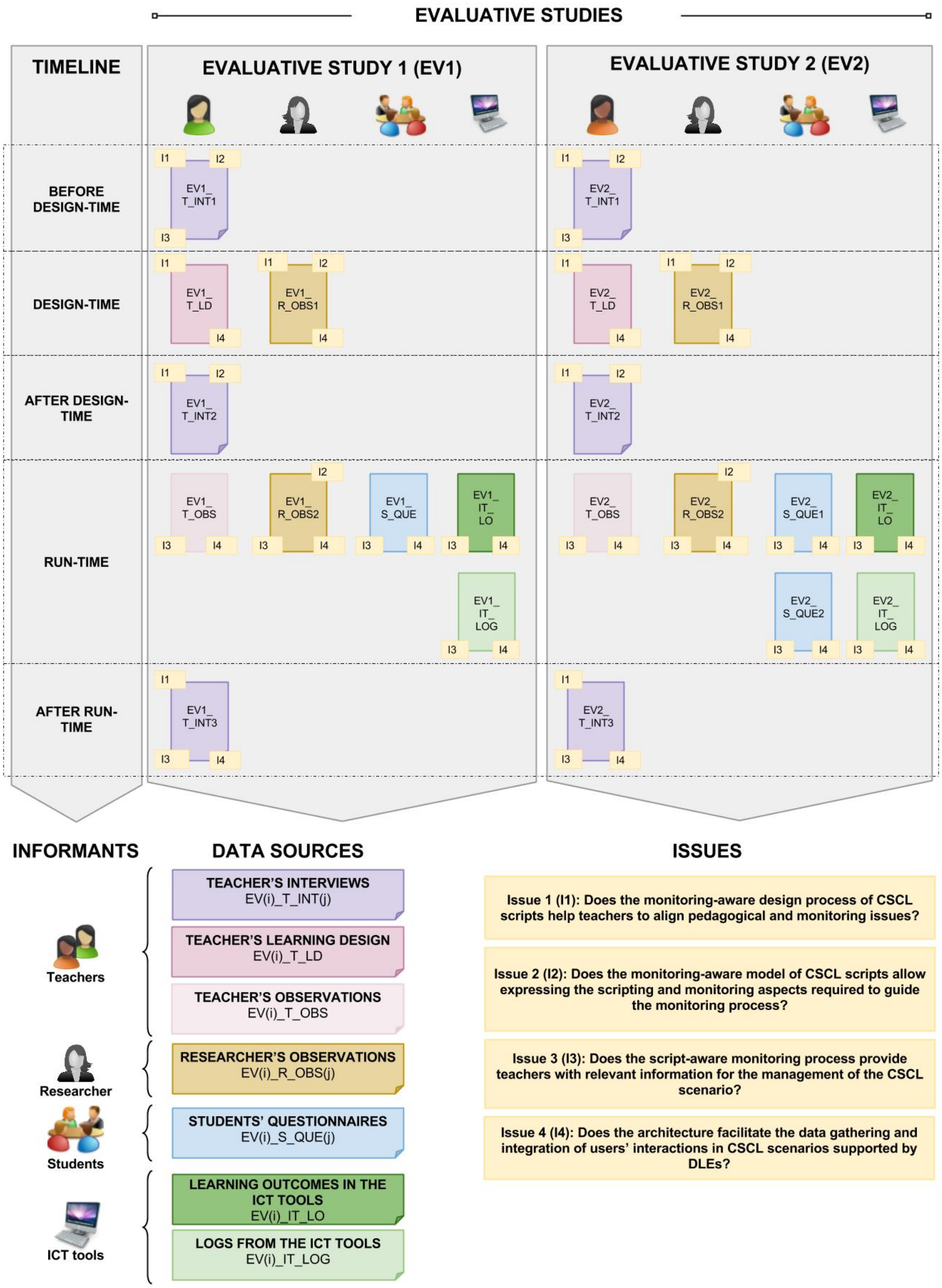


Figure 5.3: Connections between evaluative studies, evaluative questions and data sources

detected; the logs from the ICT tools [EXP(i)_IT_LOG] and the learning outcomes generated by the students in the DLE [EXP(i)_IT_LO]; the researcher's observations during the enactment [EV(i)_R_OBS2], where she registered the time devoted to carry out the monitoring process, the problems detected during the enactment, and the changes made in the design (e.g., delays in the activities, changes in the learning type); the questionnaires answered by the students about their participation in the learning activities [EV(i)_S_QUE1][EV(i)_S_QUE2]; and, finally, a third interview to the teachers, at the end of each learning scenario, to collect their opinions on the script-aware monitoring process, and to evaluate the proposals as a whole [EV(i)_T_INT3]. Figure 5.3 indicates the labels used to refer to data sources throughout the text. The evaluation happenings and the findings are described in the following section.

5.3 Evaluative studies

The evaluative studies involved two teachers (T3 and T5 in Figure 5.1). These teachers have different backgrounds (computer science and pedagogy), different levels of expertise in CSCL scenarios, and different knowledge about the proposal (one was involved during the exploratory iterations, one was novice). Besides, the studies were focused on two learning scenarios with a common profile: 3-4 weeks, CSCL scenarios supported by DLES, interleaving blended learning and blended interactions among students. Figure 5.1 describes the scenarios in terms of number of students, activities and resources, as well as the tools that made up the DLE.

The first evaluative study (EV1 in Figures 5.1 and 5.3) was carried out during March and April 2013 in a course on psycho-pedagogical basis for attention to diversity of the "Degree in Early Childhood Education", involving a non-expert teacher on CSCL scenarios, *Elena*[2], and 150 students (out of 165 students enrolled in the course). The learning scenario lasted 4 weeks and consisted of various distance and face-to-face activities combining individual and collaborative work. The purpose of these activities was to help students understand the Spanish educational legislation on disabilities. To support the learning activities, the students used Moodle and Google applications, summing up a total of 316 resources. The main challenge of this scenario was to cope with the high number of students and resources.

The second evaluative study (EV2 in Figures 5.1 and 5.3) took place from April to May 2013 in a course on educational research belonging to the "Master's Degree for Pre-service Secondary Education Teachers". An expert teacher on CSCL scenarios (*Julia*[3]), who participated in the exploratory studies, and 15 students were involved in this study. Over a period of 3 weeks the students worked on the definition of a proposal of an educational research project, combining individual, group and class-wide activities, as well as face-to-face and distance learning. The learning process was technologically supported by means of MediaWiki and Google applications, requiring a total amount of 77 files. The main difficulty of this scenario was the complexity of the design: there were many interrelated learning activities occurring in a short period of time, demanding much attention from the teacher to avoid problems that could jeopardize the scenario.

Figure 5.4 shows the workflow followed throughout the evaluative studies. In both cases we proceeded in the same way:

[2]To preserve teachers' and students' anonymity, we have modified their names.

[3]As we did in the third and fourth exploratory studies, the teacher will be renamed *Julia* and the students' name will be substituted by *Student1* to *Student15* to keep their identity anonymous.

- At design-time, we provided the teachers with worksheets and forms. The worksheets guided them throughout the *monitoring-aware design process*, and the forms helped them specify the information required by the *monitoring-aware model of CSCL scripts*. The design of the learning scenario consisted of two sessions, corresponding to the two cycles of the design process. Then, we used *WebCollage* to create a computational representation of the CSCL script, *GLUE!-PS* to deploy the design into the VLE, and *GLUE!* to integrate the third-party tools into the VLE. Finally, the author manually transformed the forms filled in by the teachers into a XML representation.

- During the enactment, the scripts were put into practice and, throughout the different activities, we provided teachers with monitoring reports to help them with the awareness and later regulation of the learning scenarios. These reports were obtained following the *script-aware monitoring process*, using *GLIMPSE* and *GLUE!-CAS* prototypes (see Section 4.6.2 and Section 4.6.3) to automate the data gathering, integration and analysis tasks.

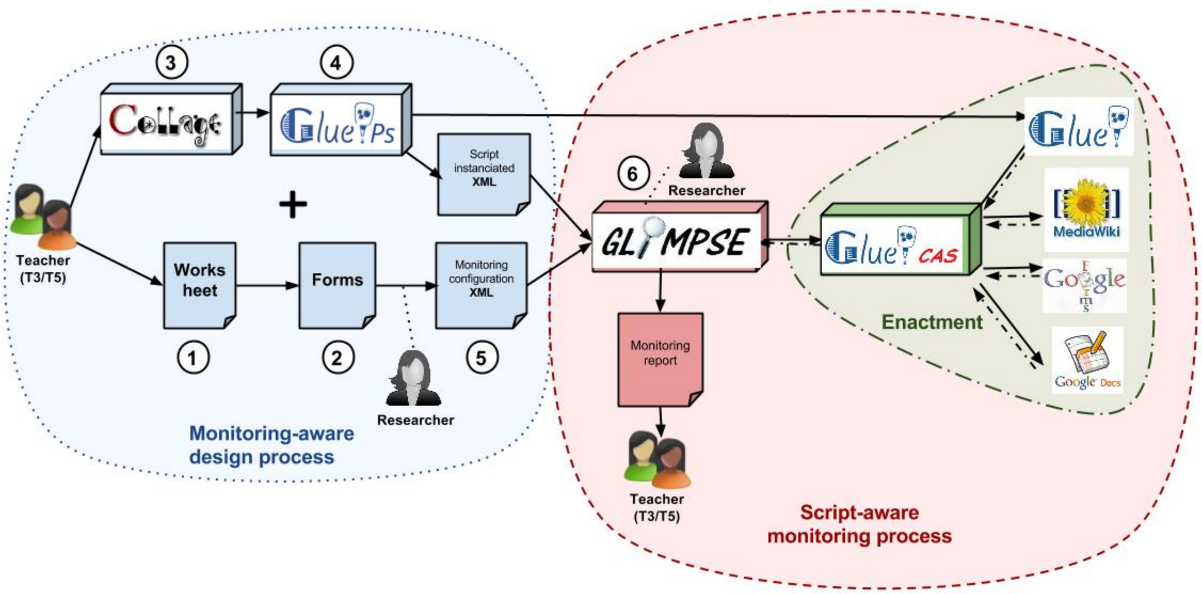


Figure 5.4: Overview of the workflow and tools used in the evaluative studies.

The following subsections provide a brief description of the design and enactment of the CSCL scenarios to introduce the reader to the studies carried out. Then the section summarizes the main findings obtained.

5.3.1 Description of the first evaluative study (EV1)

Elena designed the learning scenario following the *monitoring-aware design process of CSCL scripts* in two sessions. The first session took her 55 minutes and was devoted to the first cycle of the design process. Figure 5.5a shows an example of an activity form filled in by the teacher. After this session, the researcher obtained the list of constraints and verified whether there was enough monitorable evidence to inform about the accomplishment of each constraint. Simulating an automated process, this analysis was included in the activity forms (see Figure 5.5b). Then, in a second session of 30 minutes, Elena, based on the researcher's analysis, faced the second cycle of the design process, including new data gathering and monitoring support activities to enhance the monitoring process. The main decisions made in the two cycles of the design process are summarised in Table 5.1).

Table 5.1: First evaluative study: overview of the activities included in the script. Italicised text is used for the elements that were added in the second cycle of the study in order to improve the monitoring process.

Phase	**Activity**	**Social level**	**Interaction**	**Learning**	**Resources & tools for learners**	**Teacher's monitoring support activities**
Individual phase	1.1 Individual analysis of a subset of laws	Individual	Computer-mediated	Distance	- Reference materials (6 PDFs)	- Check monitoring report
	1.2 Individual synthesis	Individual	Computer-mediated	Distance	- Individual reports (150 GPres)	- Check monitoring report
Expert phase	2.1 Group discussion & synthesis of a subset of laws	Expert groups	Blended	Blended	- Shared documents (60 GDocs) - Concept maps (60 GDrawings)	- Check monitoring report ***- Control attendance***
Jigsaw phase	3.1 General review of laws	Jigsaw groups	Blended	Blended	- Group reviews (23 GDocs) ***- Workgroup report (23 GForms)***	- Check monitoring report ***- Control attendance***
					TOTAL= 316 instances	

The learning design combined some ideas of the *Pyramid* and the *Jigsaw* CLFPs [HL10a]. In the first activity, students reviewed individually some documents dealing with a subset of Spanish educational laws on disabilities. The laws to be reviewed were split into 6 subsets, and each student had one subset assigned to work on it. Then in the second activity, they prepared an individual synthesis about the reviewed laws. In the third activity, students joined in *expert groups* of 2-to-3 people who had been working on the same subset of laws. At this stage, students shared their points of view about the laws reviewed and created, collaboratively, a concept map with the main ideas. Finally, students were redistributed in *jigsaw groups*, composed of at least 6 people, each one expert on a different subset of laws. The jigsaw group members shared their knowledge on the different legislation subsets and elaborated a report with the main ideas of each law as well as the conclusions extracted by the group.

To illustrate how the teacher used the activity forms, we describe the design of the *Activity 2.1 Group discussion and synthesis*. First, Elena provided the general details of the activity (see section "general activity description" in Figure 5.5a). The teacher planned to carry out this activity between May 15th (at 8 a.m.) and May 20th (at 12:00 p.m.), and she considered useful to receive a monitoring report after the deadline (at 12:15 p.m.). This activity entailed blended interaction between students and blended learning but, as Elena specified in the activity form, most of it was face-to-face. Besides, the teacher specified that, even though the activity had

GENERAL ACTIVITY DESCRIPTION			
Activity name:	Group discussion and synthesis		
Phase name or number:	2 (Experts)	**Sequence order:**	2.1
Beginning: (YYYY-MM-DD hh:mm:ss)	2013-04-15 08:00:00	**End:** (YYYY-MM-DD hh:mm:ss)	2013-04-20 12:00:00
Enable monitoring: (yes / no)	Yes	**Monitoring dates:** (YYYY-MM-DD hh:mm:ss)	2013-04-20 12:15:00
Learning mode: (Face-to-face / Distance / Blended)	Both (mainly face-to-face)	**People involved in the activity:** (Number of students, teachers, observers, others)	- 165 students - 1 teacher
Participation: (Optional / Mandatory for individuals / Mandatory for groups)	Mandatory for individuals	**Social level:** (Individual / By groups / Whole class)	By groups
Technological support for the learning tasks: (Total / Partial /No support)	Total	**Interaction type:** (Face-to-face / Computer mediated / Blended)	Blended

GROUP FORMATION			
Does this group formation join groups from a previous activity because interaction should happen? (yes / no)		no	
If there's any dependence with groups conformed in a previous activity, specify which activity:			
Group name:	Expert group on topic A1(a)	**Participants:**	Student1, Student9, Student11
Group name:	Expert group on topic A2(a)	**Participants:**	Student3, Student6
Group name:	Expert group on topic A3(a)	**Participants:**	Student2, Student7
Group name:	Expert group on topic A4(a)	**Participants:**	Student5, Student12
Group name:	Expert group on topic B(a)	**Participants:**	Student4, Student13
Group name:	Expert group on topic C (a)	**Participants:**	Student8, Student10
Group name:	[…]	**Participants:**	[…]

ICT TOOLS & ADDITIONAL DATA SOURCES						
Resource name	**Tool name**	**Resource reused from previous activities**		**Expected use from participants**		**Actions to be monitored** (see attached table)
		(yes / no)	If reused from which activities	(optional / mandatory)	(individual / by groups)	
Shared document	GDocs	No	--	optional	individual	User's accesses to the documents and group's editions
Concept map	GDraw	No	--	mandatory	by groups	User's accesses to the documents and group's editions
Teacher's observations	*Teacher's observations*	--	--	--	--	*Student's attendance to the lab sessions and other comments*

(a) Information provided by the teacher.

Monitorable data available for each constraint after the first design cycle V = Relevant evidence P = Partial evidence X = No evidence		
Activity constraints: (Derived from the analysis of the activity features)	1. *Individual participation:* all participants must be involved in the activity	P
	2. *Social level: t*here must be enough students involved in the activity to ensure collaboration	P
	3. *Expected use of resources:* every group member must use the resource "Shared document"	V
	4. *Expected use of resources:* every group must use the resource "Concept map"	V
Flow constraints: (group dependences, reused resources, etc,)	5. *Group formation policies:* There must be enough students involved in the activity to ensure the group formation in Activity 3.1	P
	6. *Resource reuse:* the resource "Concept map" will be reused in Activity 3.1	V
Warnings related to the constraints to be monitored	1. *Individual participation:* students participation is mandatory, and they can participate face-to-face and or by means of the technological support. However, the current configuration of the activity only provides evidence of computer-mediated interactions. 2. *Social level:* there must be at least two people involved in each expert-group to ensure collaboration, and they can interact face-to-face and or by means of the technological support. However, the current configuration of the activity only provides evidence of computer mediated interactions. 3. -- 4. -- 5. *Group formation policies:* There must be enough students involved in the activity to ensure the group formation in Activity 3.1, and they can interact face-to-face and or by means of the technological support. However, the current configuration of the activity only provides evidence of computer mediated interactions. 6. --	
How to enhance monitoring:	- **Additional data sources:** The data sources used for monitoring this activity are reduced to part of the technological support (GDocs and GDraw). If you need additional information, you could obtain it from the VLE (Moodle) or from the people involved in the activity (students and teacher). - **Learning mode and Students interactions:** This activity is carried out mainly face-to-face during class session, combining face-to-face and computer mediated interactions. However the evidence gathered from the learning scenario come exclusively from the technological support. Thus, the monitoring results may not be significant.	

Monitorable data available for each constraint after the second design cycle V = Relevant evidence P = Partial evidence X = No evidence		
Activity constraints: (Derived from the analysis of the activity features)	1. *Individual participation:* all participants must be involved in the activity	V
	2. *Social level: t*here must be enough students involved in the activity to ensure collaboration	V
	3. *Expected use of resources:* every group member must use the resource "Shared document"	V
	4. *Expected use of resources:* every group must use the resource "Concept map"	V
Flow constraints: (group dependences, reused resources, etc,)	5. *Group formation policies:* There must be enough students involved in the activity to ensure the group formation in Activity 3.1	V
	6. *Resource reuse:* the resource "Concept map" will be reused in Activity 3.1	V
Warnings related to the constraints to be monitored		
How to enhance monitoring:		

(b) Feedback given to the teacher.

Figure 5.5: First evaluative study: Activity form used during the design process of *Activity 2.1 Group discussion and synthesis*. Red text in italics represents the changes included by the teacher during the second cycle of the design process.

to be done by groups, the participation was mandatory for every student. Then Elena chose the tools that supported the activity: a Google Document, where each student could add her synthesis from the previous activity, and a Google Drawing, where the group created the concept map. Besides, the teacher picked out among the monitorable actions the ones relevant for her monitoring purposes.

During the second cycle, Elena reviewed the feedback provided by the researcher (see section "monitorable data available for each constraint after the first design cycle " in Figure 5.5a). This review led her to the enrichment of the learning design with new activities and resources (see italicised text in Table 5.1). Focusing on the activity *Group discussion and synthesis*, there were several constraints to be informed related to the individual participation, the social level, the expected use of resources, and the activity flow. Although the initial configuration of the activity provided evidence on the computer-mediated students' interactions, there was no data source about face-to-face interactions (necessary to inform about the individual participation, the social level, and the group formation constraints). Therefore, the teacher decided to control the attendance to the lab sessions and included some comments from her observations (see red italicised row in section "ICT tools and additional data sources", Figure 5.5a). Due to the changes made in the second cycle, there was relevant evidence to inform about the accomplishment of the script constraints, as it is shown in Figure 5.5b.

The script was put into practice in the context previously described, and throughout the different activities we provided Elena with monitoring reports. To obtain the data analysis we used the *GLIMPSE* and *GLUE!-CAS* prototypes (see Section 4.6.2 and Section 4.6.3). By means of the script and the activity forms the *GLIMPSE* prototype automated the analysis process. First, based on the activity description (time-frames, participants, resources, and actions to be monitored), *GLIMPSE* launched the data gathering, using *GLUE!-CAS* to collect the participants' actions from the different data sources. Then, *GLIMPSE* analysed the collected evidence, taking into account the indicators and conditions obtained from the script constraints, and generated the monitoring reports[4] that were sent to the teacher in the moments that she had planned.

In most cases, the monitored reports helped Elena confirm that the students were following properly the script. As it is shown in Table 5.2, out of the 1217 evaluated conditions, 1176 (96,63%) were consistent with what was defined in the script, while the other 41 (3,37%) pointed out to potential problems. Based on these problems, Elena reviewed the learning outcomes in the DLE and, when necessary, contacted the students to be aware of the reasons that caused the problem and to find a solution.

Figure 5.6 displays the monitoring report sent to the teacher at the end of *Activity 2.1 Group discussion and synthesis* (just 12 groups have been included for space reasons). On the one hand, dealing with the participants (rows), cells coloured in green point out that there is evidence of student or group participation. Regarding the resources (columns), green cells represent that there is evidence of use. On the other hand, red cells highlight that there is no evidence supporting the teacher's expectations (about the students involvement or the use of resources). As it can be seen in this figure, no action was registered in the concept map shared by *Student4* and *Student13.* This situation triggered an additional problem in the following activity:

[4]An anonimized version of the monitoring reports is available in the additional material attached to this document. See Appendix H.

Table 5.2: First evaluative study: activity and flow constraints obtained from the script description.

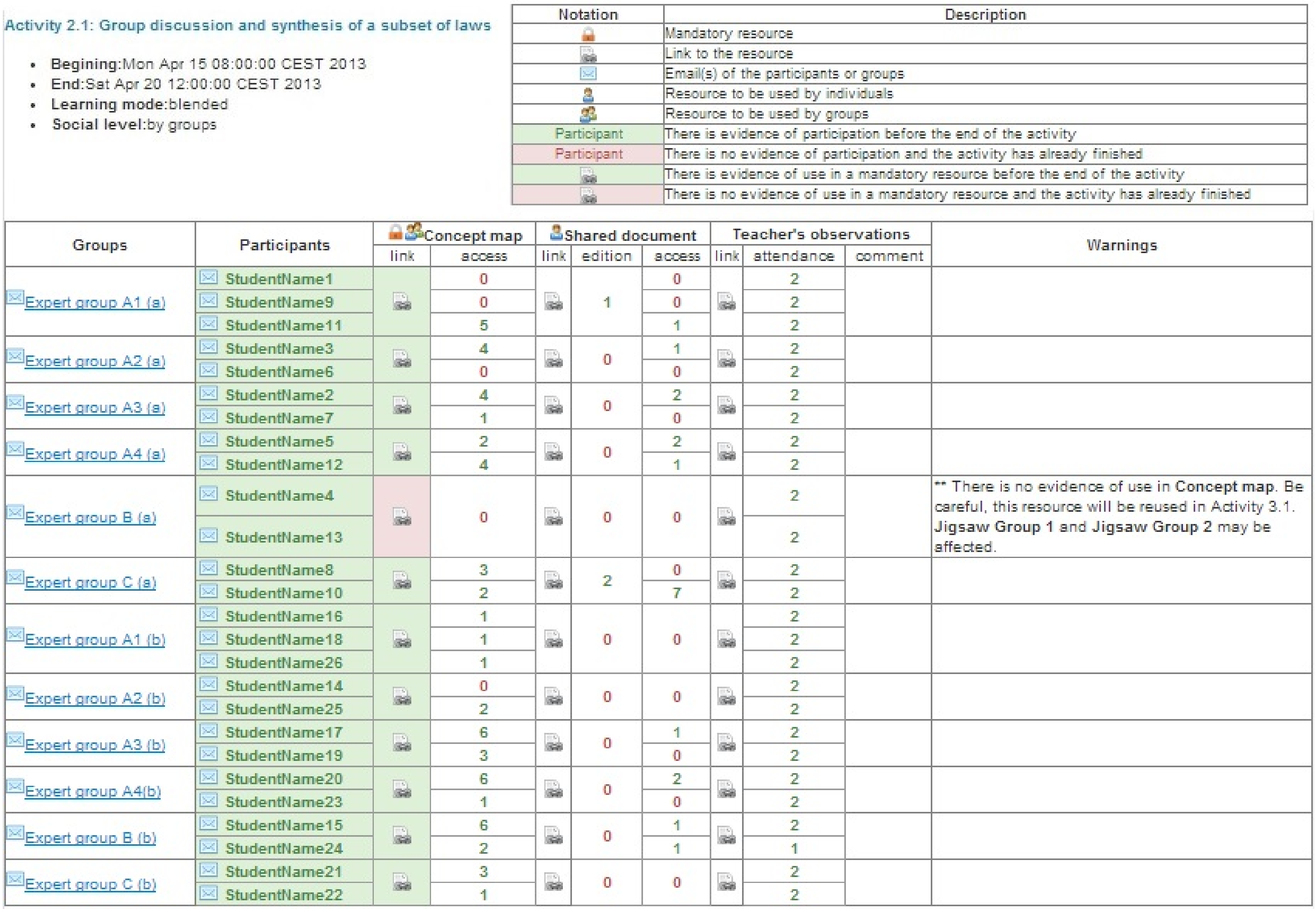
Activity	Constraint type	Constraint description	Elements evaluated	Problems detected
Activity 1.1 Individual analysis of a subset of laws	Activity	A.1) Participation: Each student has to participate	150 students	3
	Activity	A.2) Expected use of resources: Each student has to access to his/her subset of laws	6 resources	0
	Flow	F.1) Group formation: There must be enough students involved to maintain the expert groups	60 groups	2
	Flow	F.2) Group formation: There must be enough students involved to maintain the jigsaw groups	23 groups	3
Activity 1.2 Individual synthesis	Activity	A.1) Participation: Each student has to participate	150 students	0
	Activity	A.2) Expected use of resources: Each student has to access and edit his/her synthesis	150 resources	2
	Flow	F.1) Group formation: There must be enough students involved to maintain the expert groups	60 groups	0
	Flow	F.2) Group formation: There must be enough students involved to maintain the jigsaw groups	23 groups	1
	Flow	F.3) Resource dependence: The students' synthesis must be available to be used by the expert groups in Activity 2.1	60 groups	0
Activity 2.1 Group discussion and synthesis of a subset of laws	Activity	A.1) Participation: Each student has to participate	150 groups	1
	Activity	A.2) Expected use of resources: Each group has to use the concept map (Google Drawing)	60 resources	1
	Activity	A.3) Social level: The must be at least two students involved in each group	60 groups	0
	Flow	F.1) Group formation: There must be enough students involved to maintain the jigsaw groups	23 groups	0
	Flow	F.2) Resource dependence: There must be a concept maps about each law subset available for each jigsaw group in Activity 3.1	23 groups	1
Activity 3.1 General review of laws	Activity	A.1) Participation: Each student has to participate	150 groups	2
	Activity	A.2) Expected use of resources: Each group has to use the group review (Google Documents)	23 resources	0
	Activity	A.3) Expected use of resources: Each group has to use the workgroup report (Google Forms)	23 resources	23
	Flow	F.1) Group formation: There must be enough experts involved to maintain the jigsaw groups	23 groups	2
		TOTAL:	**1217**	**41**

if this situation continued, *Jigsaw Group 1* and *Jigsaw Group 2* would not have a concept map -dealing with the subset of laws 'B'. These problems were visualized in the report by means of the red cell corresponding to Student 4 and Student 13, and the warning that appears on the right hand side of the table.

5.3.2 Description of the second evaluative study (EV2)

Julia designed the learning scenario in two sessions, one for each cycle of the design process, that lasted altogether around 105 minutes (90 minutes for the first cycle and 15 minutes for the second cycle). In the first cycle, the teacher, guided by the worksheet, designed the learning scenario and filled out the activity forms with the monitoring configuration (Figure 5.7a shows an example of activity form). Then, the researcher analysed the constraints of the design and introduced them in the activity forms. With this information, the teacher faced the second cycle, where she included new data gathering and monitoring support activities in the scenario. Table 5.3 summarizes the main decisions made in both cycles.

This course followed a project-based learning strategy, where the students had to define in groups an educational research project, based on the principles of Action Research [Sus78].



Activity 2.1: Group discussion and synthesis of a subset of laws

- **Begining:**Mon Apr 15 08:00:00 CEST 2013
- **End:**Sat Apr 20 12:00:00 CEST 2013
- **Learning mode:**blended
- **Social level:**by groups

Notation	Description
	Mandatory resource
	Link to the resource
	Email(s) of the participants or groups
	Resource to be used by individuals
	Resource to be used by groups
Participant	There is evidence of participation before the end of the activity
Participant	There is no evidence of participation and the activity has already finished
	There is evidence of use in a mandatory resource before the end of the activity
	There is no evidence of use in a mandatory resource and the activity has already finished

Groups	Participants	Concept map		Shared document			Teacher's observations			Warnings
		link	access	link	edition	access	link	attendance	comment	
Expert group A1 (a)	StudentName1		0		1	0		2		
	StudentName9		0			0		2		
	StudentName11		5			1		2		
Expert group A2 (a)	StudentName3		4		0	1		2		
	StudentName6		0			0		2		
Expert group A3 (a)	StudentName2		4		0	2		2		
	StudentName7		1			0		2		
Expert group A4 (a)	StudentName5		2		0	2		2		
	StudentName12		4			1		2		
Expert group B (a)	StudentName4		0		0	0		2		** There is no evidence of use in **Concept map**. Be careful, this resource will be reused in Activity 3.1. **Jigsaw Group 1** and **Jigsaw Group 2** may be affected.
	StudentName13							2		
Expert group C (a)	StudentName8		3		2	0		2		
	StudentName10		2			7		2		
Expert group A1 (b)	StudentName16		1		0	0		2		
	StudentName18		1					2		
	StudentName26		1					2		
Expert group A2 (b)	StudentName14		0		0	0		2		
	StudentName25		2					2		
Expert group A3 (b)	StudentName17		6		0	1		2		
	StudentName19		3			0		2		
Expert group A4(b)	StudentName20		6		0	2		2		
	StudentName23		1			0		2		
Expert group B (b)	StudentName15		6		0	1		2		
	StudentName24		2			1		1		
Expert group C (b)	StudentName21		3		0	0		2		
	StudentName22		1					2		

Figure 5.6: First evaluative study: monitoring report sent to the teacher at the end of *Activity 2.1 Group discussion and synthesis*.

Table 5.3: Second evaluative study: overview of the activities included in the script. Italicised text is used for the elements that were added in the second cycle of the study in order to improve the monitoring process.

Phase	Activity	Social level	Interaction	Learning	Resources & tools for learners	Teacher's monitoring support activities
Level 1	1.1 Individual research proposal	Individual	Computer-mediated	Distance	- 15 Individual proposals (1 Google Docs/student) - Activity description (1 Online document)	- Check monitoring report ***- Control submission***
Level 2	2.1 Initial research proposal	Small groups	Blended	Blended	- 6 Small group proposals (1 Google Docs/small group) - 15 Individual proposals (1 Google Docs/student) ***- Workgroup report (1 Google Forms)*** - Activity description (1 Online document)	- Check monitoring report ***- Control attendance*** ***- Control submission***
Level 3	3.1 Final research proposal	Super-groups	Blended	Blended	- 3 Final research proposal (1 Google Docs/super-group) - 6 Small group proposals (1 Google Docs/small group) - Activity description (1 Online document)	- Check monitoring report ***- Control attendance*** ***- Control submission***
	3.2 Development of the research plan	Super-groups	Blended	Distance	- 3 Final research proposal (1 Google Docs/super group) - Activity description (1 Online document)	- Check monitoring report ***- Control submissions***
	3.3 Peer review	Individual	Computer-mediated	Distance	- 3 Reviews (1 wiki page/super group) - 3 Final research proposal (1 Google Docs/super group) - Activity description (1 Online document)	- Check monitoring report ***- Control submissions***
	3.4 Answer to the reviewers	Super-groups	Blended	Blended	- 3 Reviews (1 wiki page/super group) - 3 Final research proposal (1 Google Docs/super group) - Activity description (1 Online document)	- Check monitoring report ***- Control attendance*** ***- Control submissions***
	3.5 Improvement of the proposals	Super-groups	Blended	Blended	- 3 Final research proposal (1 Google Docs/super group) ***- Workgroup report (1 Google Forms)*** - Activity description (1 Online document)	- Check monitoring report ***- Control attendance*** ***- Control submissions***
Level 4	4.1 Presentation of the proposals & plans	Whole class	Blended	Blended	- 1 Wiki page - 3 Final research proposal (1 Google Docs/super group) - Activity description (1 Online document)	- Check monitoring report ***- Control attendance*** ***- Control submissions***
	4.2 Peer evaluation	Individual	Computer-mediated	Distance	- Peer evaluation questionnaire (1 Google Forms) - Evaluation rubric (1 Online document)	- Check monitoring report ***- Control submissions***

TOTAL= 77 instances

To achieve this aim, Julia designed a learning scenario that implemented a four-level *Pyramid*, including a *Peer-review* in one of the *Pyramid's* phases [HL10a]. The *Pyramid* pattern guided the main structure of the activity flow, made up by four phases, corresponding with the four levels of the *Pyramid* . At level-1, students proposed a research question suitable for a participatory research project. At level-2, *small groups* -made up of 2 or 3 students- agreed on a research question inspired by their previous work. At level-3, the *Peer-review* pattern was applied. *Super-groups* -formed by two small group- had to agree a research question based on the ones formulated by each small group, propose a research plan, review and provide feedback on at least one of the proposals produced by the other super-groups, and refine the proposal taking into account the received comments. Finally, at the fourth level of the *Pyramid* , super-groups performed an oral presentation about their proposal and evaluated the presentations of the other super-groups.

We will use Figure 5.7a and Figure 5.7b to illustrate how Julia described the *Activity 3.5 Improvement of the proposals*. In the first design cycle, the teacher specified the activity name, the phase and the position in the activity-flow (fifth activity at level-3 of the *Pyramid*). This activity was planned between May 17th and May 21st, however, due to some eventualities that emerged during the learning scenario, it was delayed. The new time frames were from May 18th (at 00:30 a.m.) to May 22nd (at 12:00pm), and Julia scheduled to receive a monitoring report 10 minutes after the deadline. In the activity there was no other participant than the teacher and the 15 students and it was mandatory that all of them got involved. The activity was expected to be carried out by groups, part during the lab sessions and part at home, combining face-to-face and computer-mediated interactions. All these details appear in the "General activity description" section of Figure 5.7a. Then, the teacher specified how students were organized (3 super-groups of 5 students) and chose the ICT tools that supported the learning tasks (see sections "Group formation" and "ICT tools and additional data sources" in Figure 5.7a). In this case, the students were provided with a link to the detailed description of the activity and a Google Document with the research proposal and plan (previously elaborated in Activity 3.4). While using the activity description was optional, Julia decided that it was mandatory that each group used its Google Document. To control the use of these learning resources, the teacher considered relevant to monitor the students' accesses to the activity description and both the students' accesses and the groups' editions in the research proposal and plan.

After the first cycle, the researcher analysed the activity forms and obtained the script constraints. Figure 5.7b, in section "Monitorable data available for each constraint after the first design cycle", shows the list of constraints related to the Activity 3.5. For each constraint the researcher specified whether relevant evidence could be monitored considering the activity configuration. With this feedback, the teacher faced the second cycle of the design process, introducing some changes in the design in order to enhance the monitoring process. For example, in the activity "Improvement of the proposals", there were two constraints that lacked additional data sources, the ones related to the participation and the social level. As it was explained to the teacher in the forms, the activity entailed blended learning interaction and therefore, focusing the monitoring process on computer-mediated interactions, the results would provide a partial view of the students work. Taking this advice into account, Julia included two new data sources in the activity: her own observations during the face-to-face sessions (mainly registering the attendance) and the students' feedback about the group work, obtained by means of a questionnaire. With these two modifications, the teacher adapted the script to obtain relevant monitorable actions for each activity constraint, as it is shown in Figure 5.7b, section "Monitorable data available

GENERAL ACTIVITY DESCRIPTION			
Activity name:	Improvement of the proposals		
Phase name or number:	3 (Level-3)	**Sequence order:**	3.5
Beginning: (YYYY-MM-DD hh:mm:ss)	~~2013-05-17 16:00:00~~ 2013-05-18 00:30:00	**End:** (YYYY-MM-DD hh:mm:ss)	~~2013-05-21 12:00:00~~ 2013-05-22 12:00:00
Enable monitoring: (yes / no)	yes	**Monitoring dates:** (YYYY-MM-DD hh:mm:ss)	~~2013-05-21 12:10:00~~ 2013-05-22 12:10:00
Learning mode: (Face-to-face / Distance / Blended)	Blended	**People involved in the activity:** (Number of students, teachers, observers, others)	15 students 1 teacher
Participation: (Optional / Mandatory for individuals / Mandatory for groups)	Mandatory for individuals	**Social level:** (Individual / By groups / Whole class)	By groups
Technological support for the learning tasks: (Total / Partial /No support)	Partial	**Interaction type:** (Face-to-face / Computer mediated / Blended)	Blended

GROUP FORMATION			
Does this group formation join groups from a previous activity because interaction should happen? (yes / no)		no	
If there's any dependence with groups conformed in a previous activity, specify which activity:			
Group name:	Super group 1	**Participants:**	Student1, Student2, Student3, Student4, Student5
Group name:	Super group 2	**Participants:**	Student6, Student7, Student8, Student9, Student10
Group name:	Super group 3	**Participants:**	Student11, Student12, Student13, Student14, Student15

ICT TOOLS & ADDITIONAL DATA SOURCES						
Resource name	**Tool name**	**Resource reused from previous activities**		**Expected use from participants**		**Actions to be monitored** (see attached table)
		(yes / no)	If reused from which activities	(optional / mandatory)	(individual / by groups)	
Activity description	Web Content	no	--	optional	individual	Users' accesses
Research proposal & plan	Gdocs	yes	4	mandatory	individual	User's accesses and group's editions
Teachers' observations	*Teacher's observations*	*--*	*--*	*--*	*--*	*Student's attendance to the lab sessions and other comments*
Workgroup report	*Students' feedback*	*no*	*--*	*mandatory*	*by groups*	*User's accesses and students' participation percentage*

(a) Information provided by the teacher.

Monitorable data available for each constraint after the first design cycle V = Relevant evidence P = Partial evidence X = No evidence		
Activity constraints: (Derived from the analysis of the activity features)	1. *Individual participation:* all participants must be involved in the activity	P
	2. *Social level:* there must be collaboration between group members	P
	3. *Expected use of resources:* every group member must use the resource "Research proposal & plan"	V
Flow constraints: (group dependences, reused resources, etc,)	4. *Resource reuse:* the resource "Research proposal & plan" will be reused in Activity 4.1	V
Warnings related to the constraints to be monitored	1. *Individual participation:* students participation is mandatory, and they can participate face-to-face and or by means of the technological support. However, the current configuration of the activity only provides evidence of computer mediated interactions. 2. *Social level:* in every group, there must be at least two participants involved in the activity to ensure collaboration, and they can interact face-to-face and or by means of the technological support. However, the current configuration of the activity only provides evidence of computer mediated interactions. 3. – 4. --	
How to enhance monitoring:	- **Additional data sources:** The data sources used for monitoring this activity are reduced to part of the technological support (MediaWiki, WebContent and GDocs). If you need additional information, you could obtain it from the people involved in the activity (students and teacher). - **Learning mode and Students interactions:** This activity is carried out partially face-to-face during class session, combining face-to-face and computer mediated interactions. However the evidence gathered from the learning scenario come exclusively from the technological support. Gathering evidence from face-to-face interactions may contribute to more significant monitoring results.	

Monitorable data available for each constraint after the second design cycle V = Relevant evidence P = Partial evidence X = No evidence		
Activity constraints: (Derived from the analysis of the activity features)	1. *Individual participation:* all participants must be involved in the activity	V
	2. *Social level:* there must be collaboration between group members	V
	3. *Expected use of resources:* every group member must use the resource "Research proposal & plan"	V
	4. *Expected use of resources:* every group must use the resource "Workgroup report"	V
Flow constraints: (group dependences, reused resources, etc,)	5. *Resource reuse:* the resource "Research proposal & plan" will be reused in Activity 4.1	V
Warnings related to the constraints to be monitored		
How to enhance monitoring:		

(b) Feedback given to the teacher.

Figure 5.7: Second evaluative study: Activity form used during the design process of *Activity 3.5 Improvement of the proposals*. Red text in italics represents the changes included by the teacher during the second cycle of the design process.

for each constraint after the second design cycle".

During the enactment, a monitoring report[5] was sent to the teacher in the moments specified by her (generally, 10 minutes after the deadline of each activity). For that purpose, we used a *GLUE!-CAS* prototype (see Section 4.6.3) to automatically gather and integrate the monitorable data sources, and *GLIMPSE* (described in Section 4.6.2) to analyse the participants' actions according to the indicators and conditions obtained from the script constraints.

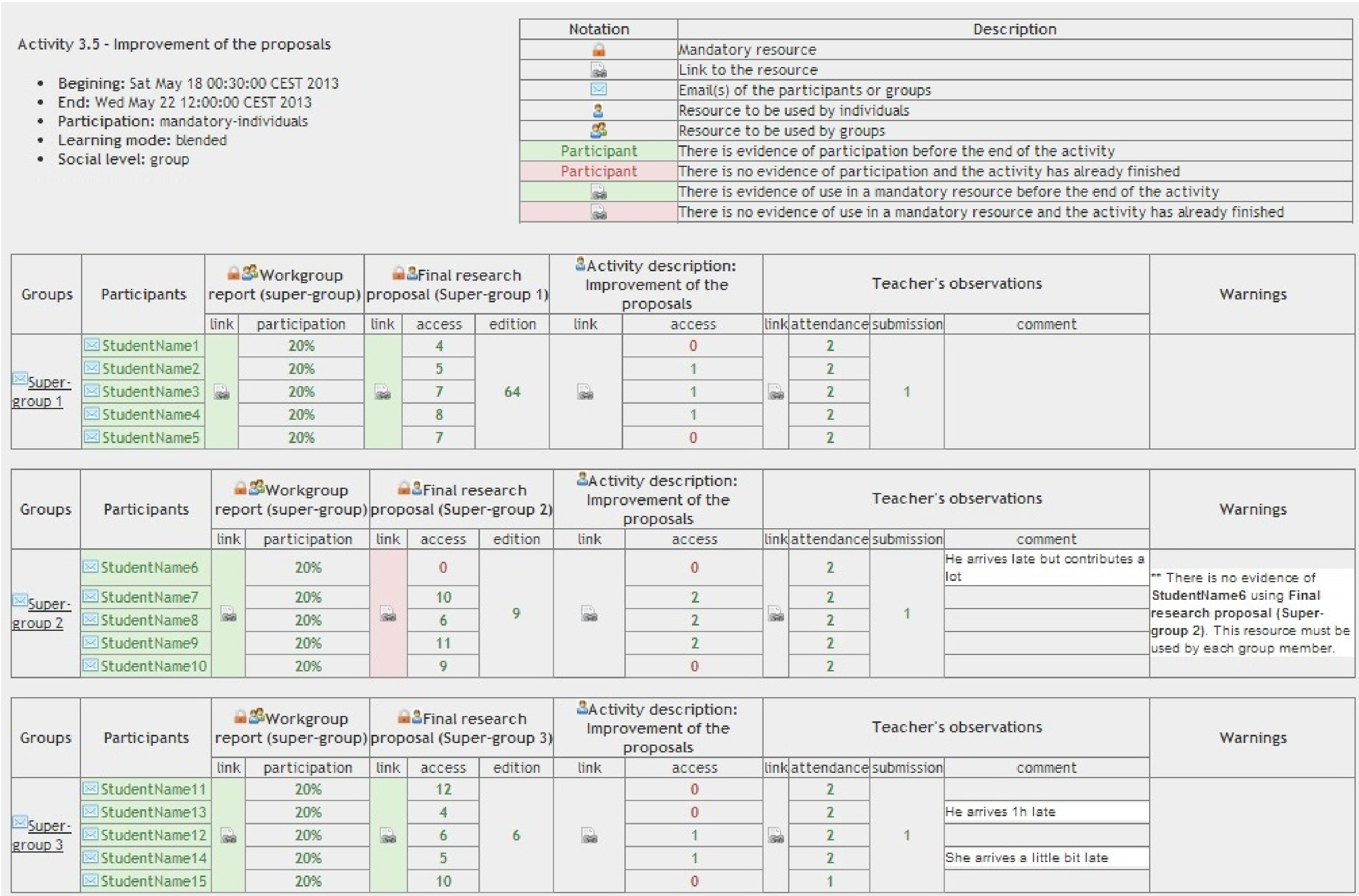
As it happened in the previous study, the monitoring reports helped Julia verify that the students were following properly the script. Out of the 274 evaluated conditions, 255 (93,07%) were consistent with the script expectations, and the other 16 cases (5,84%) were unexpected problems. These problems were generally related to lack of use of resources, except 4 cases of lack of students participation. Based on the problems detected in the monitoring reports, Julia reviewed the learning outcomes in the DLE and contacted the students, when it was necessary, to be aware of the reasons that caused the problem and to find a solution. Table 5.4 presents the constraints analysed and the problems detected during the Activity 3.5.

Table 5.4: Second evaluative study: activity and flow constraints obtained from the description of *Activity 3.5 Improvement of the proposals.*

Constraint type	Constraint description	Elements evaluated	Problems detected
Activity	A.1) Participation: Each student has to participate	15 students	0
Activity	A.2) The must be at least two students involved in each group	3 groups	0
Activity	A.3) Expected use of resources: Each student has to access and edit the"Research proposal & plan" of his/her group	3 resources	1
Activity	A.4) Expected use of resources: Each group has to access the "Workgroup report"	1 resources	0
Flow	F.1) Resource reuse: the resource "Research proposal & plan" will be reused in Activity 4.1	3 resources	3
	TOTAL:	**25**	**1**

Figure 5.8 shows the monitoring report corresponding to *Activity 3.5, Improvement of the proposals*. This report combines the evidence gathered from the ICT tools (actions and editions to the ICT tools) with the teacher's observations (number of times that the students attended to the lab sessions, the register of submissions, and other notes made during the activity), and the students' feedback (percentage of participation). As it is depicted by the red cell under the "Final research proposal" from *Super-group 2*, one warning was detected during the monitoring process. The warning was caused because no action was registered from *Student6* in the final research proposal of her group, and all group members were expected to use the resource. Looking at the number of times that the student attend at the lab session, there was evidence of the student had participated face-to-face, so it was possible that she was using the account of another group member. In addition, based on the students' feedback, they agreed that all of them had distributed uniformly the workload. Thus, although the use of the resource was mandatory for each individual, the complementary data sources helped the teacher understand

[5] An anonimized version of the monitoring reports is available in the additional material attached to this document. See Appendix H



Activity 3.5 - Improvement of the proposals

- **Begining:** Sat May 18 00:30:00 CEST 2013
- **End:** Wed May 22 12:00:00 CEST 2013
- **Participation:** mandatory-individuals
- **Learning mode:** blended
- **Social level:** group

Notation	Description
	Mandatory resource
	Link to the resource
	Email(s) of the participants or groups
	Resource to be used by individuals
	Resource to be used by groups
Participant	There is evidence of participation before the end of the activity
Participant	There is no evidence of participation and the activity has already finished
	There is evidence of use in a mandatory resource before the end of the activity
	There is no evidence of use in a mandatory resource and the activity has already finished

Groups	Participants	Workgroup report (super-group)		Final research proposal (Super-group 1)			Activity description: Improvement of the proposals		Teacher's observations				Warnings
		link	participation	link	access	edition	link	access	link	attendance	submission	comment	
Super-group 1	StudentName1		20%		4			0		2			
	StudentName2		20%		5			1		2			
	StudentName3		20%		7	64		1		2	1		
	StudentName4		20%		8			1		2			
	StudentName5		20%		7			0		2			

Groups	Participants	Workgroup report (super-group)		Final research proposal (Super-group 2)			Activity description: Improvement of the proposals		Teacher's observations				Warnings
		link	participation	link	access	edition	link	access	link	attendance	submission	comment	
Super-group 2	StudentName6		20%		0			0		2		He arrives late but contributes a lot	** There is no evidence of StudentName6 using Final research proposal (Super-group 2). This resource must be used by each group member.
	StudentName7		20%		10			2		2			
	StudentName8		20%		6	9		2		2	1		
	StudentName9		20%		11			2		2			
	StudentName10		20%		9			0		2			

Groups	Participants	Workgroup report (super-group)		Final research proposal (Super-group 3)			Activity description: Improvement of the proposals		Teacher's observations				Warnings
		link	participation	link	access	edition	link	access	link	attendance	submission	comment	
Super-group 3	StudentName11		20%		12			0		2			
	StudentName13		20%		4			0		2		He arrives 1h late	
	StudentName12		20%		6	6		1		2	1		
	StudentName14		20%		5			1		2		She arrives a little bit late	
	StudentName15		20%		10			0		1			

Figure 5.8: Second evaluative study: monitoring report sent to the teacher at the end of *Activity 3.5 Improvement of the proposals*.

that the collaboration had happened as expected, and she did not carry out any regulatory action.

5.3.3 Findings

Findings from the two studies were collected to show whether our proposal of alignment between scripting and monitoring helps teachers orchestrate blended CSCL scenarios supported by DLEs. For a better understanding, these findings are organized according to the issues and topics presented in section 5.2.1.

Issue1: Does the monitoring-aware design process of CSCL scripts help teachers to align pedagogical and monitoring issues?

Topic 1 (teachers' background/experience). At the beginning of each study, Elena and Julia were interviewed in order to have an idea of their background and previous experience in the design of CSCL scripts (some comments are collected in Table 5.5). The two teachers have a different background. On the one hand, Elena has a pedagogical background. In 2009, she started teaching in higher education, applying CSCL techniques in her own practice. On the other hand, Julia has a computer scientist background. From 1999, her research career has been related to CSCL, paying especial attention to the evaluation of CSCL scenarios. Some years later, around 2004, she began to integrate CSCL activities in her teaching practice in university settings.

Table 5.5: Findings and selected supporting evidence for *Issue1*, around *Topic 1 (teachers' background/experience)*.

Finding	**Selected supporting evidence**
Teachers have an initial idea of the potential problems based on their previous practice	"When we enact a collaborative scenario, generally it has already been enacted in previous academic years, and thus I already know which are the most problematic issues or aspects in the activities, and I try to think of a 'plan B' in case difficulties arise. If it is the first time I do a certain scenario, it is a bit more uncertain. Even if I can anticipate some conflictive situations, I may miss others." [EV1_T_INT1]
Teachers know which activities and resources must be reviewed and when in order to provide feedback to the students	"I consider when I have to review students' work [...] to provide feedback to students and enable them to improve their work [...] I also identify which are the activities and resources that I have to review [...] not only to check if they have submitted it, but also to assess the quality of the contributions." [EV1_T_INT1]
The teachers' design decisions cover most of the decisions recommended in our proposal but they are mainly focused on pedagogical concerns	Elements considered by the teacher in her designs: Pedagogical pattern constraints, deadlines, resources, participants, groups, social level, students' interaction type, learning mode, participation, and monitoring periods. [EV1_T_INT1]
	Elements considered by the teacher in her designs: constraints of the pedagogical pattern, activity flow, group formation policies, deadlines, resources, participants, groups, social level, collaboration, participation, and reuse of resources. "Sometimes I take into account those activities and the resources to be monitored (if they risk other activities)". [EV2_T_INT1]
	"I usually forget the monitoring aspects. I'm concerned about them but, usually, at design-time, I'm more focused on the activities to be developed and on the learning outputs." [EV2_T_INT1]
	"The choice of tools is based on pedagogical reasons, ease of use, tool intuitiveness, possibility of application in the future work context of students." [EV1_T_INT1]
	"I don't take into account the monitoring capabilities of the ICT tools in the selection of resources." [EV2_T_INT1]

Reviewing the elements that Elena and Julia usually included in the design process, we can observe that they were mainly focused on the pedagogical decisions, even though both of them were concerned about the monitoring tasks. Furthermore, the teachers mentioned that, at design-time, they already know which activities and resources required to be reviewed (and when) in order to provide feedback to the students, or to avoid problems on account of the dependences between activities. Dealing with the potential problems that may jeopardize the scenario, they sometimes have an idea based on their experience from previous scenarios where the designs were applied [6]. However, in those cases where there is no previous knowledge, although they try to foresee conflictive situations, they do not fill confident of taking into account all the possible situations.

Comparing the decisions that the teachers made at design-time and the ones recommended in our proposal, we can detect that the difference between them rely on few additional decisions that make the connections with the monitoring process. Thus, the application of our design proposal *a priori* should not increase significantly the teachers' effort. Besides, given the list of design decisions provided by the teachers, we expected our proposal to be familiar to them. Both aspects will be addressed in topics 2 and 5.

Topic 2 (process's coherence). After having designed both CSCL scenarios, Elena and Julia stated that the structure of the design process -in two cycles- was reasonable for them [EV1_T_INT2][EV2_T_INT2]. According to their comments, the new decisions related to the monitoring process were aligned with the pedagogical purposes. Indeed some aspects helped them to better reflect on what they expected from the students and to be more explicit with them. Thus, the teachers identified the monitoring-related tasks as just another design issue to deal with, and not something they could not afford.

Regarding the terminology used, although Elena did not identified noteworthy problems [EV1_T_INT2], Julia detected that some details were not clear enough, requiring disambiguation or illustrative examples to guide the teacher in the design process (e.g., 'monitoring dates', 'people involved', 'participation', 'social level', 'join groups dependence') [EV2_T_INT2]. Julia suggested that in order to make the process clearer and more efficient for teachers/designers, it would be useful to offer an interactive form that guide them throughout the design process, like a recommender system. Evidence of these findings are presented in Table 5.6.

Topic 3 (process's pedagogical relevance). Looking at the activity forms [EV1_T_LD][EV2_T_LD], even though the monitoring-related tasks were not mandatory, the teachers accomplished them. Indeed, Elena and Julia introduced some changes in their original designs. For example, during the first cycle of the design process, the selection of tools was influenced by their monitorable actions as it was observed by the researcher [EV1_R_OBS1][EV2_R_OBS1] and later confirmed by the teachers during the interviews [EV1_T_INT2][EV2_T_INT2]. Moreover, during the second cycle they decided to modify the script (including new monitoring data sources from teachers and students) in order to enhance monitoring [EV1_T_INT2][EV2_T_INT2][EV1_R_OBS1][EV2_R_OBS1].

During the interview the teachers stated that the design process helped them to refine the script and to avoid inconsistencies ("I just have seen that I have provided the 'system'

[6] This fact was also identified during the exploratory studies. See, for example, Table D.3

Table 5.6: Findings and selected supporting evidence for *Issue1*, around *Topic 2 (process's coherence)*.

Finding	Selected supporting evidence
The teachers stated that the process was coherent	"I think it is coherent as it has been defined." [EV1_T_INT2]
The teacher saw the monitoring-related tasks as another design issue to deal with.	"I think monitoring is just another design issue to tackle." [EV1_T_INT2]
	"I see this design process almost as a single activity. Some questions, especially those that describe the activities and the resources, help to reflect better on what I expect from the students, and on which resources they should use to manage the situation." [EV2_T_INT2]
The feedback provided to the teacher was useful	In a 1 to 5 scale (1= not useful at all; 5= absolutely useful) the values were: 4 (How to enhance monitoring), 5 (activity constraints, flow constraints, warnings) [EV1_T_INT2]
	In a 1 to 5 scale (1= not useful at all; 5= absolutely useful) the values were: 5 (activity constraints, flow constraints, warnings, how to enhance monitoring) [EV2_T_INT2]
Some terms used to describe the activities are not understandable/intuitive enough and require further explanation, examples of being renamed.	In a 1 to 5 scale (1= not understandable at all; 5= absolutely understandable) the values were: 4 (monitoring dates), 5 (beginning end, learning mode, people, participation, social level, technological support, students interactions, expected use of resources, actions to be monitored, constraints) [EV1_T_INT2]
	In a 1 to 5 scale (1= not understandable at all; 5= absolutely understandable) the values were: 1 (monitoring dates), 2 (technological support), 3 (people involved, participation, social level, join groups dependence), 4 (beginning and end, students' interactions, expected use of resources), 5 (learning mode, actions to be monitored, constraints) [EV2_T_INT2]
	"I also had some problems in specifying which activity should be taken into account when the groups used groups from previous activities." [EV2_T_INT2]
	"It would be helpful some 'interactivity' in the process of filling out the designs (which could be provided by an electronic form). " [EV2_T_INT2]
	Julia carried out the design process without reading the worksheets, therefore, she was not aware of the meaning and she did not see the examples [EV2_R_OBS1]

Table 5.7: Findings and selected supporting evidence for *Issue1*, around *Topic 3 (process's pedagogical relevance)*.

Finding	Selected supporting evidence
The design decisions were influenced by the teachers' monitoring needs	"In the original design it was not foreseen to control in a systematic manner the classroom attendance, nor to administer a questionnaire to find out the collaboration, task distribution and workload aspects, for each of the phases of the script." [EV1_T_INT2]
	"Now that I am more aware of this kind of information's benefits for the teacher, I would try to look for other tools with similar characteristics, but which could provide me with evidence of some kind (access, edition, etc.)" [EV1_T_INT2]
	"In case that the tools that I had in mind did not provide monitoring information, I would have substituted them by other tools (provided they have similar functionality to support the students work, of course)." [EV2_T_INT2]
The design process enriched the scripts	"The plan has been refined, avoiding inconsistencies, and because it provides now more evidence about the students' work." [EV2_T_INT2]
The integration is transparent to the teacher	"I just have seen that I have provided the 'system' with some characteristics, and then, the 'system' has analysed them to provide aspects for improvement, Something similar to a recommender system to enhance the design, which is quite a nice thing to have." [EV2_T_INT2]

with some characteristics, and then, the ‘system’ has analysed them to provide aspects for improvement” [EV2_T_INT2]). For example, some questions, especially those that describe the activities (e.g., is the participation mandatory?) and the resources (e.g., must the resource be used by individuals or groups?), helped them reflect on what they expected from the students, and on which resources they should use to manage the situation [EV2_T_INT2].

Therefore, we can state that the monitoring aspects influenced the design decisions and helped improve the CSCL script. Table 5.7 shows evidence that supports these findings.

Topic 4 (impact on monitoring). The reflection on the monitoring issues at design time had benefits regarding the satisfaction of the teachers’ monitoring needs and their awareness of the script constraints (see Table 5.8). By means of the design process, Elena and Julia configured the monitoring process up to their needs (e.g., saying which activities have to be monitored, when they need to receive the information, which resources and actions are relevant for the monitoring purposes [EV1_T_LD][EV2_T_LD]). Besides, they included new data sources [EV1_T_LD][EV2_T_LD], enriching the computer-mediated actions with evidence of the face-to-face work provided by teachers and students. In relation to this point, Julia mentioned: “The design process has made me appreciate the importance of including new information sources that enable the gathering of additional evidence” [EV1_T_INT2]. Finally, teachers also highlighted that the reflection on the monitoring issues at design-time helped them to be more aware of the potential eventualities and the impact that they could have on the learning situation [EV1_T_INT2][EV2_T_INT2].

Topic 5 (teachers’ effort). As we already said during the presentation of the scenarios, Elena and Julia devoted, respectively, 85 and 105 minutes to the monitoring-aware design process [EV1_R_OBS1] [EV1_R_OBS1]. The teachers pointed out that the proposed design process did not increase significantly the effort devoted [EV1_T_INT2][EV2_T_INT2]. As Julia mentioned, the main effort is to design a learning situation in advance and, as we have seen in the teachers’ previous experience, they were already used to do it. Indeed, reviewing the elements that they usually included in their designs, we realize that all of them were covered by our design process, and just a few monitoring-related aspects were added in our side (e.g., actions to be monitored or the expected use of the resources). Both agreed that including the new tasks is worth the effort considering the benefits obtained: the scripts have been refined, they enabled them to save time during the enactment, and provides more evidence about the students’ work (see Table 5.9).

Topic 6 (process’s perceived usefulness). During the interviews [EV1_T_INT3][EV2_T_INT3], teachers were asked whether they would adopt our design process in their practice. Both, Elena and Julia, agreed that they would follow this design process and they also considered that the proposal would be useful for other teachers because “it aids in better guiding the teacher’s work” [EV1_T_INT3], and, moreover, blended CSCL scenarios “require a lot of attention (e.g., regarding the deadlines, the dependencies between activities, etc.) and having some kind of system that reminds you of all these kinds of restrictions and tasks eases the work greatly” [EV2_T_INT3]. Table 5.10 collects some teachers’ comments.

Table 5.8: Findings and selected supporting evidence for *Issue1*, around *Topic 4 (impact on monitoring)*.

Finding	**Selected supporting evidence**
The reflection on the monitoring issues at design-time helped the teachers to be aware of the potential eventualities and their impact on the learning situation	"It has helped me to first reflect about which were the most conflictive points of the design. Once they were identified, and knowing which technological tools I'm going to use in each phase, I could know what kind of information they can provide and what the most adequate moment to get that information was." [EV1_T_INT2]
	"Now I am more aware of the parts of the design I've proposed that can be more conflictive." [EV1_T_INT2]
	"These questions make you reflect more on the characteristics of the designed activities, and on what can happen that can hinder the situation." [EV2_T_INT2]
Involving teachers in the configuration of the monitoring process contributes to better adapt it to their needs	"The design process has made me appreciate the importance of including new information sources that enable the gathering of additional evidence. Thanks to these measures we have been able to know how students have collaborated and have been involved." [EV1_T_INT2]
	"I will have information about whether students have accessed to the documents that they forcefully have to read in order to complete the dyad work. Moreover, I can have such information mid-way towards the deadline, giving me a certain margin of action, to be attentive and guide those students that are not performing well in this phase of the activity." [EV1_T_INT2]
	"I added further evidence of the students' work within the groups and of their participation in f2f sessions. Besides, I have re-thought some activities, adding characteristics (new resources)." [EV2_T_INT2]
	"The script provides now more evidence about the students' work. I will be able to follow them better. " [EV2_T_INT2]
	"The question of whether participation was compulsory at the individual or group levels, has made me reflect on what I want to monitor (in this case, the fact that all the students participate within their groups). The fact that the 'system' also provided information about what actions could I monitor, depending on the tools I chose, has enabled me to add new monitoring information for some of the activities, which I did not plan to have initially." [EV2_T_INT2]
	"The inclusion of new sources has improved the design, since it helps you have a more clear/complete map of how the activity has evolved." [EV2_T_INT3]

Table 5.9: Findings and selected supporting evidence for *Issue1*, around *Topic 5 (teachers' effort)*.

Finding	**Selected supporting evidence**
Reflecting on monitoring at design-time is worth the effort	"No, especially compared to the time savings of automating the monitoring of this amount of students. This information can help the teacher to guide students during the activity, and be useful to do a more accurate assessment of the work that students submit." [EV1_T_INT2]
Integrating monitoring-related tasks at design time did not increase significantly the teacher's effort	"The main effort is the fact that we design in advance, but not the extra work to think on the particular aspects related to monitoring." [EV2_T_INT2]

Table 5.10: Findings and selected supporting evidence for *Issue1*, around *Topic 6 (process's perceived usefulness)*.

Finding	Selected supporting evidence
The teachers would follow the presented monitoring-aware design process in their daily practice	"Yes, I would follow this approach, especially with large cohorts. This kind of experience cannot be done (by me, at least) without monitoring support. Especially in the current context in which cohorts are increasingly large." [EV1_T_INT3]
	"I would adopt this approach, because the day-to-day practice of this kind of activity (blended, collaborative or with multiple submissions) requires a lot of attention (e.g., regarding the deadlines, the dependencies between activities, etc.) and having some kind of system that reminds you of all these kinds of restrictions and tasks eases the work greatly." [EV2_T_INT3]
The teachers would recommend the process to other practitioners	"I recommend it to all those teachers that want to do CSCL, since it aids in better guiding the teacher's work." [EV1_T_INT3]
	"The effort required to enact this kind of designs is very low. I recommend it especially for complex activities (e.g., with peer-reviews, jigsaw, etc.)." [EV2_T_INT3]

Issue2: Does the monitoring-aware model of CSCL scripts allow expressing the scripting and monitoring aspects required to guide the monitoring process?

Topic 1 (model's expressiveness). To address this question, it was necessary to evaluate the model in two directions: first, validating whether the model allowed teachers to express the design decisions; and second, verifying whether the model provided the details required by the monitoring process to guide the data gathering and analysis. Table 5.11 shows the main findings obtained.

On the one hand, we compared the elements that Elena and Julia usually took into consideration during the design process and verified that all of them were covered by our model [EV1_T_INT1][EV2_T_INT1]. Besides, after having designed the scripts of both evaluative scenarios, the teachers confirmed that they did not miss any design aspect. Hence, the model was expressive enough to represent their pedagogical concerns [EV1_T_INT2] [EV2_T_INT2]. On the other hand, the information represented in the model allowed the GLIMPSE tool to automatically carry out the script-aware monitoring process in both scenarios. Therefore, the model was also expressive enough to guide the monitoring process.

However, we identified some drawbacks dealing with the participants' profiles. Although in the evaluation studies we had no problem due to their specific configuration (each participant had a single user identifier in the DLE), we realized that, typically, people do not have the same user id for every tool. Thus, it is necessary to know in advance all the user ids from a single student in order to map the actions registered from the different tools to the corresponding owner. In consequence, it would be necessary to include in our model a new relation between participants and tools. This relation will represent the profiles of the users in the different tools.

Issue3: Does the script-aware monitoring process provide teachers with relevant information for the management of the CSCL scenario?

Topic 1 (teachers' background). At the beginning of each study we interviewed Elena and Julia about their normal practice dealing with monitoring the learning situation [EV1_T_INT1, EV2_T_INT1]. The main message obtained from these interviews was that despite the relevance of this task, they did not pay as much attention to monitoring as they would like, due to the

Table 5.11: Findings and selected supporting evidence for *Issue2*, around *Topic T1 (model's expressiveness)*.

Finding	Selected supporting evidence
The elements usually described by the teachers are taken into account in the model	Elements considered by the teacher in her designs (Pedagogical pattern constraints, deadlines, resources, participants, groups, social level, students' interaction type, learning mode, participation, monitoring periods) are taken into account in the model [EV1_T_INT1]
	Elements considered by the teacher in her designs (constraints of the pedagogical pattern, activity flow, group formation policies, deadlines, resources, participants, groups, social level, collaboration, participation, reuse of resources, and sometimes the activities and resources to be monitored) are taken into account in the model [EV2_T_INT1]
	The teachers did not miss any design aspect [EV1_T_INT2] [EV2_T_INT2]
The monitoring process was guided by the information represented in the model	The monitoring reports were generated by GLIMPSE using the information offered by the model [EV1_R_OBS2] [EV2_R_OBS2]

lack of time and resources to do it. In addition, there are some problems that may aggravate the situation such as the lack of systematization in the data gathering, or the lack of relevant information (from the ICT tools). Indeed, though Elena and Julia (sometimes) take advantage from the information provided by the LE to monitor the students' work (e.g., students who have finished their tasks in LAMS or pages modified in MediaWiki), none of them use specific monitoring tools. Both teachers agreed that the monitoring process relies mainly on the students feedback ("We assume that, if students do not make problems explicit when working in groups, then things are going well" [EV1_T_INT1]). Besides, this information is complemented by the awareness gained during face-to-face sessions, and whenever possible the teachers try to have a look to the students work. However, Elena and Julia stated that, generally, they review the final product without paying attention to how the students have carried out the learning activities. The main findings obtained from these interviews are summarized in Table 5.12.

Topic 2 (results' representativeness). Ir order to validate whether the monitoring reports provided a realistic view, we compared the results obtained versus the complementary teachers' observations [EV1_T_OBS, EV1_T_OBS], the additional students' comments [EV1_S_QUE, EV2_S_QUE1, EV2_S_QUE2], the researcher's observations [EV1_R_OBS2, EV2_R_OBS2], and the learning outcomes in the tools [EV1_IT_LO, EV2_IT_LO]. From this analysis we realized that the monitoring reports presented an error rate of 0,33% (4 out of 1217 evaluated conditions) in the first study, and 2,19% (6 out of 274) in the second study. In the first case, the deviation consisted in two undetected problems (caused because the students used the resources but did not finish the task they had been assigned) and two false positives, i.e., warnings that did not match any problematic situation, (due to students who shared their computers and did not switch the user account, so that no evidence from some of them was registered by the tools). In the second study, the 6 values that did not match with the rest of the evidence were also false positives produced because the students collaborated with the same and with one single account. Nevertheless, despite the appearance of errors, we can state that the monitoring reports provided a perspective of the learning process close to the real facts. Some pieces of evidence used to support this finding are included in Table 5.13.

Table 5.12: Findings and selected supporting evidence for *Issue3*, around *Topic T1 (teachers' background)*.

Finding	Selected supporting evidence
Main problems that hinder teachers from monitoring the learning process: time available, workload, lack of systematization, lack of information	"Monitoring the work of students takes up a lot of time, especially if you want to provide feedback that can help them improve their work. This aspect is often a problem since the time available for these tasks is very limited. " [EV1_T_INT1]
	"The main problem is time. One cannot make a deep review, especially when there are many students. At most, you manage to find out which groups have completed their tasks, and even that requires a great deal of time." [EV1_T_INT1]
	"My main problems are: my lack of systematization and organization (what I have to do and when); it requires more time than the time available; there is information that is not available (e.g. online work)" [EV2_T_INT1]
	"I cannot follow the learning process; I'm not able to do it by myself due to the lack of time (i.e., I have no time to address these tasks) and the lack of evidence (e.g., there are activities out of the classroom). [...] The amount of time that I devote to this task is less than it should be (to follow the students properly)" [EV2_T_INT1]
Teachers (sometimes) take advantage from the information provided by the LE to monitor the students' work. But they do not use specific monitoring tools	"When I have used LAMS it was very useful the fact that the learning environment records when the students finished their tasks. Sometimes we have stored the work done by students in order to analyse it later on (at a researcher level)." [EV1_T_INT1]
	"I do not monitor the work they do outside the classroom (I do not look at the changes history of the documents)." [EV1_T_INT1]
	"I don't use specific monitoring tools by default, just the information provided by some learning tools (e.g. MediaWiki)." [EV2_T_INT1]
The main monitoring data sources are the students' feedback and the awareness got during face-to-face sessions	"I take advantage of the face-to-face classroom time to talk with students and ask them, group by group, how the work is going (e.g., doubts, problems)." [EV1_T_INT1]
	"We assume that, if students do not make problems explicit when working in groups, then things are going well. [...] Sometimes, [...] we ask them who are the ones that have participated more [..]. In my personal experience, students normally agree on who are the ones that have contributed more." [EV1_T_INT1]
	"I rely on the students the responsibility of telling me how they have worked. I don't do it because I'm not able to.' [EV2_T_INT1]
	"I usually delegate this task on the students and I take it into account their feedback in the evaluation. I asked them how they have collaborated, participated and distributed the work but I don't follow the process." [EV2_T_INT1]
	"I have a general idea of what happens during f2f sessions. Sometimes I take some notes about who attends and participates; however, I don't register systematically what I have detected and I don't have the notes organized. Thus, I frequently forget or loose this information." [EV2_T_INT1]
Teachers generally review the final product without paying attention on how they have carried out the learning activities	"When I have the time (which depends on my workload in other areas), I try to check that students submitted their work [...] However, generally I review the final product, and I do not look into by whom nor when it has been edited (if one student from the group submits the work or signs on behalf of all the group, it is enough)." [EV1_T_INT1]
	"When the students have a submission and this submission affects other activities or I have to provide feedback, I check if they have done it, but I don't pay attention to whether they have accomplished the deadlines." [EV2_T_INT1]
	"The overall workload required to orchestrate a CSCL scenario is so big that some teachers' tasks remains in the background, e.g. monitoring. I just can pay attention to the submissions and learning outputs, ignoring the learning process." [EV2_T_INT1]

Table 5.13: Findings and selected supporting evidence for *Issue3*, around *Topic T2 (results' representativeness)*.

Finding	**Selected supporting evidence**
The results were aligned with the real facts in 99,67% and 97,81% of the evaluated conditions	In EV1 there were 2 undetected problems (due to students that used the tools but did not complete the task) and 2 false positives (due to collaborative work during the classroom): 0,33% error (over 1217 evaluated conditions) [EV1_T_OBS] [EV1_IT_LO] [EV1_IT_LOG] [EV1_S_QUE] [EV1_R_OBS2]
	There have been cases of problems that have gone unnoticed (at least a couple of persons have done minimal edits to the documents without finishing the task). I have learned about those cases one week later, when students themselves told me. [EV1_T_INT3]
	In EV2 there were 0 undetected problems and 6 false positives (due to collaborative work during the classroom): 2,19% error (over 274 evaluated conditions) [EV2_T_OBS] [EV2_IT_LO] [EV2_IT_LOG] [EV2_S_QUE1][EV2_S_QUE2][EV2_R_OBS2]

Topic 3 (results' novelty and relevance). Dealing with the content of the monitoring reports, we studied whether we had provided Elena and Julia with new and relevant feedback (see the main findings and evidence in Table 5.14). The study shows that in many cases (98,44% out of 1217, and 62,41% out of 274 evaluated conditions in the first and second study respectively) the teachers were not aware of the results when they showed the monitoring reports. Besides, although Elena and Julia had a certain idea of what was happening based on the face-to-face sessions and the students who directly contacted them, they considered that the information was always relevant (except for the undetected problems and some false positives). Besides, the teachers highlighted two main benefits of the presented monitoring approach [EV1_T_INT3, EV2_T_INT3]: the analysis of the students' work on the accomplishment of the decisions made at design-time, which contributed to provide relevant feedback for the management of the learning scenario, as well as the integration of the different data sources (from ICT tools, teachers and students).

Topic 4 (teachers' effort). In order to ensure whether our proposal supported teachers in the monitoring process, we asked them about the effort devoted to monitor the students work [EV1_T_INT3, EV2_T_INT3]. According to Elena and Julia (see some comments in Table 5.15), the monitoring reports was easy and fast, taking, in the case of Elena, less than 10 minutes both the review on the reports and the corresponding regulatory tasks. Moreover, they remarked that the monitoring reports decreased the time and effort devoted to the management of the CSCL scenario, contributing to a more efficient use of the time available.

Table 5.14: Findings and selected supporting evidence for *Issue3*, around *Topic 3 (results' novelty and relevance).*

Finding	Selected supporting evidence
The monitoring reports provided information unknown by the teachers	"With so many students I was not aware of who had submitted." [EV1_T_INT3]
	"In many cases I was not aware of what was happening. Without help, I could not have a clear perspective of what was happening with so many students (one does not remember any more what students have told you, who told you, or what emails they have sent you)." [EV1_T_INT3]
	"The part regarding student activity and the distance activity is not obvious. Besides, when the reports arrived, I had not yet revised the work by students. It is true that I had seen them work with the tools when they were in the classroom, and that gave me a general/approximate idea of what could appear in the reports." [EV2_T_INT3]
	98,44% unknown and 99,67% useful values (out of 1217 evaluated conditions). The single values that were not considered relevant were de errors [EV1_T_OBS]
	62,41 % unknown and 97,81% useful values (out of 274 evaluated conditions). The single values that were not considered relevant were de errors [EV2_T_OBS]
The information form face-to-face sessions was obvious but relevant	" There is some obvious information, since I had provided it, but such information is not easy to do without, since it helps to complete the rest, and draw conclusions based on the sum of the evidence." [EV2_T_INT3]
Focusing the analysis of the user's action on the accomplishment of the decisions made at design time was relevant and useful for the teachers	"The monitoring reports were relevant for me because they responded to my expectations." [EV1_T_INT3]
	"The monitoring reports very useful to ensure that there would be productive discussions and a common product. This information allowed me to avoid problems caused by students not doing the work previous to an activity." [EV1_T_INT3]
	"This type of analysis is useful. The fundamental aspect is that it tells you how students are progressing with respect to the plan. Concretely, in this scenario, reports gave the certainty that students were following the plan without having to dedicate a lot of time on my side." [EV2_T_INT3]
	41 out of 43 problems (95,35%) were detected [EV1_T_OBS] [EV1_IT_LO] [EV1_IT_LOG] [EV1_S_QUE][EV1_R_OBS2]
	16 out of 16 problems (100%) were detected [EV2_T_OBS] [EV2_IT_LO] [EV2_IT_LOG] [EV2_S_QUE1][EV2_S_QUE2][EV2_R_OBS2]
The integration of the different data sources (from ICT tools, teachers and students) and having the information centralized was helpful for the teachers	"The students' report has been very useful, in order to take into account their perspective" [EV1_T_INT3]
	"Having all the data gathered in one place simplifies the monitoring. Having the information centralized helps avoid misunderstandings and keep the situation under control." [EV1_T_INT3]
	"Being able to incorporate my notes with the comments received from students has simplified a lot my work." [EV1_T_INT3]
	"It is also useful to have a general view of everything that has happened." [EV1_T_INT3]
	"The integrations is not only useful, it is necessary. It gives you a complementary view of an activity that happens in different settings/moments. It uses blended sources to inform blended activities." [EV2_T_INT3]

Table 5.15: Findings and selected supporting evidence for *Issue3*, around *Topic T4 (teachers' effort)*.

Finding	Selected supporting evidence
Interpreting the monitoring reports was easy and fast	"Interpreting the monitoring reports was very easy, with one look I knew whether there had been any problems." [EV1_T_INT3]
	"I dedicated 10 minutes at most: 5 minutes to read everything, plus another 5 minutes to take the corresponding measures." [EV1_T_INT3]
	"Interpreting the reports was simple and immediate. The information that is provided is clear and does not lead to misinterpretations." [EV2_T_INT3]
The monitoring reports decreased the time and effort devoted to the management of the CSCL scenario	"Clearly, I have dedicated less time. If I hadn't had the monitoring information, I would not have been able to assess students." [EV1_T_INT3]
	"Given the current teacher workload, it is impossible to dedicate more time to follow students. In this way, it is possible to manage available time in a more efficient fashion. Furthermore, students appreciate the assessment greatly, since they see that you care about them, and they are grateful for the guidance about what they are doing, learn more, and redirect their work in a timely fashion (not once the activity has ended)." [EV1_T_INT3]
	"The time has diminished and the management has been improved. [...] One has to be very systematic and dedicate a lot of time to enact this kind of activities without external support, and to record all problems." [EV2_T_INT3]

Topic 5 (process's perceived usefulness). Table 5.16 gathers some pieces of evidence that support the usefulness of the script-aware monitoring process, especially based on interviews made to the teachers at the end of each scenario [EV1_T_INT3, EV2_T_INT3]. According to the teachers' feedback, the monitoring reports helped them follow the learning situation, not only detecting emerging problems, but also providing evidence about the proper accomplishment of the activities. Besides, the monitoring reports triggered regulatory tasks that avoided further problems in the learning scenarios. For both teachers, the fact of knowing that the learning situation was being monitored, contributed to increase the teachers' sense of 'control' and foster the students' responsibility.

As they said about the design process, Elena and Julia, agreed that they would follow this monitoring process and they also considered that the proposal would be useful for other teachers. Elena recommended the proposal for scenarios with large cohorts of students, and Julia suggested that it would be also suitable for scenarios with complex activity flows.

Table 5.16: Findings and selected supporting evidence for *Issue3*, around *Topic T5 (process's perceived usefulness).*

Finding	Selected supporting evidence
The monitoring reports helped the teachers follow the learning situation	"The monitoring reports helped me to follow the learning process" [EV1_T_INT3]
	"It has been useful to do a monitoring of the work, especially for detecting how people worked when they could not attend the class, or in the distance activities." [EV2_T_INT3]
The monitoring reports triggered regulatory tasks an avoided future/further problems	"When I detected some problem, I contacted students. In fact, I have sent quite a few emails with wake up calls, reminders, and asking what had happened. This is something we normally not do because we do not have means to closely follow the students' work." [EV1_T_INT3]
	"The monitoring reports entailed regulatory tasks only in two cases. In general all students/groups followed the plan, except the development of the report in small groups (which I commented verbally with them in the classroom) and in the last activity, in which three students forgot to send the co-assessment report, and thus I had to remind them via email. It was critical because neither they nor I would have remembered (until the moment of the final assessment), since that moment coincided with the end of the course. The rest served to check that everything was going well." [EV2_T_INT3]
	"It has helped detect problems beforehand." [EV1_T_INT3]
The monitoring reports are also useful when the learning process is going well	"In any case, knowing that the plan is being fulfilled enables you to go on with greater confidence." [EV2_T_INT3]
The teachers would follow the script-aware monitoring process in their daily practice	"Yes, especially with large cohorts. This kind of experience cannot be done (by me, at least) without monitoring support. Especially in the current context in which cohorts are increasingly large." [EV1_T_INT3]
	"Yes, because the day-to-day practice of this kind of activity (blended, collaborative or with multiple submissions) requires a lot of attention (e.g., regarding the deadlines, the dependencies between activities, etc.) and having some kind of system that reminds you of all these kinds of restrictions and tasks eases the work greatly." [EV2_T_INT3]
	"In another course I'm teaching, making this kind of activity forced me to go group by group, checking whether students had completed the task I had set." [EV2_T_INT3]
The script-aware monitoring process could be useful for other teachers	"I recommend it to all those teachers that want to do CSCL, since it aids in better guiding the teacher's work." [EV1_T_INT3]
	"Yes, I would recommend it. Blended environments are being increasingly used, and having a register of who makes their work in the allotted times is useful. The effort required to enact this kind of designs is very low. I recommend it especially for complex activities (e.g., with peer-reviews, jigsaw, etc.)." [EV2_T_INT3]
Knowing that the learning scenario is being monitored, teachers feel more confidence	"It has helped me and it has provided more confidence." [EV1_T_INT3]
	"Knowing that the activity was being monitored and having evidence that the work was being done gave a sense of order and control on which you can build up." [EV2_T_INT3]

Issue4: Does the architecture facilitate the data gathering and integration of users' interactions in CSCL scenarios supported by DLEs?

Topic 1 (impact on the design process). As it was confirmed by the researcher's observations [EV1_R_OBS1, EV2_R_OBS1] and the teacher's feedback [EV1_R_OBS1, EV2_R_OBS1], the information retrieved by the *GLUE!-CAS* prototype about the monitoring affordances of the tools, was helpful to support the teachers during the design process (see Table 5.17). Concretely, Elena and Julia based the selection of tools on the monitorable actions (of those tools that could be integrated in the DLE via GLUE!). Moreover, this information allowed the teachers to decide which actions were relevant for the monitoring process [EV1_T_LD, EV2_T_LD].

Table 5.17: Findings and selected supporting evidence for *Issue4*, around *Topic T1 (impact on the design process).*

Finding	**Selected supporting evidence**
The list of monitorable actions guided the tool selection	Both teachers selected the tools and specified the monitorable actions that they wanted to monitor. [EV1_T_LD, EV2_T_LD]
	Both teachers used the list of tools and monitorable actions to select the tools that made up the DLE. [EV1_R_OBS1, EV2_R_OBS1]
	"If the tools that I had in mind had not provided relevant information, then I would have chosen different ones" [EV1_T_INT2]
	"Due to the fact that the 'system' gave me information of what monitoring data is provided by the tools available, I have added some more information than expected a priori about the students' activity" [EV2_T_INT2]

Topic 2 (data gathering). All the data to be included in the monitoring reports was automatically collected by the GLUE!-CAS prototype tool, including the computer-mediated actions [EV1_IT_LOG, EV2_IT_LOG] and the ad-hoc evidence provided by teachers [EV1_T_OBS, EV2_T_OBS] and students [EV1_S_QUE, EV2_S_QUE1, EV2_S_QUE2]. Thus, we can state that the proposed architecture allowed the gathering of the data available in the learning scenario (see evidence supporting this finding in Table 5.18). It is also noteworthy that, although the analyses of these data provided Elena and Julia with relevant information about the learning process, new data could be gathered. For example, the teachers suggested [EV1_T_INT3, EV2_T_INT3]: to obtain further information about the actions carried out in Google Documents (e.g., measuring the number of words), to collect information from external observers, or to elaborate rubrics that help teachers in the data gathering. These proposals would require improving the adapters (e.g., developing methods that provide further information about the user's actions), and developing specific tools to collect feedback for teachers, students or any other observer.

Topic 3 (data gathering and integration time cost). Regarding the costs, the automation of the data gathering and integration reduced drastically the teachers' workload in terms of the effort and time that they would have had to invest in order to obtain the same information [EV1_T_INT3, EV2_T_INT3]. Although the data collection took a couple of minutes in the worst situation (depending on the number of tool instances to be analysed and the speed of the internet connection)[EV1_R_OBS2, EV2_R_OBS2], it was acceptable for Elena and Julia. However, it would be necessary to improve the time-costs in case that the teachers need the information in real-time. Table 5.19 collects some evidence that supports these findings.

Table 5.18: Findings and selected supporting evidence for *Issue4*, around *Topic T2 (data gathering)*.

Finding	Selected supporting evidence
The GLUE!-CAS prototype allowed the data gathering of the monitorable actions available in the learning scenario	The GLUE!-CAS prototype collected the data available in the DEL (Google Documents, Google Presentations and GLUE! Logs) [EV1_IT_LOG]
	The GLUE!-CAS prototype collected the data provided by teachers (registry of attendance and notes) [EV1_T_OBS]
	The GLUE!-CAS prototype collected the students feedback on the topics related to the script constraints (time devoted by the students) [EV1_S_QUE]
	The GLUE!-CAS prototype collected the data available in the DEL (MediaWiki, Google Documents, and GLUE! Logs) [EV2_IT_LOG]
	The GLUE!-CAS prototype collected the data provided by teachers (registry of attendance and notes) [EV2_T_OBS]
	The GLUE!-CAS prototype collected the students feedback on the topics related to the script constraints (students' percentage of participation) [EV2_S_QUE1, EV2_S_QUE2]
The monitorable data could be improved	"External people's observations could be included in the face-to-face activities." [EV1_T_INT3]
	"In computer-mediated activities more information could be extracted. Since GDocs is a very widely used tool, the interactions through GDocs could be analyzed more exhaustively (e.g., assigning a minimum number of words in order to know whether a task has been completed). To establish a word limit (or interval) could help minimize hidden problems." [EV1_T_INT3]
	"Regarding teacher-provided information, it would help a lot to define a rubric beforehand, with the things to observe in order to assess the students' work. Knowing this rubric beforehand (i.e., the quality criteria) would be also very useful for students, since it would help them better manage their time, dedicating it to the most relevant things, so that the score obtained is coherent with the time invested." [EV1_T_INT3]
	"Monitoring could be improved including quality criteria." [EV1_T_INT3]
	"The information is superficial, and by default you should mistrust it." [EV2_T_INT3]
	"To improve the evidence gathered from face-to-face activities not supported by technology, a more complete observation template by the teacher could provide more information." [EV2_T_INT3]

Table 5.19: Findings and selected supporting evidence for *Issue4*, around *Topic T3 (data gathering and integration time cost)*.

Finding	Selected supporting evidence
The automation of the data gathering and integration tasks reduced the time that teachers had to invest in the management of the learning scenario	The time required to gather and integrate the students work in EV1 was between 12 and 124 seconds [EV1_R_OBS2]
	The time required to gather and integrate the students work in EV2 was between 5 and 23 seconds [EV2_R_OBS2]
	"I would have had to dedicate a lot of time to tasks that are very mechanical and daunting (e.g., to open the "thousands" of documents in order to note down who had performed the task), especially in very large cohorts." [EV1_T_INT3]
	"It automates a low-level task that requires a lot of time, but which is very useful for the management." [EV2_T_INT3]
Having the reports available at any time could be useful but not crucial	"Maybe in the end it is too much information, that one does not have time to process. I think the reports for the teacher are necessary and valuable in the sense that they provide relevant information to better guide your students, detect problems on-the-fly, etc. I am not sure that having more reports would help in this regard, especially if the teacher does not have time to analyze them." [EV1_T_INT3]
	"Having the information available at any time would be interesting at some precise moments, notwithstanding the scheduled reports, since these are the most important, reminding you of the state of the activity without the teacher having to do anything." [EV2_T_INT3]

5.4 Conclusions

The DBR methodology combines exploratory and evaluative work throughout the iterations that made up the research process. This chapter has focused on the third iteration of this DBR process, whose purpose was the evaluation of the proposals formulated in Chapter 4. This thesis evaluation was guided by CSCL-EREM framework. Following its recommendations, four issues were defined to conceptually organize the evaluation. The anticipated data reduction procedure was applied to decompose these issues into different topics and informative questions, thus allowing their exploration from different perspectives. Then, two evaluation happenings were carried out in order to collect data to discuss the aforementioned issues. It is important to underline that these happenings produced both qualitative and quantitative data following a mixed method approach.

The evaluation happenings were based on two authentic CSCL scenarios. In this scenarios participated two teachers with different expertise and background. Indeed, one of this teachers, Julia (T3 in Figure 5.1) was also involved in the exploratory iterations. These scenarios presented some commonalities: blended CSCL scenarios supported by DLEs, that lasted between 3 and 4 weeks, and entailed learning at different social levels, combining face-to-face and computer-mediated interaction among students, as well as face-to-face and distance learning. However, each one of them stood up for being complex on account of different reasons: the first study required monitoring a high number of students and resources, and the second study presented a complex script with multiple dependences between the activities.

The data gathered in these two happenings was triangulated to discuss the four evaluation issues. The first issue asked if the monitoring-aware design process of CSCL scripts helps teachers to align pedagogical and monitoring issues. The evaluation concluded that, *without increasing significantly the effort devoted, the design process guided teachers to express and reflect on their monitoring concerns*. Besides, this process provided teachers with useful feedback that *contributed to the refinement of the script* from the pedagogical and the monitoring point of view. In addition, the reflection on the monitoring issues at design-time had a *positive impact during the enactment*, because it helped the teachers to be aware of the potential eventualities and their impact on the learning situation; and *involving teachers in the configuration of the monitoring process contributed to better adapt it to their needs*. According to the teachers that participated in the evaluation, *the integration of the monitoring-related tasks is worth the effort*, and not only they would follow the presented monitoring-aware design process in their daily practice, they would also recommend it to other practitioners. However, we have identified some drawbacks that will require our attention in the future work. First of all, to promote the adoption of this process by teachers, it is necessary to provide them with a tool that supports and guides them throughout the process, automating the gap between the first and the second cycle of the design process (i.e., the generation of recommendations for the improvement of monitoring data sources). Besides, we should review the terminology and provide some examples that make the process understandable and intuitive enough. The second drawback that we aim to address in our future work deals with the selection of the ICT tools that constitute the DLE. Learning situations are very complex and different characteristics should be taken into account to select an appropriate technology to support them. These aspects make the selection of ICT tools for a specific learning situation a challenging task that requires educators to be aware of different characteristics of the ICT tools. A more generic solution to provide teachers with information regarding the monitoring affordances of the tools, independent of the specific architecture that supports the DLE, should be found. For example, existing proposals, such as *U-Seek* and *We-Share* [RC14], that allow teachers to search and discover new tools based on certain pedagogical of technical issues, could be extended to include the monitoring features of the ICT tools. This approach could offer teachers with a sustainable solution that helps them select suitable tools taking into account both pedagogical and the monitoring concerns.

The second issue asked if the monitoring-aware model of CSCL scripts allows expressing the scripting and monitoring aspects required to guide the monitoring process. On the one hand, the evaluation reveals that *the elements that the teachers usually describe in their designs are taken into account in the proposed model*. Moreover, the *teachers* confirmed that they *were able to express the design decisions*. On the other hand, we verified that *the model provided the details required by the monitoring process* (implemented by means of the *GLIMPSE* prototype) to guide the data gathering and analysis. Although in the evaluative scenarios we did not face remarkable problems dealing with the participant's authentication, it is necessary to extend the model in order to represent the user's identifier that the participants have in each ICT tool. With this additional information, it could be possible to associate a monitored action to its owner, independently of the identifier used in the corresponding platform.

The third issue addressed whether the script-aware monitoring process provides teachers with relevant information for the management of the CSCL scenario. As the teachers involved in the evaluation stated, the main problems that hinder teachers from monitoring the learning process are the time available, the workload, the lack of systematization, and the lack of relevant information. In relation to these problems, *our monitoring proposal reduced considerably the time required by the teachers to follow the student work*, and *contributed to use more efficiently the time devoted* to these tasks. Furthermore, *the process collects systematically the data from the learning environment*, following the monitoring plan defined by the teacher at design-time, *and integrates the data from the different sources* (ICT tools, teachers and students), centralizing all the information. Regarding the feedback offered to the teachers, focusing the analysis on the accomplishment of the design-decisions *helped the teachers contextualize and interpret the results of the data analysis. The monitoring reports contained information* sometimes unknown by the teachers, sometimes obvious, but in both cases considered *relevant to improve the teacher's awareness, the detection of eventualities, and the regulation of the learning situation towards a more efficient direction.* Both teachers stated that they would follow the script-aware monitoring process in their daily practice, and they recommend it to other practitioners, especially for CSCL scenarios with with large cohorts of students, numerous resources to monitor, or complex scripts that may require much attention. Despite this positive results, the monitoring process presents some deficiencies that we expect to face in our future work, particularly in order to minimize the number of undetected problems and false positives. One possible option could be improving the monitorable data, for instance, collecting data not only about the action properties (such as the timestamp, the user, or the action type) but also about the 'content' of the action itself (e.g., in the case of an 'edition', the text written by the user). In addition, to make the feedback provided to the teacher more understandable and intuitive, we expect to devote part of our future work to find new ways of presenting the monitoring information.

The fourth issue analysed whether the architecture makes easier the data gathering and integration of users' interactions in CSCL scenarios supported by DLEs. By means of the *GLUE!-CAS* prototype we have checked that it was possible to obtain information about the monitoring affordances of the ICT tools. *Based on the list of monitorable actions, the teachers could decide which tools could satisfy both their pedagogical and their monitoring needs*, and what actions could be relevant for the monitoring purposes. Regarding the automation of the data gathering and integration tasks, the *GLUE!-CAS* prototype collected the monitorable data provided by the ICT tools, and it was also possible to support the collection of data generated ad-hoc by teachers and students. According to the teachers feedback, this prototype *automates a low-level task, very time-consuming but very useful for the management*. Even though this prototype covered the purpose of the architecture in the evaluative studies, we detected some problems that could appear in other scenarios. Concretely, it is necessary to adapt the architecture to avoid data gathering problems related to the time frame within the tools store data about the students' actions, and the lifecycle of the tool instances (e.g., frequently no information about the users' performance after removing a tool instance). The current proposal of the architecture collects data on demand, to avoid the aforementioned limitations, we should adopt a mixed approach where the data is gathered on demand but also the tools (or the adapters) publish the information under certain circumstances (e.g., before the tool instance is deleted).

Finally, from the evaluation of the aforementioned issues, we can conclude that t*he combination of the four proposals presented in this dissertation* (namely, the monitoring-aware design process, the monitoring-aware model of CSCL scripts, the script-aware monitoring process, and the architecture for data gathering and integration in DLEs) *has allowed us to accomplish our research objective, i.e., to provide teachers with design and enactment support capable of linking pedagogical intentions with monitoring needs for orchestrating blended CSCL scenarios supported by DLEs*. Despite the positive results obtained throughout this dissertation, this work is far from being the definitive work about the combination of scripting and monitoring CSCL scenarios. Multiple threads of research have been identified throughout the evaluations, that prompt for further work in order to achieve the full potential/an improved level of teacher support of the approach presented here.

Chapter 6

Conclusions and future work

Summary: This chapter concludes the dissertation, by summarizing the overall research objective being tackled (the alignment of scripting and monitoring to support teachers in the orchestration of blended CSCL scenarios in DLEs), the contributions proposed, and the way in which those contributions have been evaluated throughout the dissertation. The results of these evaluations lead us to conclude that the thesis objectives have been fulfilled, but also point us towards future lines of research work, which are also described in this chapter.

The publications related to the contents of this dissertation (including five papers in international peer-reviewed journals and five international conference papers) can be considered as first indicators of the relevance and originality of our proposals, and they also support the importance of the aforementioned future work.

6.1 Conclusions of the dissertation

There are three main trends that are increasingly common in TEL scenarios, especially in formal education contexts: the combination of face-to-face and distance learning (i.e., blended learning), the inclusion and use of collaborative strategies to promote learning, and the use of Distributed Learning Environments (DLEs) that comprise multiple learning platforms and tools. The union of these three pillars constitutes the main research context of our study: *blended CSCL scenarios supported by DLEs*. Despite the high adoption of this kind of scenarios (due to the learning opportunities that they offer), their use in authentic practice also presents certain challenges such as their orchestration (which tends to be even more complex and demanding for teachers).

The use of Learning Design and Learning Analytics strategies, such as *scripting and monitoring*, has been shown in the literature to be helpful. Even though these strategies are often applied separately, they are complementary and several researchers stand for their *alignment*. Indeed, they envision that this approach could mitigate one of the major challenges in TEL (and CSCL): *the need for interpreting the analysis of the data obtained from the learning environment against the pedagogical intent and the local context of a particular learning activity*. This dissertation focused on the alignment between scripting and monitoring in blended CSCL scenarios supported by DLEs (a context not addressed by other existing solutions), and set out to **propose, develop and evaluate tools** (either technological and/or conceptual) **that support such alignment**.

The complex, evolving nature of our research goal (this aligning of scripting and monitoring to support teachers in designing and managing CSCL scenarios) led us to employ a Design-Based Research approach. Following the DBR criteria, our research process comprised several iterations with the aim of improving educational practices based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories. The main purpose of the first and second iterations (summarized in Chapter 3) was to explore the dependencies between scripting and monitoring, as well as to collect the requirements for the alignment of these two strategies. The exploratory work resulted in the definition and refinement of the proposals (presented in their current status in Chapter 4): *a monitoring-aware design process, an accompanying model of CSCL scripts, a script-aware monitoring process, and an architecture for data gathering and integration in DLEs.* Then, these proposals were applied and validated in a third iteration, as it has been described in Chapter 5. The emphasis of CSCL research on the social aspects of learning, as well as the importance of contextual factors in orchestration, led us to conduct our studies in authentic educational settings. Furthermore, we employed mixed methods, as they are considered adequate for exploring the different perspectives and multiple factors that affect learning situations – indeed, these methods are typically used in DBR and CSCL.

The first problem that we encountered when trying to align scripting and monitoring was a design problem: *the lack of reflection about monitoring issues at design-time, sometimes conditioned the monitoring results.* The second problem we found concerned the monitoring process: *existing proposals often follow a data-driven approach, inferring indicators from the data available* instead of using a predefined model (based on the teacher's concerns) to guide the analysis. Finally, a technological problem was detected in current CSCL practice that uses DLEs: *the heterogeneous and distributed nature of the learning environment* hindered the gathering and integration of monitoring data.

With these three problems in mind, we proposed three partial dissertation goals that addressed them:

To support teachers to identify and include monitoring aspects throughout the design process of CSCL scenarios. Our literature review revealed that current design proposals and scripting models do not take into account monitoring issues, hampering the alignment of both strategies. Besides, our own exploratory work showed multiple dependencies among them to be taken into account, as well as the need for helping teachers reflect and express their monitoring concerns. In response to these issues, this dissertation proposes a *monitoring-aware design process of CSCL scripts* (Section 4.3). This design process guides teachers-designers of CSCL scripts in order to reflect on those aspects that affect monitoring, adapt the monitoring process to their needs, and collect the script information necessary for monitoring the learning scenario.

This design process was validated during two authentic learning scenarios, involving two teachers with different levels of expertise in CSCL. We have analysed the pedagogical and monitoring benefits, the teachers' effort, as well as the coherence and usefulness of such design process. The results of the evaluations show that, by following this process, the teachers identified improvements not only in the script (which was refined), but also in the monitoring results, and in the teachers' awareness about the eventualities that might jeopardize the learning scenario. Besides, both teachers considered that the effort devoted was affordable, and stated they would adopt it in their own practice. Also, they recommended the process on other teachers facing CSCL scenarios with a significant number of students or with complex designs. The evaluation also helped to identify some refinements to the process, such as the need to clarify the terminology, and the potential use of an interactive form to guide the teachers throughout the design. The implementation of such a form should be quite straightforward, based on the specification of the process made in this thesis. The intermediate versions of the design process have already been published in [RT12b], [RT13a], and [EM14]. In addition, the evaluation of this contribution will be also published [RT14] in the near future. Thus, although this design process can be refined in further research iterations, e.g., by providing further guidance to the teachers, *the proposed monitoring-aware design process of CSCL scripts has fulfilled the goal of supporting teachers to identify and include monitoring aspects throughout the design process of CSCL scenarios.*

Moreover, we formulated a *monitoring-aware model of CSCL scripts* (Section 4.2) in order to compile the details that have to be provided in the design process, and to model the links between scripting and monitoring. This model emerged from the exploratory work and was also used in the evaluative studies to represent the scripts generated by the aforementioned design process. In these studies we evaluated whether the model was expressive enough to describe the design decisions and the information required to guide the monitoring process. The evidence shows that the model satisfied properly these expressiveness requirements in both scenarios. However, in order to validate and refine the expressiveness of the proposal, the model should be applied in new scenarios involving different style of script designs (e.g., including role changes, alternative paths) and monitoring needs (e.g., identifying the roles taken by the students). Intermediate versions of monitoring-aware model have been already presented in [RT12a] and [RT13a]. Moreover, the final version presented in this document will be published in a short-term [RT14].

To provide teachers with awareness information about the evolution of the CSCL situation, related to the learning design decisions. In order to link the awareness information to teachers' design decisions, we reviewed existing Learning Analytics proposals, detecting that many of them follow mainly a bottom-up approach, i.e., they infer indicators based on the available data. However, this approach does not ensure the alignment between the resulting indicators and teacher awareness needs. Besides, during the exploratory studies, we found out that it was possible to better adapt the analysis to their needs (e.g., focusing the analysis on the aspects relevant for the teacher, and providing the information in those moments that the teacher considered relevant for the management of the learning scenario) through the involvement of teachers in the configuration of the monitoring process. To address these issues, this dissertation proposes a *script-aware monitoring process of CSCL scenarios* (Section 4.4) that aims to inform teachers about the accomplishment of their design decisions.

The monitoring information provided by this process was generally accurate, reflecting a realistic view of the learning process. There were a few false positives (situations flagged as potentially problematic, which ended up not being so) and actual problematic ones that passed unnoticed – however, they were not considered a critical issue by the teachers. The proposed approach does not rely exclusively on the automatic data gathering by the system, also providing the teacher with tools to help them make their own judgement. This strategy has proven useful to face these accuracy problems, which are difficult to avoid in the complex educational settings we work with. One limitation of our approach, noticed in the evaluations, is that it does not take into account finer-grained analysis of content quality for the analysis: we have not distinguished between a student who changes a few words in a document and another one who writes a whole report – both are detected as editions to the document. Thus, we should filter somehow the students' actions in order to increase the accuracy of the monitoring results. Regarding the relevance of the monitoring results, both teachers stated that the reports helped them either to verify that the students were following the plan as it was expected, or to detect emerging problems. This feedback made the regulation of the learning scenarios easier, and even in those cases where they already were aware of the information, the teachers considered the monitoring reports to be useful in order to remember what had happened in a short/medium term, thus supporting the assessment tasks. According to the teachers' point of view, interpreting the monitoring reports took them very little time, and the fact of receiving an integrated view of the multiple data sources reduced significantly the amount of time and effort required to accomplish these tasks, promoting a more efficient use of the time available. Finally, the teachers expressed that they would use the monitoring process in their practice, and that they recommend it to other practitioners. Intermediate proposals of this monitoring process as well as evidence of the application in authentic CSCL scenarios in Higher Education (based on the exploratory studies) have been already published in [RT11c] [RT12b], [RT13a], [RT13b], and [EM14]. Thus, we can conclude that *the script-aware monitoring process can provide teachers with relevant feedback to improve the awareness on the learning situation and to support the regulation tasks*, thus fulfilling our second partial goal.

To support the automation of the monitoring data gathering and integration tasks in blended CSCL scenarios supported by DLEs. Technology enhanced learning contexts such as CSCL scenarios offer the possibility to store educational data [Sie11]. However, as we have identified in the literature and in the exploratory studies, *there are certain problems that hinder the data gathering and integration* (e.g., the variety of the data being recorded, and the lack of standards to represent these data). Besides, these problems increase *in heterogeneous and decentralized contexts such as DLEs, or when the data is generated not only automatically through technological means but also ad-hoc by the participants*. The automation of the data gathering and integration tasks is considered to be a clear need due to: a) the complexity of the data gathering and integration; b) the time required to carry them out manually; and c) the teachers' restrictions (in terms of time available and the need to react on time during the enactment of the learning situation). To address this challenge, we have proposed an *architecture for data gathering and integration in DLEs* (see Section 4.5) that provides a conceptual solution for gathering and integrating participants' actions in CSCL DLEs. Since the scenarios in the exploratory studies all were supported by DLEs implemented using the GLUE! architecture to integrate external tools into VLEs, a compatible implementation of our data gathering and integration architecture, the *GLUE!-CAS* prototype (presented in Section 4.6.3) was developed to automate such tasks. This prototype was also used in the evaluative scenarios.

The evidence obtained from the evaluation studies points out that the architecture achieved its objectives both at design- and run-time. First, to support the design decisions, the *GLUE!-CAS* prototype allowed us to inform teachers about the monitorable actions of each VLE and tool that could be integrated via GLUE!. Then, during the enactment, thanks to the integration of computer-mediated actions and additional information provided by students and teachers, we could offer teachers a realistic view of the learning process. Nonetheless, new data could be gathered by means of the tool / learning environment adapters (e.g., developing new methods that provide further information about the users' actions), and developing specific tools to collect relevant monitoring information provided by teachers and students. Regarding the costs, the automation of the data gathering and integration reduced the teachers' workload in terms of the effort and time that they would have had to invest in order to obtain the same information. Although the data collection took a couple of minutes in the worst situation (depending on the speed of the Internet connection), such level of performance was acceptable for teachers. However, it would be necessary to improve the response time in case the teachers need the information in real-time. This *GLUE!-CAS* prototype *has shown the potential of the proposal to support the data gathering and integration in blended CSCL scenarios supported by DLEs*, thus fulfilling our third partial objective. It is also noteworthy that former versions of the architecture have already been presented in [RT11a] and [RT11b]. Also, several studies where the prototype was used (mainly related to the exploratory iterations) have been published [RT11c] [RT12a] [RT12b] [RT13a] [RT13b] [RT13a].

The fulfilment of the three partial goals of the thesis leads us to safely assert that *this dissertation has achieved its goal of providing teachers with design and enactment support capable of linking pedagogical intentions with monitoring needs for orchestrating blended CSCL scenarios supported by DLEs*. Nevertheless, we can also reflect on a number of lessons that we have learnt throughout the dissertation:

Regarding the design process and the limitations found to support teachers in authentic settings, we have learnt that the main drawback refers to the support of teachers in the selection of tools. Although the teacher may have an idea of the tools that she wants to include in the learning environment, it is unlikely that she knows about the monitoring information that may be extracted from the learning tool. We have developed an ad-hoc solution for GLUE! environments (*GLUE!-CAS*), wherein the monitoring description of the tools may be obtained from the adapters. Therefore, the developers of such adapters are in charge of providing such information. However, in order to support teachers in this endeavour, independently of a specific architecture, it is necessary to find more generic solutions. One possible option could consist in allowing teachers to look up the monitoring properties of the tools or even to discover new tools based on their monitoring needs. For example, *U-Seek* and *We-Share* are two applications that allow educators to retrieve and publish information about educational ICT tools [RC14]. Extending their underlying ontology with the monitoring features of the ICT tools, it would be possible to offer teachers with a sustainable solution that helps them select suitable tools taking into account both pedagogical and the monitoring concerns.

With respect to the monitoring of authentic learning scenarios, we have learnt about the importance of providing teachers with easy to interpret visualizations, complemented with contextual information that simplifies the regulation tasks (e.g., accesses to the tool instances or links the students' emails). Besides, taking into account the blended nature of the learning scenarios, we have become aware of the importance of enriching the computer-mediated evidence with the complementary views that teachers and students may offer. In this dissertation we have just scratched the surface of this "participants' involvement" in the monitoring process. Consequently, further research should be attempted in order to support the gathering (and allow the subsequent integration) of data directly provided by teachers and students. For example, the use of tools that support the creation and management of rubrics, such as *iRubric*[1], could be a first approach to collect this kind of data.

In relation with the technological architecture, we have identified several problems that hinder the data gathering and integration in DLEs. First, security and data privacy issues of data gathering should be addressed: usually, it is necessary to have special permissions in order to access the monitoring data, and such permissions are not granted in typical teachers' accounts. Thus, the DLE's security policies must be adapted in order to allow teachers (or the corresponding user in charge of monitoring) access to the necessary information. Other data gathering problems are related to data persistence (i.e., how long will the user action data be available from the tools) and the lifecycle of the tool instances (e.g., once a Google Document or a Moodle course is removed, no information can be obtained about them). Our current architecture proposal of the architecture collects data on demand; however, to avoid data loss, it would be more appropriate to adopt a mixed approach where the data is gathered on demand but also the tools (or the adapters) publish the information under certain circumstances (e.g., before the tool instance is deleted). In terms of integration, a problem, probably unavoidable in DLEs, deals with the participants' identification in the tools. On the one hand, many tools do not require logging, and therefore it is not possible to trace who has carried out each activity. On the other hand, in those tools where users have to log in, the problem appears with the identifiers: participants often do not have the same user identifier for every tool. Hence, it is necessary to take into account all the user identifiers from a single student in order to map the actions registered from the different tools to their corresponding owner.

This research work has been narrowly focused, from the pedagogical and technological point of view, on blended CSCL scenarios supported by DLEs. As we mentioned in Section 2.2, there were three main reasons that justify this decision: a) blended learning, CSCL and DLEs are trends increasingly adopted in learning scenarios; b) the orchestration of TEL scenarios is, itself, a complex and demanding tasks, and the combination of the aforementioned trends aggravates the complexity, effort, and time costs; c) the teachers' need of awareness information that helps them regulate the learning situation is a well-known grand challenge in the TEL community; moreover, in blended learning and CSCL scenarios, the information obtained from the technological environment may be insufficient in order to provide a representative view of the learning process (since part of it occurs face-to-face and may be not mediated by technologies); and, in addition, the use of DLEs increases the heterogeneity and decentralization of the monitoring data available in these scenarios, hindering the data gathering and analysis. Thus, our proposal has been devoted to support teachers in blended CSCL scenarios in DLEs because they are particularly challenging, but it also addresses common problems of CSCL and TEL. Although the studies carried out in this dissertation do not allow us generalize about the applicability of our proposal in different contexts, we envision that the contributions of this thesis could be also useful in other learning contexts, and we expect to explore it in our future work as we described in the following section.

[1]iRubric :`http://www.rcampus.com/indexrubric.cfm` (Last visit: 24 May 2014)

6.2 Future lines of work

Besides the aforementioned lessons learnt during the research process of this thesis, several issues and opportunities emerged that point out to future research lines. The most significant ones are presented below.

Enabling teachers to carry out the design of a monitoring process by themselves. Although our design and monitoring proposals (as they stand today) can be applied to a variety of scenarios, they still require a few manual steps that only a researcher/specialist may be able to take. Thus, in order to make this proposal fully operational for teachers, it is necessary to support both processes by automatic means. As a matter of fact, the main problem that hinders the short-term adoption of our proposal in teachers' practice is this lack of technological support to face the design and the monitoring process by themselves. A prototype of the first cycle of the design process has been implemented (by means of the *EdiT2++* tool). However, this partial implementation must be enriched with the second cycle and should be tested with actual teachers. In the monitoring process, the current *GLIMPSE* and *GLUE!-CAS* prototypes have been used by the researcher to generate monitoring reports, and so the next step is to generate usable versions of these tools that can be managed by teachers.

Refinement and identification of data analysis indicators. In this dissertation we have identified script constraints and monitoring needs that we have tried to inform using quite simple indicators (e.g., participation, collaboration, and use of resources). These indicators are especially focused on detecting evidence of student's actions. However, as we have noticed throughout the exploratory and evaluative studies, these indicators did not allowed the appearance of certain problems related to the quality of the student's actions. Thus, taking into account the data sources available in the learning scenario, new indicators should be found in order to analyse the quality of the actions. This research line is aligned with the current efforts of the Learning Analytics community in order to define a framework for quality indicators[2]. Besides, new script constraints and monitoring needs could emerged from the analysis of different scenarios. For example, it would be relevant to infer constraints from the roles adopted by/assigned to the students, and then obtain new indicators that connect the role with the expected behaviour. This approach could take advantage from the extensive research already done in the area of Interaction Analysis [Dim04a][MG09][Har13].

Offering more advance proposals for visualization of monitoring reports. Throughout this research process, we have provided teachers with visualizations which aimed to avoid hindering the interpretation of the monitoring results. To achieve this aim, we discussed about the visualizations with the teachers involved before and after each study, gathering feedback in order to improve how the information was presented and what additional information could help teachers in the monitoring and management tasks. Despite this preliminary work, more advanced proposals for visualisation of monitoring reports would be desirable in order to provide teachers (or other stakeholders) with more intuitive and user-friendly visualizations. For instance, using

[2]Learning Analytics Community Exchange (LACE project): `http://www.laceproject.eu/blog/towards-framework-quality-indicators-learning-analytics/` (Last visit: 25 May 2014)

graphical representations and offering different views of the learning process, not only focused on the activities but focused on the students or the learning resources, could be also relevant. Besides, special attention should be paid to the scalability of the visualizations (e.g., in terms of the number of activities, students, or resources) in order to offer generalizable proposals.

Extending the proposal to different educational levels (not only Higher Education). All the studies conducted in this dissertation have been performed in Higher Education contexts, even if the proposal itself is not necessarily tied to such educational level. During our work in the PREATY[3] project, we have identified that, despite the myriad of tools available to support the assessment for learning (such as monitoring tools), there still exists a gap in the application of these tools in Primary and Secondary School settings [RT13c]. Some of the causes of this gap are: the purpose behind the tools (many of them are thought for researchers), the lack of technical support, the language barriers (most of the tools are in English, while in many countries teachers do not necessarily speak this language), and that they have been created by and for the Higher Education context. Thus, we are currently exploring what are the teachers' monitoring needs and concerns at these other educational levels, and how our proposal may be adapted to address them.

Going beyond web learning environments. Up to now, we have tested our proposal in learning environments made up of VLEs and Web 2.0 tools. However, over the last two decades, there has been substantial progress in the development of technologies that enable learning across different spaces. For instance, the EEE[4] project deals with the combination of three different spaces: the web space, the 3D virtual space, and the augmented physical space. Yet other spaces may be taken into consideration, such as the ones generated by pervasive computing devices in smart classrooms (e.g., interactive tabletops and whiteboards). Therefore, another research line is the analysis of awareness needs imposed by these spaces and the integration of monitoring data from such contexts, as some other authors have already pointed out [MnC13b] [MM13].

Addressing other stakeholders. Our proposal has the ultimate aim of supporting teachers in the orchestration of the learning scenario. However, in many educational contexts the orchestration workload is relied partially or totally to other kinds of participants (e.g., students, in more student-centered pedagogies, or even parents or institutions) [Sha13]. Thus, it would be also interesting to collect their design decisions (to the extent that they can decide about them) and to address their monitoring interests. For example, in student-centric initiatives for individual or collaborative learning (e.g., the ROLE[5] and Metafora[6] projects), where the students organize their own work, it could be useful to provide information to them about the accomplishment of their plans in order to help them to self-regulate their learning.

[3]PREATY (Proposing modern e-assessment approaches and tools to young and experienced in-service teachers), LLP project:`http://www.preaty.org` (Last visit: 24 May 2014).

[4]EEE (Educational Reflected Spaces), Spanish national project:`http://eee.gast.it.uc3m.es/` (Last visit: 24 May 2014)

[5]ROLE (Responsive Open Learning Environments), FP7 project: `http://www.role-project.eu/` (Last visit: 24 May 2014)

[6]Metafora (Learning to learn together: A visual language for social orchestration of educational activities), FP7 project:`http://www.metafora-project.org` (Last visit: 24 May 2014)

From 'small' classrooms to massive courses. Another interesting challenge deals with the use of our proposal in Massive Open Online Courses (MOOCs), since a) they occur in decentralised, distributed teaching and learning networks, and b) they involve large numbers of people, and produce big volumes of data to analyse. These courses are usually structured a priori and the learning process is supported (at least in part) by the technological infrastructure of the MOOC providers. Thus, applying our proposal to these contexts would be mainly a matter of scalability. We envision that, adapting our proposal to the MOOCs, we could offer feedback to teachers (and students) about the learning process, helping them to better understand and assess the students' work, and maybe, in this way contributing to improve the low rates of completion.

Exploring different types of learning. In this dissertation we have tackled formal blended learning settings. However, our proposals could also be applied to other types of scenarios. For example, the I-Treasures[7] project explores innovative ways of teaching and learning intangible live expressions of cultural heritage (such as music, dance, singing, or craftsmanship). In order to promote the transmission of this know-how to apprentices, one of the main objectives of the project is the development of an appropriate methodology based on multi-sensory technology for the creation of information that has never been analysed or studied before. In such context our proposal could be useful to collect data from the multi-sensory technological context, and help apprentices compare their performances with the ones carried out by professionals in the area.

Gathering learning outcomes. In order to monitor and assess learning there are two main issues to be considered: how the learning process is carried out, which has been tackled in this thesis; and what are the outcomes of the learning process. This second part has been addressed in the technological context of DLEs by research works such as the NEXT-TELL[8] project or by [LA13]. We believe that joining both lines of work could help to achieve a more holistic support of teachers and students in the learning process.

Overall, this thesis has tried to address the problem of the alignment between teacher's pedagogical and monitoring concerns in blended CSCL scenarios supported by DLEs. We have proposed different solutions that aim to address the problem from three perspectives: the design of the learning scenario, the analysis of the learning process, and the technological context that supports the learning activities. In this endeavour we have tried to keep in mind the needs stated by our final users, involving the teachers throughout the different research stages. However, as we can see from the numerous list of outstanding questions and problems, we are still on the path towards a more complete understanding, and better solutions for the challenges addressed in this dissertation.

[7] I-Treasures (Intangible Treasures - Capturing the Intangible Cultural Heritage and Learning the Rare Know-How of Living Human Treasures), FP7 project: `http://www.i-treasures.eu` (Last visit: 24 May 2014).

[8] NEXT-TELL (Next Generation Teaching, Education and Learning for Life), FP7 project: `http://next-tell.eu/` (Last visit: 24 May 2014).

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Appendix A

Acronyms

Summary: In this appendix, we provide the meaning of some acronyms frequently used throughout the dissertation.

- **API:** Application Programming Interface
- **CMS:** Content Management System
- **CSCL:** Computer-Supported Collaborative Learning
- **CSCL-EREM:** Computer-Supported Collaborative Learning - Evaluand-Oriented Responsive Evaluation Model
- **C4LPT:** Center for Learning and Performance Technologies
- **C*i*:** Contribution number i
- **DBR:** Design-Based Research
- **DLE:** Distributed Learning Environments
- **EDM:** Educational Data Mining
- **ELI:** EDUCAUSE Learning Initiative community
- **EXP*n*:** EXPloratory study number n
- **EXQ_DAT.IT*i.j*:** EXploratory Question number j related to the DATa gathering and integration in DLEs, addressed during the iteration i
- **EXQ_DES.IT*i.j*:** EXploratory Question number j related to the DESign of blended CSCL scenarios supported by DLEs, addressed during the iteration i
- **EXQ_MON.IT*i.j*:** EXploratory Question number j related to the MONitoring of blended CSCL scenarios supported by DLEs, addressed during the iteration i
- **EV*n*:** EValuative study number n

- **EV_DAT.*j*:** EValuative Question number j related to the DATa gathering and integration in DLEs
- **EV_DES.*j*:** EValuative Question number j related to the DESign of blended CSCL scenarios supported by DLEs
- **EV_MON.*j*:** EValuative Question number j related to the MONitoring of blended CSCL scenarios supported by DLEs
- **GLIMPSE:** Group Learning Interaction Monitor for Pedagogical Scripting Environments
- **GLUE!:** Group Learning Unified Environment
- **GLUE!-CAS:** Group Learning Unified Environment- Collaboration Analysis Support
- **GLUE!-PS:** Group Learning Unified Environment - Pedagogical Scripting
- **ICT:** Information and Communication Technologies
- **JISC:** Joint Information Systems Committee
- **KSAs:** Knowledge, Skills and Abilities
- **LA:** Learning Analytics
- **LAK:** Learning Analytics & Knowledge
- **LD:** Learning Design
- **LMS:** Learning Management System
- **OBJ_DAT:** DATa gathering and integration OBJective
- **OBJ_DES:** DESign OBJective
- **OBJ_MON:** MONitoring OBJective
- **PBDP:** Pattern-Based Design Process of CSCL scripts
- **PLE:** Personal Learning Environment
- **RQ_DAT:** Research Question related to the DATa gathering and integration in DLEs
- **RQ_DES:** Research Question related to the DESign of blended CSCL scenarios supported by DLEs
- **RQ_MON:** Research Question related to the MONitoring of blended CSCL scenarios supported by DLEs
- **SoLAR:** Society for Learning Analytics Research
- **TAPPS:** Think Aloud Pair Problem Solving (CLFP)
- **TEL:** Technology-Enhanced Learning
- **TPS:** Think-Pair-Share (CLFP)
- **VLE:** Virtual Learning Environment

Appendix B

CLFP constraints

Summary: This appendix focuses on Collaborative Learning Flow Patterns, concretely on *Brainstorming, Jigsaw, Peer-review, Pyramid, Role-playing, TAPPS,* and *TPS.* The following sections include their definitions (extracted from [HL10a]) and a list of constraints that must be satisfied in order to achieve the pedagogical purposes of the pattern.

B.1 Introduction

As it has been already mentioned in Chapter 2, depending on the granularity or the detail level, pre-structuring collaboration can be accomplished in a coarse-grained process level (i.e. phases or flow of activities) and/or fine-grained level of detailed learning actions (actions within an activity) [Dil07b]. Collaborative Learning Flow Patterns, or CLFPs [HL05a], capture the essence of broadly accepted well-known techniques for structuring the flow of activities (collaborative and not) that comprise a collaborative learning situation. Instead of trying to create their own CSCL scripts from scratch, practitioners can use these patterns as a starting point. CLFPs can be used collectively in order to define richer collaborative learning flows, for instance hierarchically or sequentially, as the studies presented in this dissertation illustrate.

Several authors [Dil07b] [Dem08] [Kar09a] [PS11b] have analyzed scripts in order to identify which features are modifiable (extrinsic constraints) and which ones have to be accomplished in order to maintain their pedagogical intentions (intrinsic constraints). The determination of the script constraints has significant implications for the monitoring of the learning situation. In this appendix, we focus on determining which pattern constraints should take place in order not to compromise the fulfilment of a script based on CLFPs.

The following sections focus on seven CLFPs: *Brainstorming, Jigsaw, Peer-review, Pyramid, Role-playing, TAPPS,* and *TPS*. For each one of them, we will provide an overview of the pattern description, based on the one given by Hernández-Leo et al. [HL10a], as well as the list of pattern constraints that we have identified.

B.2 Brainstorming

Description

Overview. This pattern gives the collaborative learning flow for a context in which several participants face the generation of a large number of ideas.

Problem. Problem, whose solution is the generation of a large number of possible answers/ideas in a short period of time.

Educational benefits. The flow of collaborative learning activities to be followed in a *Brainstorming* should promote the following educational benefits:

- To encourage learners to take risks in sharing their ideas.
- To demonstrate students that their knowledge and their language abilities are valued and accepted.
- To teach acceptance and respect for individual differences.
- To focus students' attention on a particular topic.

Complexity. The *Brainstorming* entails low-risk. It is ideally suited for individuals who are new to collaborative learning.

Solution. The teacher asks a question that has a large number of possible answers. Students in the same group write down their answers until they run out of possible solutions. After the brainstorming, the teacher gives time for the team to review and clarify their ideas. If needed, the group can present the generated ideas to the rest of the class.

Guidelines for particularization, instantiation and execution. Several tasks should be performed: definition of objectives and prerequisites of the learning design; specification of each activity description (e.g., definition of the topic of the brainstorming); provision of necessary resources (contents and tools); decisions about completion of activities (e. g. control of time); and creation of particular brainstorming groups, binding each individual to a group.

Constraints

Based on the definition of the *Brainstorming* [HL10a], we obtained a list of constraints that must be satisfied to comply with this pattern. Table B.1 shows the pattern constraints that should be monitored in the different phases that constitute the learning flow.

Table B.1: List of constraints of the *Brainstorming* CLFP.

Structuring constraints	Description
$\forall group : size >= 2$	There must be enough participants to collaborate in each group.

B.3 Jigsaw

Description

Overview. This pattern gives the collaborative 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.

Problem. Complex problem/task that can be easily divided into sections or independent sub-problems.

Educational benefits. The flow of collaborative learning activities to be followed in order to solve a complex divisible task should promote the following educational benefits:

- To promote the feeling that team members need each other to succeed (positive interdependence)
- To foster discussion in order to construct students' knowledge
- To ensure that students must contribute their fare share (individual accountability).

Complexity. The *Jigsaw* entails high-risk. It is more appropriate for collaborative learning experienced individuals.

Solution. Each participant (individual or initial group) in a *Jigsaw group* studies or work around a particular sub-problem. The participants of different groups that study the same problem meet in an *Expert group* for exchanging ideas. These temporary focus groups become experts in the section of the problem given to them. At last, participants of each *Jigsaw group* meet to contribute with its expertise in order to solve the whole problem.

Guidelines for particularization, instantiation and execution. Several tasks should be performed: definition of objectives and prerequisites of the learning design; specification of each activity description (definition of global problem, subproblems, etc.); provision of necessary resources (contents and tools); decisions about completion of activities (e.g. control of time); creation of particular *Jigsaw group*, binding of expert type to each member of the groups (and thus creating *Expert groups*).

Constraints

Based on the definition of the *Jigsaw* [HL08] and on the literature review [Alv09] [PS11b], we obtained a list of constraints [Dil02a] that must be satisfied to comply with this pattern. Table B.2 shows the pattern constraints that should be monitored in the different phases that constitute the learning flow.

B.4 Peer-review

Description

Overview. This pattern proposes a collaborative learning sequence that can be used in a context in which the students have similar knowledge and experience.

Problem. How to involve students in the assessment process, so that each review their partners.

Educational benefits. The flow of collaborative learning activities to be followed in a *Peer-review* should promote the following educational benefits:

- To practice writing (to write feedback for their partners).
- To promote analysis and critic assessment.
- To foster reasoning and argumentation.

Complexity. The *Peer-review* entails high-risk. It is more appropriate for collaborative learning experienced individuals.

Solution. Each participant or group develops a solution or document to a problem (this activity is actually previous to this CLFP). Then, reviewers are assigned so that every group reviews at least one document and every group receives at least one review. Each reviewer is given the document to review, reads it, and produces feedback for the author. Groups analyse the received feedback and discuss the feedback with reviewers. Finally, the solution is improved taking into account the reviewers' feedback.

Guidelines for particularization, instantiation and execution. Several tasks should be done: choose the activity in which the solution is produced; determine the type of review; complete the description of the activities; create the needed groups; link authors and reviewers; and ensure that the reviewers will have access to the documents they have to review.

Table B.2: List of constraints of the *Jigsaw* CLFP. **X** represents that the restriction must be satisfied in that specific phase of the pattern (individual, expert and jigsaw).

Constraints	Individual	Expert	Jigsaw	Description
group sizes		**X**	**X**	There must be enough participants to collaborate.
expert group sizes		**X**	**X**	The group sizes must be large enough to provide at least one expert to each jigsaw group.
jigsaw group sizes			**X**	The group sizes must be large enough to gather experts from all areas.
no. of subproblems	**X**	**X**	**X**	There must be at least 2 subproblems but no more than half the number of participants to allow for collaboration in the expert groups.
no. of expert groups	**X**	**X**	**X**	There must be at least one group of experts for each subproblem but no more than half the number of participants to allow for collaboration in the expert groups.
no. of jigsaw groups			**X**	The number of jigsaw groups must be in accordance with the number of experts of each area.
group dependences			**X**	There must be experts of all areas in each jigsaw group.
expert group collaboration		**X**	**X**	There must be collaboration between at least one member of each jigsaw group.
jigsaw group collaboration			**X**	There must be collaboration between at least one expert on each subproblem.

Table B.3: List of constraints of the *Peer-review* CLFP.

Constraints	Description
$\lvert groups \rvert >= 2$	There must be at least two groups to carry out the review process.
$\forall group : size >= 1$	There must be at least one participant in each group.
$\forall group : \exists documentToReview$	Every group must review at least one document.
$\forall documentToReview : \exists groupOfReviewers$	Every document must be reviewed by at least one group.

Constraints

Based on the definition of the *Peer-review* [HL08] and on the literature review [Dem08] [Kar10], we obtained a list of constraints [Dil02a] that must be satisfied to comply with this pattern. Table B.3 shows the pattern constraints that should be monitored in the different phases that constitute the learning flow.

B.5 Pyramid

Description

Overview. This pattern gives the collaborative learning flow for a context in which several participants face the collaborative resolution of the same problem.

Problem. Complex problem, usually without a concrete solution, whose resolution implies the achievement of gradual consensus among all the participants.

Educational benefits. The flow of collaborative learning activities to be followed in order to solve a complex task, whose resolution implies the achievement of gradual consensus, might promote the following educational benefits:

- To promote the feeling that team members need each other to succeed (positive interdependence).
- To foster discussion in order to construct students' knowledge.

Complexity. The risk involved in structuring collaboration so that a gradual consensus is achieved is medium. Therefore, the experience needed in collaborative learning is not too high.

Solution. Students start (individually or forming an initial small group) studying the problem and proposing an initial solution. Groups of participants compare and discuss their proposals and, finally, propose a new shared solution. Those groups join in larger groups in order to generate new agreed proposal. At the end, all the participants must propose a final and agreed solution.

Guidelines for particularization, instantiation and execution. Several tasks should be performed: determination of the levels of the *Pyramid* (at least 2); definition of objectives and prerequisites of the learning design; specification of each activity description (definition of global problem, etc.); provision of necessary resources (contents and tools); decisions about completion of activities (e. g. control of time); creation of actual groups and binding of participants to the groups of each level of the *Pyramid* .

Constraints

Based on the definition of the *Pyramid* [HL08] and on the literature review [Dem08] [Kar10], we obtained a list of constraints [Dil02a] that must be satisfied to comply with this pattern. Table B.4 shows the pattern constraints that should be monitored in the different phases that constitute the learning flow.

B.6 Role-playing

Description

Overview. This pattern gives the collaborative learning flow for a context in which the members of one or several groups perform a character in a simulation, a.k.a *Role-playing* .

Problem. Problem whose resolution implies the simulation of a situation in which several characters are involved.

Educational benefits. The flow of collaborative learning activities to be followed in order to solve a task, whose resolution implies the *Role-playing* of a situation in which several characters are involved, might promote the following educational benefits:

- To promote the feeling that team members need each other to succeed (positive interdependence).
- To ensure that students must contribute their fare share (individual accountability).
- To help students feel as well as understand the dynamics of a complex situation

Complexity. The risk involved in charring out a *Role-playing* is medium or high. Role-plays are usually hard to organize in large classes and that students may feel too shy or too time restricted to participate effectively in real-time simulations.

Table B.4: List of constraints of the *Pyramid* CLFP. **X** represents that the restriction must be satisfied in the different levels of the *Pyramid* .

Constraints	**Level** 1	**Level** $1 < i < n$	**Level** n	**Description**
$\forall group : size >= 1$	**X**	**X**	**X**	Every group must have participants to ensure the continuity of the next level (there cannot be empty groups).
$\forall group : size >= 2$		**X**	**X**	There must be enough participants to collaborate.
$\lvert groups(level1)\rvert <= \lvert groups(leveli-1)\rvert/2$		**X**	**X**	The number of groups must decrease in each level at least to the half part of the previous level.
$\forall group : group >= \sum groups(leveli-1)$		**X**	**X**	Each group must be formed by at least two groups from the previous level to enable interchange of ideas.
$\forall group : individualparticipation >= 2$	**X**	**X**	**X**	There must be collaboration between at least 2 participants (whenever the activity social level is not individual).
$\forall group : groups(leveli-1)participation >= 2$		**X**	**X**	There must be collaboration between at least 2 groups from the previous level.

Table B.5: List of constraints of the *Role-playing* CLFP.

Structuring constraints	Description
$\forall group : size >= 2$	There must be enough participants to collaborate in each group.
$\forall group : \forall rol \exists student$	There must be at least one role for each student.
$\forall group : \forall student \exists rol$	There must be at least one student for each role.
$\lvert groups \rvert >= 2$	There must be at least two groups to discuss about the simulation.

Solution. Each participant consults information about the problem to be simulated and prepare the role of their character. Then, the participants in the same simulation group (usually small groups) perform a particular situation related to the problem. After that, the trained simulations can be performed to the rest of the class (large group). Finally, the whole class can discuss and share their conclusion about the problem.

Guidelines for particularization, instantiation and execution. Several tasks should be performed: determination of the number and name of roles and simulation small groups; definition of objectives and prerequisites of the learning design; specification of each activity description (definition of situations to be simulated with the same roles); provision of necessary resources (contents and tools); decisions about completion of activities (e. g. control of time); and binding persons to roles and simulation groups.

Constraints

Based on the definition of the *Role-playing* [HL10a], we obtained a list of constraints that must be satisfied to comply with this pattern. Table B.5 shows the pattern constraints that should be monitored in the different phases that constitute the learning flow.

B.7 TAPPS: Think Aloud Pair Problem Solving

Description

Overview. This pattern gives the collaborative learning flow for a context in which students are paired and given a series of problems.

Problem. A series of problems, whose solutions imply reasoning processes.

Educational benefits. The flow of collaborative learning activities to be followed in order to solve a series of problems whose solutions imply reasoning processes, might promote the following educational benefits:

- To foster discussion in order to construct students' knowledge.
- To permit students to rehearse the concepts and produce a deeper understanding of the material.
- To encourage analytical reasoning skills.
- To support problem solving skills.

Complexity. The risk involved in structuring collaboration so that a series of problems are reasoned in pairs is medium. Thus, the experience needed in collaborative learning needed is not too high.

Solution. Students are paired and given a series of problems. The two students are given specific roles that switch with each problem: *problem solver* and *listener*. The problem solver reads the problem aloud and talks through the solution of the problem. The other (the listener) follows all of the problem solver's steps and catches any errors that occur. The listener may ask questions if the problem solver's thought process becomes unclear. The question asked, however, should not guide the problem solver to a solution nor should they explicitly highlight a specific error except to comment that an error has been made.

Guidelines for particularization, instantiation and execution. Several tasks should be performed: determination of number of problems (and thus, phases); definition of objectives and prerequisites of the learning design; specification of each activity description (definition of problems, etc.); provision of necessary resources (contents and tools); decisions about completion of activities (e. g. control of time); creation of groups (pairs) and binding individuals to pairs.

Constraints

Based on the definition of the *TAPPS* [HL10a], we obtained a list of constraints that must be satisfied to comply with this pattern. Table B.6 shows the pattern constraints that should be monitored in the different phases that constitute the learning flow.

B.8 TPS: Think-Pair-Share

Description

Overview. This pattern gives the collaborative learning flow for a context in which students are paired to solve a challenging or open-ended question.

Table B.6: List of constraints of the *TAPPS* CLFP.

Structuring constraints	Description
$\forall group : size >= 2$	There must be at least one participant in each group.
$\|phases\| >= \|problems\|$	There must be enough phases to allow students deal with the assigned problems.
$\forall group : size <= \|phases\|$	There must be enough phases to allow students adopt problem solver and listener roles.

Problem. A challenging or open-ended question.

Educational benefits. The flow of collaborative learning activities to be followed in order to solve a challenging or open-ended question, might promote the following educational benefits:

- To promote the feeling that team members need each other to succeed (positive interdependence).
- To foster discussion in order to construct students' knowledge.
- To focus students' attention on a particular topic.
- To give a chance to formulate answers by retrieving information from long-term memory.

Complexity. The *TPS* pattern entails low risk. Therefore, it may be ideally suited for individuals who are new to collaborative learning.

Solution. Each participant has time to think about the question. They pair and discuss their ideas about the question. (They could write down their thoughts.) Then, they comment or take a classroom "vote". Students are much more willing to respond after they have had a chance to discuss their ideas with a classmate because if the answer is wrong, the embarrassment is shared. Also, the responses received are often more intellectually concise since students have had a chance to reflect on their ideas with the one another.

Guidelines for particularization, instantiation and execution. Several tasks should be performed: definition of objectives and prerequisites of the learning design; specification of each activity description (definition of the question, etc.); provision of necessary resources (contents and tools); decisions about completion of activities (e. g. control of time); creation of groups (pairs) and binding individuals to pairs.

Table B.7: List of constraints of the *TPS* CLFP.

Structuring constraints	Description
$\forall group : size >= 2$	There must be enough participants to collaborate in each group.
$\|groups\| >= 2$	There must be at least two groups to carry out the vote.

Constraints

Based on the definition of the *TPS* [HL10a], we obtained a list of constraints that must be satisfied to comply with this pattern. Table B.7 shows the pattern constraints that should be monitored in the different phases that constitute the learning flow.

Appendix C

First exploratory study

Summary: In this appendix, we include the details of the first exploratory study. This study belongs to the first exploratory iteration and, therefore, focuses on two main issues: (1) to identify what script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs; and (2) to find out what are the required conditions for collecting relevant information of the participants' collaboration in a blended CSCL scenario supported by DLEs. The study took place in 2010, within a course of the Telecommunications Engineering degree, at the University of Valladolid (Spain), with 2 expert teachers in CSCL and 46 students. The following sections describe the context and methodologies, the different stages of the study, and the main data sources collected. To conclude, we present the findings of the exploratory work, where we discuss about what aspects of the CSCL script teachers took into account in the design and what additional information could have contributed to improve monitoring; we reflect on whether the accomplishment of the pattern constraints is relevant for the teachers and sufficient to detect the problems that emerged during the learning situation; and finally, we analyse how the analysis of computer-mediated actions registered in the DLE can be automated, and how these actions may inform the monitoring process of a blended CSCL scenario.

C.1 Context and methodologies of the study

The first study took place within a third-year (out of five) course on "Network traffic and Management" of Telecommunications Engineering degree, at the University of Valladolid (Spain). The learning scenario was carried out in November 2010, from the 4th to the 10th. Two teachers with previous experience in CSCL and 46 students attending the course were involved. To preserve teachers' and students' anonymity, we have modified their names. We will refer to the teachers as *Daniel* and *Javier* (respectively, T1 and T2 in Figures 1.2 and 3.1) and the students will be labelled from *Student1* to *Student46*.

In Daniel and Javier's course, students had to develop a chat tool using data network protocols. In order to help them plan and anticipate problems for a subsequent programming assignment, the teachers planned a preparatory set of collaborative activities where the students (in groups) had to elaborate an agreed software design, and review their classmates' proposals.

In previous years, these activities were carried out using sheets of paper that: first, each group used a paper sheet to describe the software design, and later the sheets were exchanged with other groups for peer review purposes. During this course, Daniel and Javier wanted to support technologically the activities, concretely using the institutional VLE (Moodle) and on-line documents (Google Documents) and boards (Dabbleboard) that could facilitate the collaborative work and the data sharing.

To build the DLE, Daniel and Javier had at their disposal the GLUE! architecture, that could aid them in the creation and integration of the documents and boards into the VLE. However, an issue remained open: adapting the DLE to emerging problems or needs could require too much time (e.g., a variation in the members of one group would imply, among other tasks, modifying the group configuration in Moodle and the permissions over the group resources), especially if teachers had to do it real-time. Besides, the proposed activities were not mandatory for the students to pass the course, and thus student participation was not ensured. To address this problem, two researchers monitored the learning scenario, trying to identify in advance potential problems that could require changes in the design and, consequently, in the technological support.

As we already mentioned in Chapter 3, two were the main questions that we explored in this study: on the one hand, we tried to identify what design decisions could guide us to focus the monitoring process in the detection of critical situations that could jeopardize the CSCL script [EXQ_MON.IT1]; on the other hand, we attempted to find out what were the required conditions for collecting relevant monitoring data about the participants' collaboration, taking into account that it was a blended scenario supported by a DLE [EXQ_DAT.IT1]. These exploratory questions were split into more concrete questions, that are shown in Figure C.1.

To answer these questions, we gathered several data sources throughout the study. At design time, two researchers (R1 and R2) observed the design sessions to collect and understand the teachers' decisions [EXP1_T_LD]. During the enactment, one researcher (R1) monitored the learning process by means of the logs obtained from the ICT tools (i.e, the diagrams, reports, reviews and presentations) [EXP1_IT_LOG]. Our monitoring results were triangulated with data coming from observations of the face-to-face activities [EXP1_R1_OBS, EXP1_R2_OBS], the learning outputs generated in the ICT tools [EXP1_IT_LO], the feedback obtained from the teachers at run-time [EXP1_T_FEE], and an interview with group of students that voluntarily participated at the end of the activity [EXP1_S_INT]. Figure C.1 presents an overview of the data sources, the moments in which they were collected and the exploratory questions that they answer.

The following sections of this Appendix describe the work done in the different phases of the study as well as the main findings obtained in relation to the exploratory questions.

C.2 Design-time

Two researchers (R1 and R2) observed the design sessions in order to gather and understand the design details and to be aware of the technological context that was going to support the scenario. Six sessions (lasting 7 hours in total) were held involving not only taking pedagogical

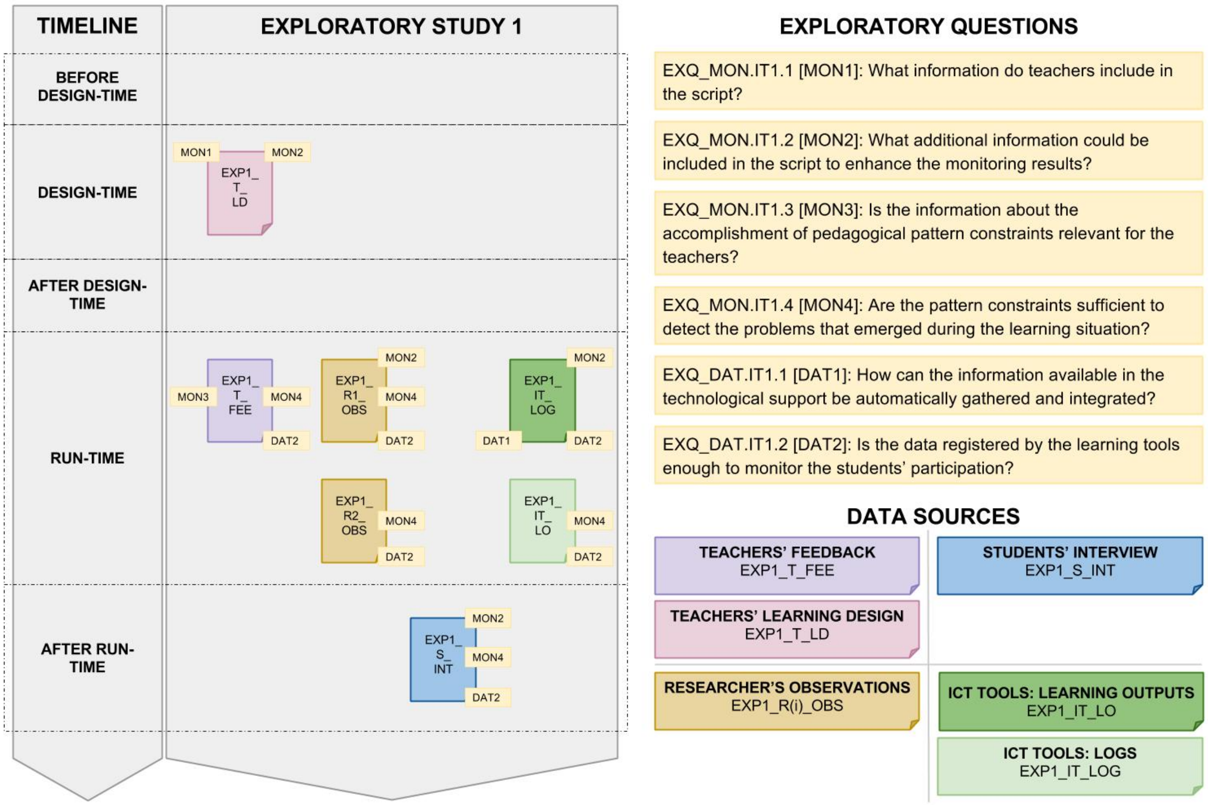


Figure C.1: First exploratory study: data sources and exploratory questions.

decisions (done without any authoring tool), but also building and configuring the DLE (using GLUE!).

The process followed by Javier and Daniel was divided into 3 steps: first, they defined the general basis of the learning scenario, choosing the pedagogical patterns to be applied, the activity flow (sequence of activities), the ICT tools that made up the DLE, and the group formation policies (size and number of groups). Second, they addressed the description of each activity (including their purpose and the social level), the dates of the lab sessions, and the relationship between sessions and activities. Finally, the teachers proceeded to distribute the students into groups, created as many tool instances, and assigned them to the respective group.

The collaboration script implemented a three-level *Pyramid* CLFP [HL10a]. At level-1, *small groups* of 2 participants attended to a face-to-face lab session to carry out the first activity. In this activity, students had to draw a preliminary version of the sequence diagram and write a report with a summary of the main decisions and open issues. At level-2, groups joined to conform *super groups* (composed of 3-4 small groups) that had to accomplish both a distance and a face-to-face activity. During the former, each *small group* had to review and provide feedback on the reports produced by their *big-group* mates (implementing itself a *Peer-review* CLFP [HL10a]); in the latter, they had to discuss and produce a joint version of the diagram, as well as a presentation with the conclusions and open issues. Finally, at level-3, each group had to present their work to the classroom at the end of the lab session. Table C.1 describes the

Table C.1: Overview of the activities included in the script of the first study. The phases correspond with the pyramid levels.

Phase	Activity	Social level	Interaction	Learning	Resources & tools for learners
1.1	First proposal	Small group	Blended	Face-to-face	- 24 Dabbleboards (1/small group) - 24 Google Docs (1/small group)
2.1	Peer review	Small group	Computer-mediated	Distance	- 24 reused Google Docs (1/small group)
2.2	Second proposals	Super group	Blended	Face-to-face	- 7 Dabbleboards (1/super group) - 7 Google Pres (1/super group) - 24 reused Dabbleboards (1/small group) - 24 reused Google Docs (1/small group)
3.1	Final proposal	Whole class	Face-to-face	Face-to-face	- 7 reused Google Pres (1/super group)
					TOTAL= 141 instances

script in general terms.

Regarding the technological support, teachers used the institutional VLE (*Moodle*) to centralize the access to all the resources and activities. To accomplish the drawing tasks, students were provided with a shared board (*Dabbleboard*) and, in order to explain, review and discuss, they had at their disposal shared documents and presentations (*Google Documents* and *Google Presentations*). Since these tools are not integrated in Moodle, the *GLUE!* architecture [AH10b] was used to integrate them into the VLE. Table C.1 summarizes the resources created in each activity.

C.3 After design-time

Based on the script description, we tried to identify which were the critical points that could jeopardize the learning scenario, and what information could be obtained from the learning environment that could help us detect emerging problems.

Regarding the requirements that should be achieved in order to accomplish the script purposes, we hypothesised that the patterns implemented by the script could provide us some hints in this regard. Since the collaboration script implemented a three-level *Pyramid* and a *Peer-review* CLFP [HL08] in one of the phases, we analysed the definition of these patterns and obtained the constraints that must be verified during the enactment[1].

The *Pyramid* CLFP defines a collaborative learning flow for a context in which several participants face the same problem, whose resolution implies the achievement of gradual consensus [HL10a]. Therefore, the pattern defines a sequence of at least two phases with some particular collaboration objectives, as well as a rule for structuring groups. In the case of the *Peer-review* [HL10a], the pattern imposes that each group plays the role of reviewer and also

[1]Further information about CLFPs definition and constraints is available in Appendix B.

Table C.2: Constraints derived from the particularization of patterns in the first study.

1.	*Pyramid levels and group formation policies:* - Level 1: 24 small groups of 1-2 participants - Level 2: 7 super groups of 3-4 small groups - Level 3: 1 whole class of 7 super groups
2.	*Activity description:* - Act 1.1: small-groups draw a sequence diagram and write a report - Act 2.1: small-groups review and provide feedback on their big-group mates' reports - Act 2.2: big-groups discuss, produce an agreed diagram, and prepare a presentation - Act 3.1: whole-class discusses about presentations made by each big-group
3.	*Activity interaction type:* - Act 1.1: face-to-face and resource mediated (Dabbleboard, Google Documents) - Act 2.1: distance and resource mediated (Google Documents) - Act 2.2: face-to-face and resource mediated (Dabbleboard, Google Presentations) - Act 3.1: face-to-face and resource mediated (Google Presentations)

receives feedback on its own proposal. While the analysis of the pattern constraints is available in Sections B.5 and B.4, Table C.2 summarizes the constraints derived from the adaptation of the patterns to the particular context.

Aware of the pattern constraints, we tried to identify whether the information available in the technological environment could provide us with useful insights for monitoring the learning scenario. As mentioned in section C.1, the software used to support the learning scenario included a VLE (Moodle), a number of external Web 2.0 tools (Dabbleboard, Google Documents and Google Presentations), and an implementation of the GLUE! architecture for the integration of external tools into the VLE. Table C.3 describes both the kind of monitoring data and the way in which these tools provided access to this information. It is noteworthy that this description corresponds to the moment when the experiment happened (November, 2010). These tools and the information offered have changed over the next years, as we will see in other studies included in this dissertation.

Table C.3 shows the high heterogeneity of both the data provided and the harvesting methods: for example, Dabbleboard did not provide any kind of user activity data and Google applications did not offer a programmatic interface to obtain this information. Regarding Moodle, it would have been necessary to query the database manually in order to complete the history information offered by the VLE. Taking into account that GLUE! offers largely the same information that could have been obtained from Moodle, we decided to use GLUE! as the sole source of activity data. Since GLUE! registered every access to the instances of the integrated tools (Dabbleboard and Google suite in this case), the computational monitoring of the collaboration, in this case study, was based on the evidence of instance accesses provided by GLUE!.

Table C.3: Description of the software used in the first study in terms of (1) the information provided about the user activity and (2) the way this information is accessible.

Software	User activity information	Retrievable from
Dabbleboard	None	Not possible
Google Tools	Document revision history: *user, date, time and document version*	User interface
Moodle	Event history: *date, time, IP address, user name, action, resource used*	User interface or database
GLUE!	History of accesses to the integrated resources *user, date, time, resource*	Event logs

The selection of the indicators used for monitoring students was based on the pattern constraints. Tables C.4 and C.5 present indicators related to some aspects (activity flow, the collaboration, and the group formation policies) and how they were used to define the current and desired state of the interaction. For instance, current collaboration is measured by the actions mediated by shared resources. On the other hand, the desired state of the interaction is derived from the values of the script parameters defined at design time. For example, if the activity is collaborative, there should be evidence of at least two students participating.

Instead of providing a qualitative interpretation of the achievement of the identified aspects, the main role of the aforementioned indicators is to detect when there is no evidence of a specific type of activity taking place (e.g., one student has not submitted its assignment). This is complemented by showing the teachers very simple data (e.g., number of accesses to a resource), that they are expected to interpret in their own contexts. We should take into account that the data obtained from the DLE was very simple and incomplete (part of the students' interaction happened face-to-face). Thus, more complex data analysis could lead to unreliable results.

Figure C.2 illustrates the connections between the pattern constraints and the students' monitorable actions. The expected collaboration is represented by the dashed orange arrows, highlighting those key collaborative aspects to be monitored. The specific sequence of activities, the resources required for each one of them, and the way the students are grouped are derived from the particularization and instantiation constraints (see Table C.2). Finally, among all the expected ways of collaboration, continuous black arrows point to the information that might be collected in order to detect collaboration evidence.

C.4 Run-time

At run-time two researchers (R1 and R2) monitored the learning scenario in order to detect potential problems that could jeopardize the script. On the one hand, R1 retrieved and interpreted the content of the GLUE! logs [EXP1_IT_LOG]. The analysis of the logs focused on detecting evidence related to the pattern constraints by means of the accesses to the shared resources.

Table C.4: Definition of the current state of the interaction according to the indicators related to participation and collaboration.

Participation: applied to individuals or groups depending on the social level.

- **Individual participation**: the involvement of each participant in the activity is measured by:
  - *The number of actions that (s)he performs:* $\{\sum \text{action}|\text{action.actor.id} = \text{participant.id}\}$
- **Group participation**: the involvement of each group in the activity is measured by:
  - *The number of actions that the group members perform:* $\{\sum \text{action}|\text{action.creator} \subseteq \text{group.participants}\}$

Collaboration among group members: for each group, the collaboration is measured by the actions in shared resources between group members (individuals or subgroups, depending on the social level):

- *The actions that the group members perform:* $\{\sum \text{action}|\text{action.creator} \subseteq \text{group.participants}\}$
- *The actions that involve shared resources in the group:* $\{\sum \text{action}|\text{action.resource} \in \text{group.resources\_to\_be\_monitored}\}$

Group formation: for each activity, it is necessary to control the group formation policies, e.g., the group size.

- **Group size**: the size of the groups is measured by the number of group members (individuals or subgroups depending on the social level) that are participating:
  - *The number of individuals who have participated:* $\{\sum \text{participant}|(\text{actor.id} = \text{participant.id})\ \&\ (\text{action.actor} > 0)\}$
  - *The number of subgroups who have participated:* $\{\sum \text{subgroups}|(\text{group.id} = \text{subgroup.id})\ \&\ (\text{action.group} > 0)\}$

Table C.5: Conditions associated to the considered indicators based on their expected values, i.e., the pattern constraints.

Participation: depending on the social level (individual/group), the expected participation values are:

- **Individual participation**:
  - *for each participant*: If activity.social_level = individual $\rightarrow$ participant.participation ≥ 1
- **Group participation**:
  - *for each small group*: If activity.social_level = (small_group or big_group) $\rightarrow$ group.participation ≥ 1
  - *for each super group*: If activity.social_level = (big_group or whole_class) $\rightarrow$ group.participation ≥ 1

Collaboration among group members: if the activity is collaborative, for each group the expected collaboration values are:

- *At least two group members participate*: If (activity.social_level $\neq$ individual) $\rightarrow$ $\{\exists$participant1, participant2$|$ (participant1.participation ≥ 1) & (participant2.participation ≥ 1)$\}$

Group size:

- *for each activity*: If activity.social_level = small_groups $\rightarrow$ group.size ≥ 1 participant
- *for each activity*: If activity. social_level = big_groups $\rightarrow$ group.participation ≥ 2 small_groups

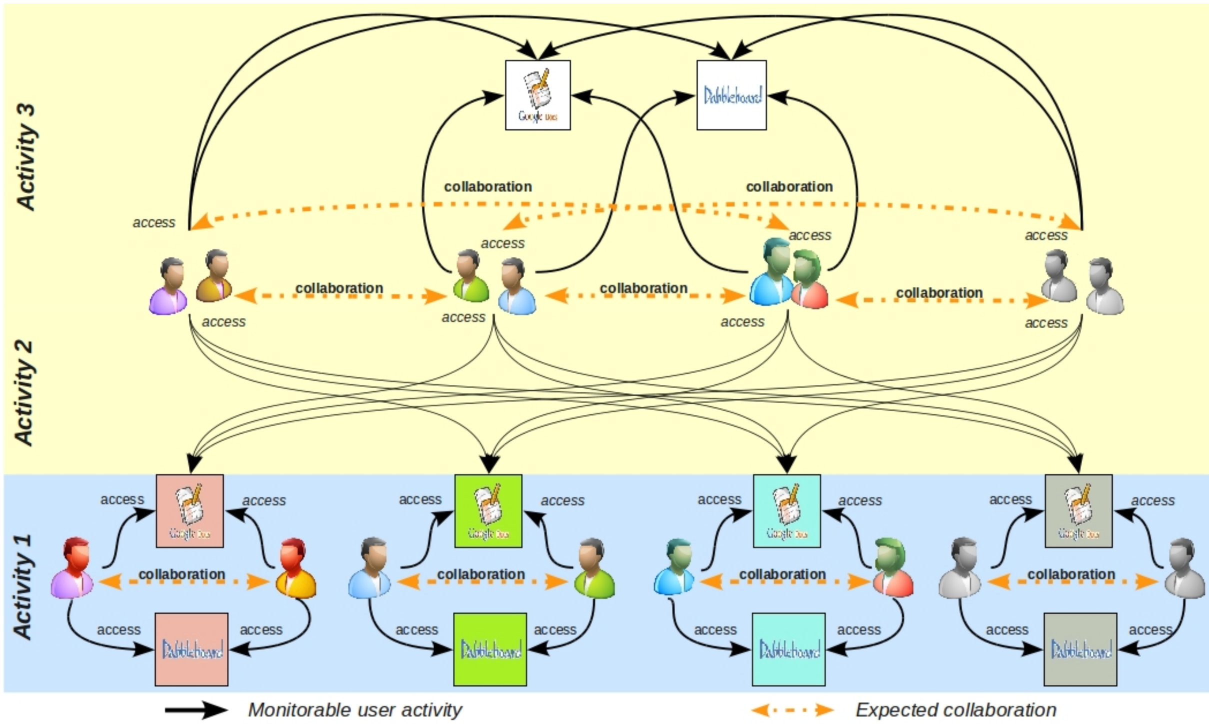


Figure C.2: Graphical representation of the expected students interaction and the monitorable actions from Activity 1.1 to Activity 2.2.

On the other hand, R1 and R2 observed the lab sessions [EXP1_R1_OBS, EXP1_R2_OBS], paying special attention to how students interacted, and surveilled the work done by the students in the instances of Dabbleboard, Google Documents and Google Presentations [EXP1_IT_LO]. These different data sources allowed us to validate the monitoring results obtained from the log analysis.

Although we could not provide feedback to the teachers in real-time about the monitoring results (especially in the face-to-face activities due to the time restrictions), Daniel and Javier were informed periodically about the potentially undesired situations that we detected throughout the 4 activities[2]. Being aware of these situations, they reviewed carefully the resources of those groups that showed irregularities, to confirm (or not) our assumptions. In case of confirmation, teachers took preventive measures (e.g., by sending to the students a reminder of the deadlines or asking them whether they had found any problem during process to finish the activity), adapted the script (e.g., delaying deadlines, re-structuring groups) and the DLE (e.g., modifying the groups in Moodle and creating new resources).

Table C.6 shows the detected problems using the (system) logs. This results were compared with the information obtained from the observations and the learning outputs in Dabbleboard, Google Documents and Google Presentations. We found out that in those cases where monitorable data showed expected behaviour, participants had actually collaborated following the script (except in one case), as extracted from the attendance to the lab sessions and the evidence

[2]An anonimized version of the monitoring reports is available in the additional material attached to this document. See Appendix H

Table C.6: Monitoring results based on the GLUE! logs: detected problems, false positives and undetected problems.

Data sources	Problem type	Activity 1.1	Activity 2.1	Activity 2.2	Activity 3.1
Detected problems (based on logs)	Individual participation	17	28	28	42
	Small Group participation	7	16	9	19
	Big Group participation	-	1	1	4
	Group collaboration	12	5	1	5
False positives	Individual participation	4	**	14	28
	Small Group participation	0	0	2	12
	Big Group participation	-	0	0	3
	Group collaboration	4	0	0	4
Undetected problems	Small Groups that did not complete the activity	0	1	0	0
	Big Groups that did not complete the activity	-	0	0	0

obtained form the learning outputs. Furthermore, almost every case of collaboration breakdown had been detected based on the monitorable data. However some cases that had been interpreted as potentially critical situations were indeed 'false positives'.

According to the observations, students arrived late to the lab session and some groups were not able to finish on time. Teachers emphasized the importance of finishing the first activity in order to continue with the second one [EXP1_R1_OBS], and allowed the students to continue on-line with an extended deadline [EXP1_R1_OBS]. Daniel and Javier also remarked to the students that during the following activity (peer review) they should provide comments to the work developed by their big-group mates.

In order to monitor the scenario, R1 and R2 devoted 3 hours to analyse the logs, 45 minutes to check whether the students had carried out the learning tasks as it was expected, and 1'5 hours to triangulate the information obtained from these two sources and the participation evidences obtained from the observations.

When the first activity was about to end (and before receiving the monitoring reports), teachers told us that, according to the participation to the lab session, they foresaw that some small groups were not involved in the activity and it could affect some super groups [EXP1_T_FEE]. In addition, they told us that, aside from the general impression they had from the (previous) lab session, they had no additional input about the progress of the scenario (no news from the students, e.g., via mail).

By means of the aforementioned data sources, we detected some potentially critical situations, as it is summarized in Table C.6. For instance, in Big Group C only one of the small groups interacted with the resources, so that they had no group to collaborate with in the following activities; and in Big Group D, Small Group 12 had drawn the diagrams in Dabbleboard but had not even accessed their Google Documents to generate the report. In group D there were just two small groups actively involved; hence, if Small Group 12 did not finished the activity, it would be necessary to relocate Small Group 14. Figures C.3 and C.4 display the actual

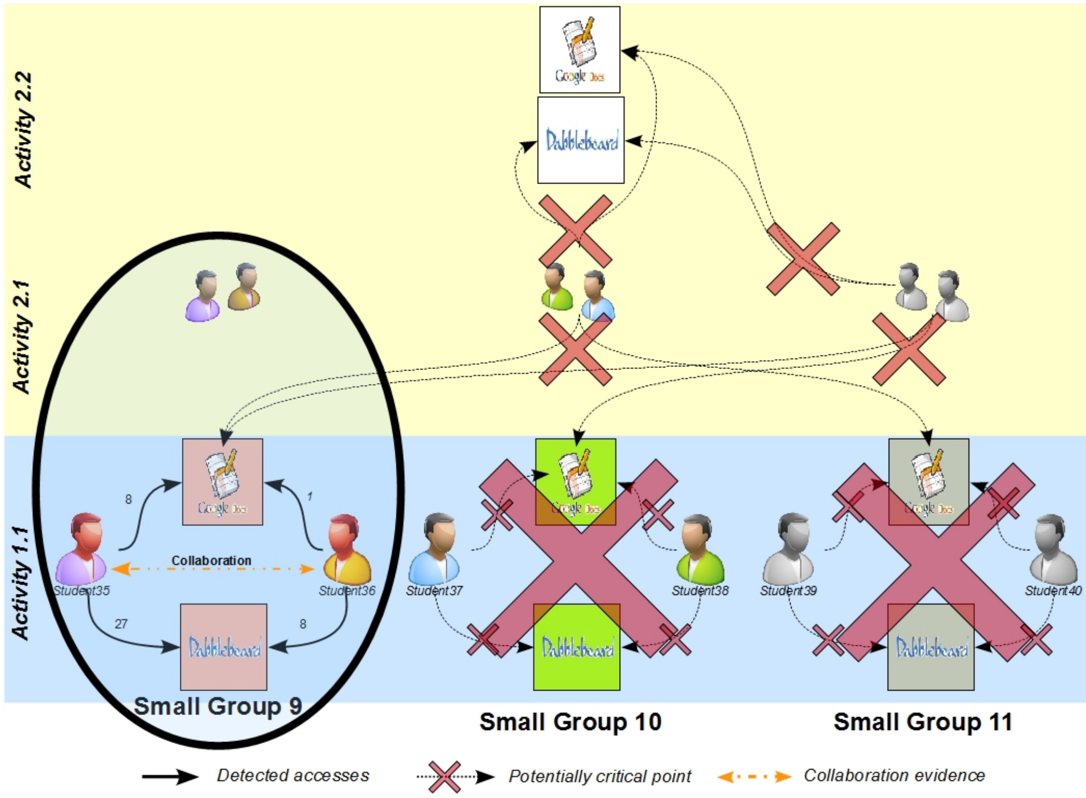


Figure C.3: Monitoring report of Big Group C that participated in the case study. After the first activity, the Small Group 9 was moved to Big Group B.

collaboration of Big Group C and D from Activity 1.1 to Activity 2.2. The labels on the links specify how many times each participant (or group) accessed the resource. Red crosses over a dotted line represent those cases where no evidence of collaboration could be deduced from the collected data.

Aware of this information, Daniel mailed the students to inform about the non-finished documents and to urge them to complete the activity. Besides, teachers decided to re-structure the group C, were there was an isolated small group, because otherwise they would be alone during the rest of the experience. Therefore, Small Group 9 was re-assigned to Big Group B, requiring to reorganize groups in Moodle and modify the Google Documents and Dabbleboard instances assigned to the groups.

The second activity was expected to be performed on-line. Thus, the GLUE! logs and the Google Documents instances were our only sources of evidence. R1 analysed the logs and verified whether each one of the 24 Google Documents had received comments from the reviewers and whether each group had carried out the review. Analysing the logs and the Google Documents took 3 hours and 1 hour respectively.

When we talked with the teachers (almost at the end of the second activity), they did not have any idea of the problems at that point in time but, based on their experience in previous courses, they imagined that several groups did not review their classmates' work. Indeed, as Table C.6 and Figures C.3 and C.4 show, many groups did not properly carry out the second activity. However, when we presented the results to the teachers, they decided not to intervene.

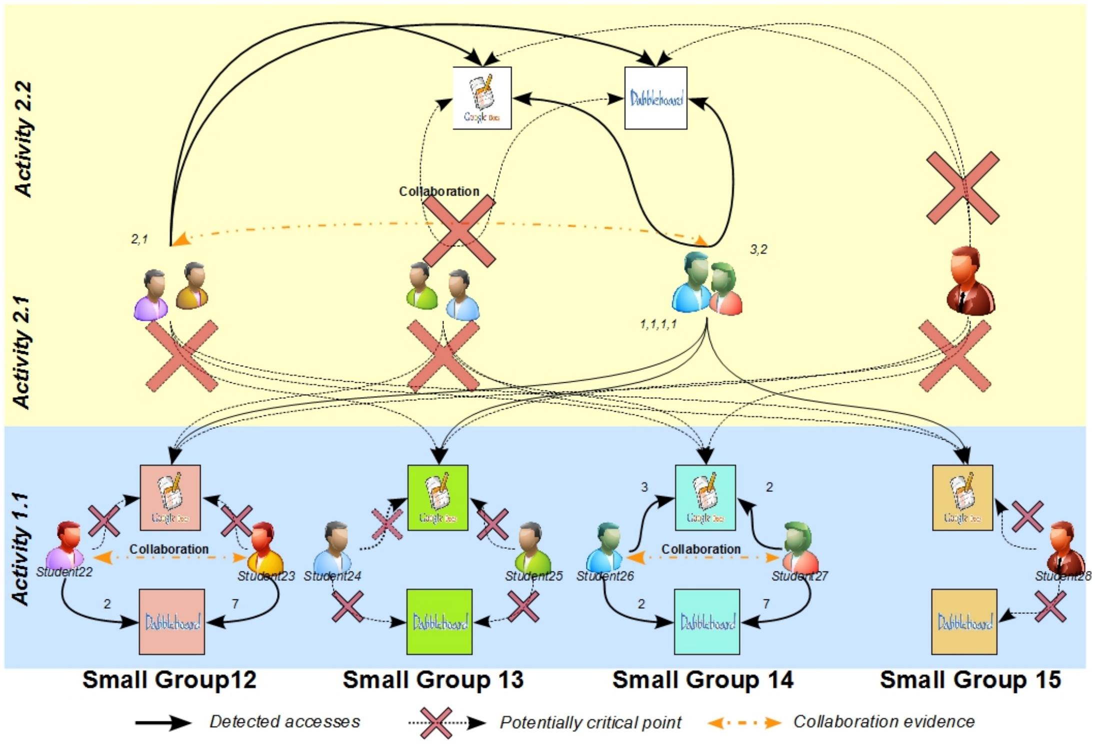


Figure C.4: Monitoring report of Big Group D that participated in the case study.

They had already envisioned that this problem could emerge and they have organized the next activity in order to have enough time for the review (in case of delay in the review). At the beginning of Activity 3.1, students would be forced to previously present their own solutions and understand the others', in order to discuss how to achieve a joint proposal.

The third activity was carried out face-to-face in the lab. As we mentioned before, when the students arrived, many of them had not reviewed their peers' work. Thus, they had to devote some time at the beginning of the session to have a look to the work of the other small groups or present each other their proposals.

During this activity one student from Group C, who was not involved in the previous activities, attended to the lab session. His group had been dissolved, so it was necessary to assign him to one existing group [EXP1_R2_OBS]. He worked with Big Group A but the technological set up was not modified (he just participated in the discussion) since it was not operational to interrupt the students work and delay the activity even more.

In this activity, Daniel and Javier did not need feedback from the monitoring reports. They were aware of the group progress since they we were walking around the computers to verify the state of the presentations. Furthermore, when the time to start the fourth activity arrived, the teachers asked the students if they were ready to present their proposal and the groups answered immediately. In any case, R1 reviewed in 10 minutes the Google presentations and analysed the logs in 1 hour to evaluate whether the results agreed with the observations.

The fourth activity took place just after the third activity, in the same lab session. As it happened in the previous activity, teachers were aware of the groups that participated since they were seeing them presenting their proposals. The teachers visualized from their computers (with the teacher accounts) the presentations that the students had elaborated, and each group offered a short explanation that was followed by a discussion with their classmates. In this activity, despite not being necessary to aid the progress of the learning situation, we also devoted 20 minutes to analyse the logs to validate the alignment with the real facts.

C.5 After run-time

Once the learning scenario had finished, we organized a group interview with 4 volunteer students (*Student3*, *Student4*, *Student5*, and *Student12*) [EXP1_S_INT]. The purpose of this interview was to better understand how they had interacted during the activities.

Dealing with the technological support, the students mentioned that to talk with each other out of the classroom they did not use either Moodle or the rest of the provided tools. The four of them used TUENTI, Skype and their email accounts to communicate with each other. Besides, *Student12* stated that the drawing tool had some usability problems, and therefore he drew the diagrams with another program (Paint) and latter uploaded the figure in Dabbleboard and Google Documents.

Regarding the use of the DLE offered by the teachers -Moodle, Dabbleboard and Google Applications-, though students *Student3*, *Student4* and *Student5* accessed the documents via Moodle (i.e., going through GLUE!), *Student12* frequently did it using directly the url (since the document could be accessed by anyone using just the document's URL). This type of access could not be detected by GLUE!, and thus we realized that there were actions that passed unnoticed for us.

Moreover, the four students confirmed that in the third activity they had reused the diagrams elaborated during the first activity to save time. They chose the diagram that better suited to the group approach and included the required changes to improve it with the feedback received. This means that, though they used Dabbleboard, they did not use the Big Group canvas that they had been expected to use.

Finally, students emphasized that the face-to-face part of the activities was essential to them during the learning process (to talk, discuss and organize the work). Therefore, focusing monitoring on the computer-mediated actions could give us a biased view of the learning process.

C.6 Findings

With this case study we aimed to explore two main aspects: first, what script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs; and second, what are the required conditions for collecting relevant information of the participants' collaboration in a blended CSCL scenario supported by DLEs. We discuss the results obtained from this study according to the exploratory questions linked to these two aspects (see Section C.1).

EXQ_MON.IT1: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?

EXQ_MON.IT1.1: What information do teachers include in the script?

During the design sessions, Daniel and Javier focused mainly on 6 aspects of the script [EXP1_T_LD]: first of all they had a clear idea of the *patterns* that they wanted to combine in the script, i.e. the *Pyramid* and the *Peer-review* , and the *ICT tools* that they were going to use (Moodle, Dabbleboard, Google Documents, and Google Presentations). Based on the pattern selection, they defined the *activity flow*, providing a general *description of each activity* (including the purpose, their relationship with the lab sessions and the dates of these sessions). Then, the teachers proceeded to distribute the *students* into small and big *groups*. Once the script was defined, they built the DLE according to the script: they created a Moodle course and the on-line resources (via GLUE!) that would support the work of each participant and group throughout the different activities.

EXQ_MON.IT1.2: What additional information could be included in the script to enhance the monitoring results?

While analysing the GLUE! logs at runtime [EXP1_IT_LOG], we realized that we needed to select which student actions should be taken into account in the analysis of each activity. Though the teachers had specified the timing of the lab sessions and the deadlines for the second and the forth activity [EXP1_T_LD], it was not enough to find out in which moment each activity began or ended. Thus, we had to ask the teachers about the specific *time-frame of each activity* (date and time) [EXP1_R1_OBS].

In addition, we discovered that there were some teachers preferences that could have contributed to provide monitoring reports closer to the teacher's needs. For instance, as we have seen in this study, not every document had the same relevance: while Dabbleboard was used to support the students in the drawing tasks (and it was even replaced by other tools such as Paint [EXP1_S_INT]), the on-line documents and presentations were crucial to collect and share the students work [EXP1_R1_OBS]. Thus, being aware of which *resources* were *mandatory* and which were *optional* might contribute to reduce the amount of detected 'problems' without a significant impact in the scenario.

EXQ_MON.IT1.3: Is the information about the accomplishment of pedagogical pattern constraints relevant for the teachers?

The monitoring reports obtained from the analysis of the computer-mediated actions helped the teachers realize which pattern constraints had not been (potentially) accomplished. By means of this information Daniel and Javier could detect on-time certain critical situations that could have jeopardized the script collaborative purposes [EXP1_T_FEE]. Especially in Activity 1.1, the monitoring reports prompted teachers to adapt the script and the technological support to continue with the second activity. Besides, it is noteworthy that, when the teachers received the results of the monitoring process, the set of identified problems was unknown to them [EXP1_T_FEE].

EXQ_MON.IT1.4: Are the pattern constraints sufficient to detect the problems that emerged during the learning situation?

The analysis of the *Pyramid* and the *Peer-review* constraints eased the identification of indicators and conditions (presented in Tables C.4 and C.5) that could be crucial in the script implementation. Indeed, with the information provided about the ICT tools involved in the learning scenario, it was possible to identify in advance which collaboration evidence could be obtained in order to inform about the key aspects of the script (depicted in C.2).

Apart from the detected problems concerning pattern constraints, the GLUE! logs [EXP1_IT_LOG], the researchers' observation [EXP1_R1_OBS, EXP1_R2_OBS], the learning outputs in the ICT tools [EXP1_IT_LO], the feedback obtained from the teachers at run-time [EXP1_T_FEE], and the interview with group of students [EXP1_S_INT] did not register any other critical situation.

EXQ_DAT.IT1: What are the required conditions for collecting relevant information of the participants' collaboration in a blended CSCL scenario supported by DLEs?

EXQ_DAT.IT1.1: How can the information available in the technological support be automatically gathered and integrated?

As we already mentioned in Section C.3, Dabbleboard did not provide any kind of information dealing with users' actions. Regarding Google Documents and Google Presentations, at that moment the only way to be aware of the changes made in the documents was through the history log in the web application's graphical user interface. However, there was no application programming interface to retrieve such information automatically. In the case of Moodle, it was possible to query the database to analyse how students used the VLE and the internal tools. However, since our main interest was on the use of the external tools, we focused on the information provided by GLUE!. GLUE! stores the logs in a file following the W3C Extended Log File Format[3] [EXP1_IT_LOG]. Thus, the analysis could be easily automated by creating an interpreter.

EXQ_DAT.IT1.2: Is the data registered by the learning tools enough to monitor the students participation?

We have shown that, just by monitoring the access to the tool instances, it has been possible to offer a general view about the collaborative activities in this specific scenario. As the teachers explicitly mentioned [EXP1_T_FEE]: "the monitoring reports are useful to have an overview of the whole scenario" and "it is easy to identify at a glance where there could be potential problems". Indeed, this simple information, we have given response to a very common problem: the lack of monitoring data in some ICT tools [MM11a] (as it happened with Dabbleboard).

In order to estimate the **reliability** of the monitoring process based on the logs, we compared the results with the evidences of participation registered by the researchers during

[3] W3C Extended Log File Format `http://www.w3.org/TR/WD-logfile.html` (Last visit: 10 March 2014)

the face-to-face sessions [EXP1_R1_OBS] [EXP1_R2_OBS] and the learning outcomes of the students in the tool instances [EXP1_IT_LO]. Table C.6 shows that there were a few problems that went unnoticed and multiple false positives, especially in those activities were part of the interaction occurred face-to-face.

The problems that were not identified were caused because some students accessed the tools [EXP1_IT_LOGS] but did not develop the tasks that they were expected to do [EXP1_IT_LO](writing the report in Activity 1.1 and providing comments in activity 2.1). However, finding a solution to this problem is not straightforward since it requires manually reviewing the content and deciding whether the students had finished their work or not.

The deviation concerning false positives was caused by two main reasons: the lack of additional data sources (about the work done within the external tools and the face-to-face interaction) and unexpected student behaviour. Although we could identify who had accessed to the resources, we were not able to know who had edited them, since the tools configuration did not impose any authentication from the users, and therefore the tools did not register who was accessing/modifying the resource.

Regarding the interaction face-to-face, the observers registered that during the lab sessions many students did not use their accounts even though they were participating. For instance, during the first activity, students were distributed by dyads sharing the same computer. Thus, in many cases, they registered in Moodle with one of the students account and developed all the work without switching [EXP1_R1_OBS]. In the third activity the members of the super groups were working all together in front of one or two computers, and just one person applied the changes or edited the documents [EXP1_R1_OBS, EXP1_R2_OBS]. Finally, the way Activity 3.1 was carried out also affected the monitoring reports. Although the students were expected to interact with the presentations, Daniel and Javier were the ones who accessed the presentations from their own computers (and accounts) in order to visualize them with the projector. Thus, students left aside the computers and focused either on listening/discussing about their colleagues presentation, or on their own explanation when the teachers visualized their group slides [EXP1_R1_OBS]. It is noteworthy that, during the group interview, students emphasized that the most important part of the work was made interacting face-to-face with their colleagues (to talk, discuss and organize the work) [EXP1_S_INT].

Based on the feedback provided by the students during the group interview and the observations, we detected additional unexpected situations about how the students did the activities. For example, one student used a different tool to draw the sequence diagram and later he uploaded the figure into his Dabbleboard and Google Documents. Another unexpected finding was that, during the third activity, several super groups reused the diagrams made by the small group, i.e., adapting an existing diagram instead of creating a new one to save time [EXP1_R1_OBS][EXP1_S_INT].

As we have seen, there were many situations that we were not able to detect. However we envisioned that there were certain enhancements that could improve the learning evidence gathered:

- To obtain more information about computer-mediated actions, it would be advisable to choose ICT tools that offer more information about the users' actions.

- We should remember that we are working with blended CSCL scenarios that involve not only computer-mediated but also face-to-face interactions. Thus, it would be necessary to include some evidence related to the face-to-face interactions. For instance, the attendance to the lab sessions could be registered by the teachers without spending too much time and effort.
- Regarding the distance and on-line part of learning the learning activities and assuming that there are parts of the students' work that cannot be registered (e.g., face-to-face collaboration out of the classroom, tasks developed with tools that do not belong to the DLE), we could ask the students about how they have participated in each activity.

Final remarks

Throughout the study, we collected some impressions and feedback from Daniel and Javier. The teachers argued that, despite the limitations of the reduced variety of monitored events, results were rather close to the real situation. Using the monitoring reports, teachers could realize at a glance which participants seemed not to be working, which ones were isolated and which was the best way to re-distribute them. Moreover, this information prevented teachers from going through all the tool instances (canvases, documents and presentations) to check the activity progress, saving them a great deal of time.

The findings obtained in this study provide evidences on the capabilities of the presented approach to generate relevant information about the evolution of the learning process. This information had educational value, especially regarding the improvement of the regulation tasks of CSCL activities.

Appendix D

Second exploratory study

Summary: In this appendix, we include the details of the second exploratory study. This study belongs to the first exploratory iteration and, therefore, focuses on two main issues: (1) to identify what script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs; and (2) to find out what are the required conditions for collecting relevant information of the participants' collaboration in a blended CSCL scenario supported by DLEs. The study took place in 2011, within a similar context than in the first study: a course of the Telecommunications Engineering degree, at the University of Valladolid (Spain), involving the same teachers, *Daniel* and *Javier*, and a different group of students. The teachers reproduced the design of the previous study and used the same technologies. While in the first study we focused on supporting teachers in the monitoring process, in this second one we paid special attention to what critical situations were expected and detected by the teachers and how the students carried out the learning activities. The following sections describe the context and methodologies, the different stages of the study, and the main data sources collected. To conclude, we present the findings of the exploratory work, where we discuss about what aspects of the CSCL script teachers took into account in the design and what additional information could have contributed to improve monitoring; we reflect on whether the accomplishment of the pattern constraints is relevant for the teachers and sufficient to detect the problems that emerged during the learning situation; and finally, we analyse how the analysis of computer-mediated actions registered in the DLE can be automated, and how these actions may inform the monitoring process of a blended CSCL scenario.

D.1 Context and methodologies of the study

The second study took place within a context similar to the one described in the first study (see Appendix C)- a third-year (out of five) course on "Network traffic and Management" of the Telecommunications Engineering degree, at the University of Valladolid (Spain), with the same two teachers, *Daniel* and *Javier*[1] (respectively, T1 and T2 in Figures 1.2 and 3.1). The learning scenario was carried out one year later, in November 2011, from the 3rd to the 10th, with a different group of students attending to the course (labelled *Student1* to *Student51*).

[1] To preserve teachers' and students' anonymity, we have modified their names.

During this course, Daniel and Javier wanted to reproduce the CSCL scenario developed in the previous year, using the same technologies: a VLE (Moodle) and multiple shared, on-line documents (Google Documents), boards (Dabbleboard) and presentations (Google Presentations) that the students had to use. An improved prototype of the GLUE! architecture was used to create and integrate the documents and boards into the VLE. The new GLUE! functionalities made the modifications of the technological setting easier and faster, reducing the need for monitoring the learning scenario in order to adapt the DLE in case of eventualities (in contrast to the first study, where it was necessary to be aware of the changes in order to have enough time to modify the DLE). Thus, during this study, only one researcher monitored the collaboration evidence (based on the computer-mediated interactions) and compared it a posteriori with the problems identified by the teachers.

As we already mentioned in Chapter 3, in this study we continued exploring the main questions targeted in the first iteration: on the one hand, *what script information was necessary to guide the monitoring process in this pattern-based CSCL scenario* [EXQ_MON.IT1]; on the other hand, *what were the required conditions for collecting relevant information of the participants' collaboration in this scenario*, taking into account that it was blended and supported by a DLE [EXQ_DAT.IT1]. These exploratory questions were split into more concrete questions, that are shown in Figure D.1.

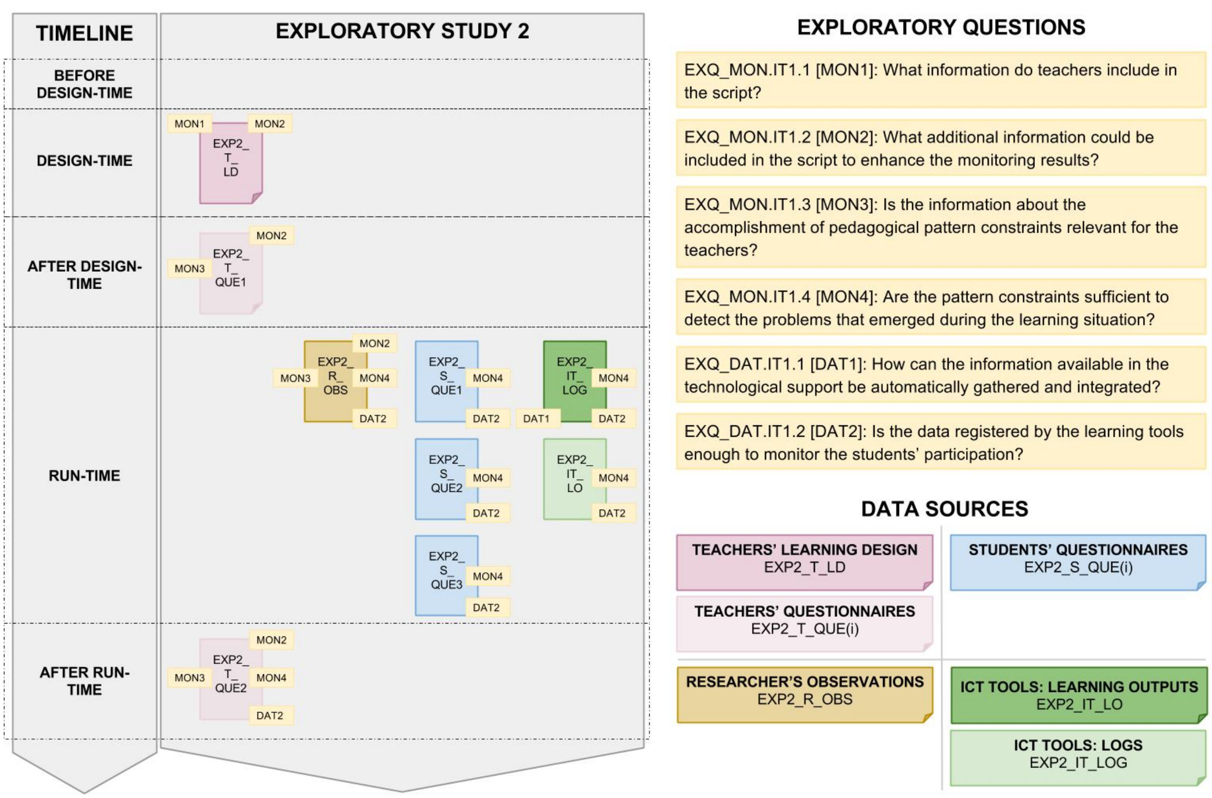


Figure D.1: Second exploratory study: data sources and exploratory questions.

To answer these questions, we collected data from several sources throughout the study. At design time, one researcher observed the design sessions to be aware of the teachers' decisions and the implementation of the DLE [EXP2_T_LD]. After the design process, the teachers (individually) answered a questionnaire about the flexibility of the design decisions and the potential problems that might emerged during the enactment [EXP2_T_QUE1]. During the enactment, in order to obtain evidence about the learning process, the researcher monitored the learning scenario by means of the ICT tool logs [EXP2_IT_LOG]. Our monitoring results were triangulated with data coming from observations of the face-to-face activities [EXP2_R_OBS], the learning outputs generated in the ICT tools [EXP2_IT_LO], and a questionnaire about the learning process sent to the students at the end of each activity [EXP2_S_QUE1, EXP2_S_QUE2, EXP2_S_QUE3]. Once the learning scenario finished, teachers answered a questionnaire about the problems that had emerged throughout the activities, and gave us feedback about the overall experience [EXP2_T_QUE2]. Figure D.1 presents an overview of the data sources, the moment they were collected and the exploratory questions that they help address. The following sections describe the work done in the different phases and the main findings obtained in relation to the exploratory questions.

D.2 Design-time

One researcher attended the design sessions in order to gather and understand the design details and to be aware of the technological context that was going to support the scenario. 4 sessions (that lasted a total of 6 hours) were celebrated involving the design of the learning scenario (done without any authoring tool) and the instantiation in the DLE (using GLUE!).

As mentioned in the previous study, in the "Network traffic and Management" course, students had to develop a message server. Before the students started the generation of code, Daniel and Javier wanted them to reflect and discuss about how the message server should be designed. The teachers designed a blended CSCL scenario to help students elaborate a sequence diagram of their software design, i.e., interleaving *face-to-face* with *distance activities mediated by ICT tools.*

The collaboration script implemented a three-level *Pyramid* CLFP [HL10a]. At level-1, small groups of one or two students had to draw a preliminary version of the sequence diagram and write a report with a summary of the main decisions and open issues. At level-2, students joined in *super groups* (composed of 3-4 small groups). First, each *group* had to review and provide feedback on the reports produced by their *big-group* mates (implementing a *Peer-review* CLFP [HL10a]); second, they had to discuss and produce a joint version of the diagram, as well as a presentation with their conclusions and open issues. Finally, at level-3, each group had to present their work to the classroom at the end of the lab session. Table D.1 provides an overview of the design decisions.

Regarding the technological support, Daniel and Javier chose *Moodle* to centralize the access to all the resources and activities, *Dabbleboard* to accomplish the drawing tasks, *Google Documents* to support the collaborative generation of reports and the review process, and *Google Presentations* for the final presentations. In addition, the *GLUE!* architecture was used to integrate the external tools into the VLE. Table D.1 summarizes the infrastructure used in each activity.

Table D.1: Overview of the activities included in the script of the second study. The phases correspond with the pyramid levels.

Phase	Activity	Social level	Interaction	Learning	Resources & tools for learners
1.1	First proposal	Small group	Blended	Face-to-face	- 28 Dabbleboards (1/small group) - 28 Google Docs (1/small group)
2.1	Peer review	Small group	Computer-mediated	Distance	- 28 reused Google Docs (1/small group)
2.2	Second proposals	Super group	Blended	Face-to-face	- 8 Dabbleboards (1/super group) - 8 Google Pres (1/super group) - 28 reused Dabbleboards (1/small group) - 28 reused Google Docs (1/small group)
3.1	Final proposal	Whole class	Face-to-face	Face-to-face	- 8 reused Google Pres (1/super group)
					TOTAL= 164 instances

D.3 After design-time

Since the script implemented the same patterns than in the previous study, the analysis of pattern constraints was straightforward. Table D.2 summarizes the constraints derived from the adaptation of the *Pyramid* and the *Peer-review* to this particular context (more detailed information about the CLFP constraints is available in Appendix B).

In addition, in this study we asked teachers about the flexibility of their design decisions, the problems that they envisioned during the enactment and how they expected to solve them. Table D.3 shows the results obtained from such questionnaire[EXP2_T_QUE1].

Surprisingly, each teacher had a slightly different opinion about such flexibility. Both of them agreed that the pattern constraints and the particular number of pyramid levels were not suitable to be modified. However, Javier considered that there were other decisions that should not vary, such as the description or the interaction type of each activity. Dealing with the problems that they envisioned that could emerge, both teachers considered probable that some students or groups would finish the first and second activity beyond the deadline. However, they expected to face this problem differently: while Daniel stated that no action would be necessary because students could exchange their opinions 'on the fly' during the third activity (second face-to-face session), Javier pointed out that the deadlines could be extended a bit to let the students finish the activity on-line. Besides, Daniel was worried about the collaborative aspects, envisioning that there could be isolated groups and lack of collaboration during the second and third activity. On the contrary, Javier explicitly said that he did not expect any problem related to the collaboration, albeit he was concerned about potential technological problems.

Regarding the information retrievable from the technological environment about the students' collaboration, the conditions were the same than in the previous year. Table D.4 describes both the kind of monitoring data and the way in which these tools provided access to this information. In November 2011, Dabbleboard did not provide any kind of user activity data and Google applications did not offer an API to obtain such information either. Regarding Moodle,

Table D.2: Constraints derived from the particularization of patterns in the second study.

1.	*Pyramid levels and group formation policies:* - Level 1: 28 small groups of 1-2 participants - Level 2: 8 super groups of 3-4 small groups - Level 3: 1 whole class of 8 super groups
2.	*Activity description:* - Act 1.1: small-groups draw a sequence diagram and write a report - Act 2.1: small-groups review and provide feedback on their big-group mates' reports - Act 2.2: big-groups discuss, produce an agreed diagram, and prepare a presentation - Act 3.1: whole-class discusses about presentations made by each big-group
3.	*Activity interaction type:* - Act 1.1: face-to-face and resource mediated (Dabbleboard, GDocuments) - Act 2.1: distance and resource mediated (GDocuments) - Act 2.2: face-to-face and resource mediated (Dabbleboard, GPresentation) - Act 3.1: face-to-face and resource mediated (GPresentation)
4.	*Resources (contents and tools):* - 1 shared board (Dabbleboard) and document (GDocuments) per small group - 1 shared board (Dabbleboard) and presentation (GPresentation) per super group

Table D.3: First questionnaire sent to the teachers: flexibility of the design decisions, problems envisioned at run-time, and potential solutions.

Teacher	**Which parameters of the script may NOT be modified?**	**Which are the critical situations that you foresee?**	**How do you expect/plan to solve each of the previous mentioned situations?**
Daniel	Pattern constraints & *Pyramid* levels	(1) Lack of collaboration among groups (2nd and 3rd activity) (2) Delays (reports or reviews not submitted) (3) Isolated groups (only one small group in a super group is making progress)	(1) No action (2) No action (the groups might exchange their views 'on the fly' during the 2nd f2f session) (3) Depends on the particular situation... but one possibility might be to merge an isolated small group with a different super group (thus reducing the number of super groups)
Javier	Activity description, interactivity type for each activity, pattern constraints & *Pyramid* levels	(1) Delays (reports or reviews not submitted) (2) Technological failures	(1) It is possible to change a bit the deadlines (2) We can replace tools with paper and pen for the proposed activities (*) I do not foresee any problem of lack of collaboration...

Table D.4: Description of the software used in the second study in terms of (1) the information provided about the user activity and (2) the way this information is accessible.

Software	**User activity information**	**Retrievable from**
Dabbleboard	None	Not possible
Google Tools	Document revision history: *user, date, time and document version*	User interface
Moodle	Event history: *date, time, IP address, user name, action, resource used*	User interface or database
GLUE!	History of accesses to the integrated resources *user, date, time, resource*	Event logs

although the database offered information about the use of the platform and the internal tools, this information did not throw any light upon the collaboration mediated by the external tools. Thus, since GLUE! registered every access to the instances of the integrated tools (Dabbleboard and Google suite in this case), we decided to use again GLUE!'s logs as the sole source of activity data.

Reproducing the work done in the previous study, the selection of the indicators used for monitoring students was based on the pattern constraints. Tables D.5 and D.6 present indicators related to certain aspects (activity flow, the collaboration, and the group formation policies) and how they were used to define the current and desired state of the interaction. For instance, current collaboration was measured by the interactions mediated by shared resources or face-to-face. On the other hand, the desired state of the interaction was derived from the values of the script parameters defined at design time. For example, if an activity is collaborative, there should be evidence of at least two participants interacting.

We should remember that the data available in the DLE was quite simple and it only provided evidence of computer-mediated actions. Thus, far from being a quality measure, the main role of the aforementioned indicators was to detect if there was no evidence of an expected type of activity taking place (e.g., one student has not submitted its assignment). Nevertheless, in this study, we decided to take into account the attendance to the lab sessions as an evidence of the face-to-face action (see discussion about [EXQ_DAT.IT1.1] in Section C). In that way, we expect to obtain more reliable data and reduce the number of false positives.

Figure D.2 shows the relation between the expected interaction and the monitorable students actions. For instance in the first activity, the expected collaboration might have happened through resource-mediated and/or face-to-face interactions (see left side of the figure), and the evidences that we could obtained from each type of interaction relied on the accesses to the resources and the attendance to the lab session (see right side of the figure).

Table D.5: Definition of the current state of the interaction according to the indicators related to participation and collaboration.

Participation: applied to individuals or groups depending on the social level.

- **Individual participation**: the involvement of each participant in the activity is measured by:
  - *The number of actions that (s)he performs:* $\{\sum \text{action}|\text{action.actor.id} = \text{participant.id}\}$
- **Group participation**: the involvement of each group in the activity is measured by:
  - *The number of actions that the group members perform:* $\{\sum \text{action}|\text{action.creator} \subseteq \text{group.participants}\}$

Collaboration among group members: for each group, the collaboration is measured by the face-to-face and computer-mediated actions in shared resources between group members (individuals or subgroups, depending on the social level):

- *The actions that the group members perform:* $\{\sum \text{action}|\text{action.creator} \subseteq \text{group.participants}\}$
- *The actions that involve shared resources in the group:* $\{\sum \text{action}|\text{action.resource} \in \text{group.resources\_to\_be\_monitored}\}$

Group formation: for each activity, it is necessary to control the group formation policies, e.g., the group size.

- **Group size**: the size of the groups is measured by the number of group members (individuals or subgroups depending on the social level) that are participating:
  - *The number of individuals who have participated:* $\{\sum \text{participant}|(\text{actor.id} = \text{participant.id})\ \&\ (\text{action.actor} > 0)\}$
  - *The number of subgroups who have participated:* $\{\sum \text{subgroups}|(\text{group.id} = \text{subgroup.id})\ \&\ (\text{action.group} > 0)\}$

Table D.6: Conditions associated to the considered indicators based on their expected values, i.e., the pattern constraints.

Participation: depending on the social level (individual/group), the expected participation values are:

- **Individual participation**:
  - *for each participant*: If activity.social_level = individual → participant.participation ≥ 1
- **Group participation**:
  - *for each small group*: If activity.social_level = (small_group or big_group) → group.participation ≥ 1
  - *for each super group*: If activity.social_level = (big_group or whole_class) → group.participation ≥ 1

Collaboration among group members: if the activity is collaborative, for each group the expected collaboration values are:

- *At least two group members participate*: If (activity.social_level ≠ individual) → {∃participant1, participant2| (participant1.participation ≥ 1) & (participant2.participation ≥ 1)}

Group size:

- *for each activity*: If activity.social_level = small_groups → group.size ≥ 1 participant
- *for each activity*: If activity. social_level = big_groups → group.participation ≥ 2 small_groups

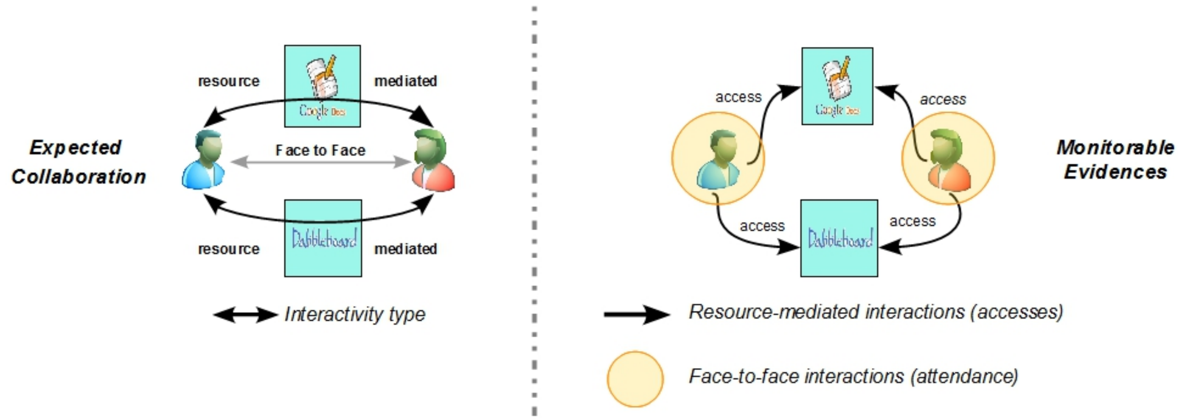


Figure D.2: Graphical representation of the expected students interaction and the monitorable actions in Activity 1.1.

D.4 Run-time

At run-time, one researcher monitored[2] the learning scenario looking for potential problems that could jeopardize the enactment of the script. Two data sources were used in the monitoring process: on the one hand, the students' computer-mediated actions registered by GLUE! [EXP2_IT_LOG] and, on the other hand, the attendance evidences gathered during the observations of lab sessions [EXP2_R_OBS]. The results were triangulated with the learning outputs [EXP2_IT_LO], the questionnaires addressed to the students about the learning process (at the end of activities 1.1, 2.1, and 3.1) [EXP2_S_QUE1, EXP2_S_QUE2, EXP2_S_QUE3], and the observations of the lab sessions [EXP2_R_OBS].

As we mentioned at the beginning of this Appendix, the monitoring reports were not indispensable for the orchestration of the CSCL scenario, since the DLE could be adapted 'on the fly' requiring an acceptable amount of time. Besides, in this case, just one researcher was involved in the monitoring process, so that the time required for such endeavour did not match with the activity deadlines. Thus, unlike the previous study, Daniel and Javier received the monitoring reports at the end of the study instead of during the enactment[3].

Table D.7 shows the detected problems based on the access to the resources and the attendance to the lab sessions. This results were compared with the information obtained from the review of the learning outputs (in Dabbleboard, Google Documents and Google Presentations) and the 3 questionnaires addressed to the students. Although the monitoring reports were aligned with the actual (scenario) events in many cases, there were some 'false positives' and problems that we did not detect.

According to the observations [EXP2_R_OBS], 40 students attended to the first lab session. Even if they arrived on time, there were some problems to access to Moodle (some students had

[2]To facilitate the interpretation of the logs, we developed an interpreter for the Extended Log File Format logs that provided us with the number of times that each user had accessed to the different resources within a period of time.

[3]An anonimized version of the monitoring reports is available in the additional material attached to this document. See Appendix H

Table D.7: Monitoring results based on the GLUE! logs: detected problems, false positives and undetected problems.

Data sources	Problem type	Activity 1.1	Activity 2.1	Activity 2.2	Activity 3.1
Detected problems (based on logs & attendance to the lab sessions)	Individual participation	10	24	11	11
	Small Group participation	5	11	6	6
	Big Group participation	-	0	1	1
	Group collaboration	6	1	1	1
False positives	Individual participation	0	0	0	0
	Small Group participation	0	2	0	0
	Big Group participation	-	0	0	0
	Group collaboration	0	0	0	0
Undetected problems	Small Groups that did not complete the activity	5	3	0	0
	Big Groups that did not complete the activity	-	0	0	0

forgotten their user-password) that delayed the beginning of the activity. During the session, each small group shared one lab computer, except the members of Small Group 5, who were using the lab computer and a laptop at the same time. Once students had started using the tools, many students mentioned that they were not comfortable using Dabbleboard, and Student8 asked Daniel if he could use another tool, a specific one devoted to create sequence diagrams. The teachers decided to allow this use of alternative drawing tools as long as the reports and presentations were done in the corresponding Google Documents and Google Presentations. When the session arrived to its end, many groups had not finished the activity, and this prompted teachers to let students continue the activity on-line with an extended deadline.

In order to monitor the scenario, the researcher devoted 1 hour to interpret the GLUE! logs [EXP2_IT_LOG] and 1 hour to integrate and analyse them together with the attendance register (obtained by the researcher during the observation of the lab session [EXP2_R_OBS]), 50 minutes to check whether the students had carried out the learning tasks as it was expected [EXP2_IT_LO], and 3 hours to compare whether the monitoring reports were consistent with the learning outputs and the questionnaire addressed to the students regarding how they had carried out the activity.

By means of the aforementioned data sources, we detected some potentially critical situations as it is summarized in Table D.7: 10 participants and 5 small groups did not participate, and in 6 groups there was no sign of collaboration. For instance, in Big Group G there was lack of collaboration in two of its composing small groups. Figure D.3 displays the actual collaboration of Big Group G from Activity 1.1 to Activity 2.2. The labels on the links specify how many times each participant (or group) accessed the resource, and a circle over a student denotes that the student attended to the lab session(s). Red crosses over a dotted line represent those cases where no evidence of collaboration could be deduced from the collected data.

34 students, out of the 51 participating in the activity, answered the questionnaire about their work [EXP2_S_QUE1]. None of the small groups that answered the questionnaire could

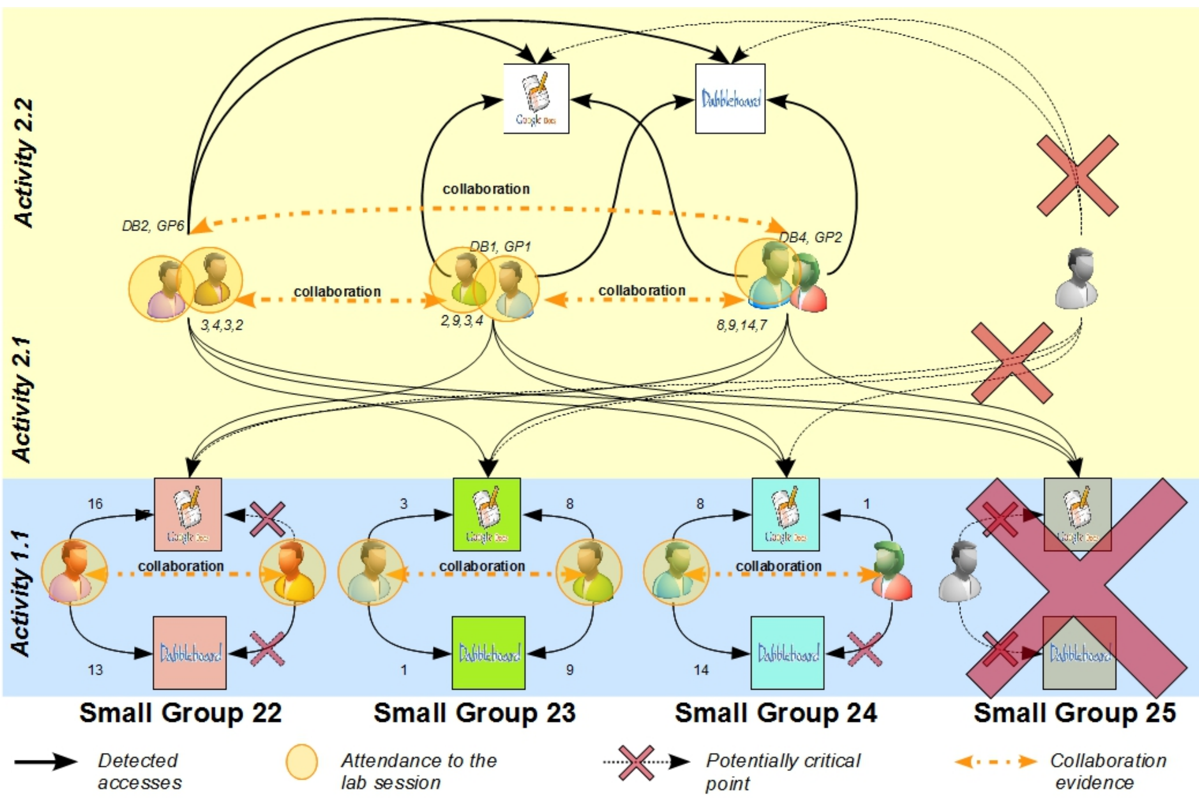


Figure D.3: Monitoring report of Big Group G that participated in the case study.

complete the first activity during the lab session, so that they had to finish it out of the classroom. 32 of them (94,12%) collaborated with his/her group mates, except two people that were isolated (Student23, who did not have a partner assigned, and Student50, whose partner did not participate). The same 94,12% of the students interacted face-to-face with their mates during the lab session but only 29,21% interacted face-to-face out of the classroom. Regarding the technological support used during the activity, 41,18% of the students used only the tools provided in the course (Moodle, Dabbleboard and Google applications), 8,82% used only other tools (such as communication and drawing tools), 23,53% used both the tools provided in the course and others, and finally 8,82% of the students did not use any of them (their partners interacted with the tools).

Since the second activity was expected to be performed on-line, the monitoring reports were based on computer-mediated actions, concretely on the GLUE! logs. The researcher analysed the logs and verified whether each one of the 28 Google Documents had received comments from the assigned reviewers and whether each group had carried out the review. Analysing the logs and the comments of the Google Documents took 1 hour and 50 minutes, respectively.

The monitoring reports showed that many students and small groups did not participate in the review process and a few groups did not get any comment at all on their work (see Table D.7). Figure D.3 illustrates that the Small Group 35 did not even access the reports of his group mates. In spite of these problems, during this activity, teachers did not make any intervention (as they had predicted in the questionnaire answered before run-time, summarized in Table D.3).

At the end of the second activity, a questionnaire was sent to the students to collect information about how they had intervened during the activity [EXP2_S_QUE2]. 39 students answered the survey and the results showed that: 82,05% of them reviewed all the documents generated by their super group mates, 12,82% reviewed part of them, and 5,13% did not review the work done by their colleagues. Even though the 94,87% had read their partners' reports, just 64,1% provided comments to their group mates. 53,85% were aware of the comments they had received, 20,51% of the students tried to read them but they did not receive any feedback, 17,95% knew that they had comments but did not read them, and 7,69% did not even check if there was any comment.

When the students arrived to the second lab session, teachers realized that many of them had not reviewed their peers' work. Thus, in many cases, the beginning of the session was devoted to present and discuss each small group proposal. Another setback was related to the Small Group 5. None of their super group mates attended to the session, and consequently the teachers moved them from Big Group B to Big Group A and adapted the DLE configuration to support this change.

According to the observations, in each super group, the students were discussing and applying changes to the documents using one or two computers. Therefore, it was expected that the computer-mediated evidence would not offer a realistic view of the students' involvement. During the third activity, Daniel and Javier were walking around the computers to be aware of the evolution of the students' work. When the time to start the fourth activity arrived, the groups had already finished their presentations. Thus, the activity began on time. Since the teachers had the links to the presentations at hand, the students left aside their computers. During this activity, the teachers visualized each group's work on the projector and the students interacted face-to-face presenting, asking and discussing about the different approaches.

To monitor the last two activities, the researcher analysed the logs and merged the results with the attendance register (a task that took 40 minutes). Besides, she reviewed the Google Presentations in 10 minutes to compare the results obtained from the different data sources.

Once the last activity finished, 27 students (out of 40 who attended to the second lab session) voluntarily answered the third questionnaire [EXP2_S_QUE3]. The results show that most of the participants interacted face-to-face (88,89% contributed providing ideas and 70,37% discussing what others said), however just a few of them used the DLE (25,93% used Dabbleboard and 29,63% Google Presentations).

Going back to the teachers' foresight about the problems that could emerge during the enactment, they were right in many cases: in the first activity it was necessary to extend the deadline because students had not finish on time; and in the second activity a number of groups had not reviewed their mates reports, then, they devoted some time of the second lab session to review and discuss about each group's work. Daniel's concerns about collaboration matched with reality. There was an isolated group that required restructuring the super groups and adapting the DLE. Besides in the second and third activity, there was lack of collaboration in some small and super groups. However, there existed also some unexpected problems from the teachers' perspective, such as the lack of participation of many students throughout the different activities and the lack of collaboration in the first activity. Finally, despite Javier's concerns, there was no technological problem throughout the whole scenario.

Comparing the potentially critical situations detected by the monitoring reports versus the learning outcomes, we realized that the number of false positives had decreased significantly in relation to the previous study. Only in two situations, the participation of a small group went unnoticed. Reviewing the questionnaires answered by the students, we discovered that they had gone directly to the Google Documents URL, thus going unnoticed by the GLUE! architecture, which could not register the access. Regardless of the improvement in the false positives, 8 problems occurred and we could not identify them. These problems correspond to groups who participated in the first and second activities but did not complete the tasks they were expected to.

D.5 After run-time

When the learning scenario came to its end, we asked Daniel and Javier about the problems that they had detected throughout the sequence of activities and how they had reacted to solve them. Table D.8 summarizes the answers [EXP2_T_QUE2].

Both teachers agreed that they had to modify the deadlines and the composition of the Big Groups. The only critical situation that they detected was that there was one isolated group. Since the teachers realized this problem when the students arrived to the second session, the change was made once the second activity had (theoretically) finished. Although the Small Group 5 members had not reviewed the other groups' proposals, they shared their opinions on the fly. Actually, the super group adopted the solution presented by the 'new group' as the basis of the agreed solution.

We also asked the teachers about what information could help them to detect those (or other) critical situations. Daniel's concerns were focused on the participation (or lack thereof)

Table D.8: Problems detected during the learning process and regulation tasks adopted to solve them

Teacher	Which parameters of the script did you have to modify during the learning experience?	Which critical situations did you find during the learning experience?	How did you solve each one of the critical situations that you found?	What kind of information would have help you to detect those (or others) critical situations?	When would have been useful to receive such information?
Daniel	Deadlines (1st, 2nd and 3rd activity), big-group size / participants	Isolated groups (only one group in a super group is making progress)	We simply moved the 'isolated' group to another super group. Although they had not reviewed the other groups' proposals, the shared their views on the fly and, actually, the agreed proposal (super group level) was based on the 'new group' proposal ...	Perhaps the lack of 'activity' with respect to the documents of the groups that did not attend the face-to-face sessions.	During the 'remote' activity... so as to inform the isolated group to review the work of the groups of the super group it was going to join...
Javier	Deadlines (1st, 2nd and 3rd activity), big-group size / participants	Isolated groups (only one group in a super group is making progress)	We reassigned the super group of a group and that was all	Maybe there were other 'critical situations', but I was not aware. It would be nice to have some kind of awareness tool for showing the performance of groups	At run-time

Table D.9: Timeframe of the the activities in the second scenario.

Activity	Initial timeframe	Final timeframe
1.1	from 2011/11/03 at 12:00 to 2011/11/03 at 14:00	from 2011/11/03 at 12:00 to 2011/11/05 at 15:00
2.1	from 2011/11/03 at 14:00 to 2011/11/10 at 12:00	from 2011/11/05 at 15:00 to 2011/11/10 at 12:00
2.2	from 2011/11/10 at 12:00 to 2011/11/10 at 13:30	
3.1	from 2011/11/10 at 13:30 to 2011/11/10 at 14:00	

of those groups that did not attend the face-to-face sessions, being especially useful at the end of the first activity in order to relocate groups in-time for the review. Javier's answers were more general. He was interested on awareness information about group performance at run-time.

D.6 Findings

As part of the first iteration, with this case study we aimed to explore two main aspects: a) what script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs; and b) what are the required conditions for collecting relevant information of the participants' collaboration in a blended CSCL scenario supported by DLEs. In this section we answer the exploratory questions presented in Figure D.1 in terms of the data sources collected throughout the study.

EXQ_MON.IT1: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?

EXQ_MON.IT1.1: What information do teachers include in the script?

Apart from the script aspects that Daniel and Javier defined in the previous study (namely, the patterns, the ICT tools, the activity flow, the activity description, and the students' assignment to small and super groups), this time they also defined explicitly the *timeframe* of each activity [EXP2_T_LD]. As it is shown in Table D.9, the sequence of activities was configure as a 'finish to start' relation, i.e., immediately after finishing one activity, the next one started. This information was useful not only for monitoring purposes but also for the students, who knew the deadlines to accomplish each task.

EXQ_MON.IT1.2: What additional information could be included in the script to enhance the monitoring results?

As we detected during the observations at run-time [EXP2_R_OBS], in the first activity teachers allowed the students to use different drawing tools than the one included in the DLE, but emphasized that it was mandatory the use of Google Documents for the elaboration of the reports. Besides, during the third activity, students had at their disposal both the big-group resources (Google Presentations and Dabbleboard instances) and the small-group resources (Google Documents and Dabbleboard instances) from the previous activities. Also in that context the role of each resource in the learning process was different: the small-group group resources could be used as reference material, the big-group Dabbleboard instances were optional (indeed many groups reused previous canvases), and the Google Presentations were expected to contain the learning outcome of the third activity. Thus, we considered that, in addition to the list of resources included in the learning design [EXP2_T_LD], specifying the *expected use of each resource* could help to detect more problems and to monitor more accurately the learning process.

Dealing with the activity description, we realized that, during the enactment, there were some activities (especially those that happened totally face-to-face) where teachers were aware of the students progress and did not need monitoring information [EXP2_R_OBS]. It led us to hypothesise that, apart from the description of the learning activities (currently provided in the script [EXP2_T_LD]), we should take into account the *teachers' estimation of potential problems* [EXP2_T_QUE1] and their expectations about when they could need to received feedback in order to detect such problems [EXP2_T_QUE2]. This information could contribute to predefine *what activities teachers need to monitor* and *when they needed the information.*

EXQ_MON.IT1.3: Is the information about the accomplishment of pedagogical pattern constraints relevant for the teachers?

Going back to the answers provided by Daniel and Javier to the first questionnaire regarding the flexibility of their design decisions and their expectations about the emerging problems [EXP2_T_QUE1], we can find several mentions to the pattern constraints. Additionally, they considered that, among the design decisions taken, pattern constraints and number of *Pyramid* levels were not modifiable. Furthermore, the 3 of the 4 problems that the teachers envisioned were related to the pattern constraints (see Table D.3).

Based on the teachers' feedback at the end of the learning scenario, they only detected two problems during the enactment, both of them related to the pattern constraints. In the first activity, none of the students had finished their reports, thus it was necessary to delay the deadline [EXP2_R_OBS, EXP2_T_QUE2]. Otherwise, this situation could have negatively affected both the *Peer-review* and the second level of the *Pyramid* , since the students could neither review or discuss about their proposals. Besides, during the second lab session, teachers discovered another critical situation [EXP2_T_QUE2] related to a *Pyramid* constraint (in each pyramid level there must be at least 2 groups involved from the previous level to ensure collaboration). To avoid this problem teachers intervened to adapt the scenario. Thus, we consider that the accomplishment of the pattern constraints is aligned with the teachers' concerns.

EXQ_MON.IT1.4: Are the pattern constraints sufficient to detect the problems that emerged during the learning situation?

As it happened in the first study, the analysis of the *Pyramid* and the *Peer-review* constraints eased the identification of indicators and conditions (presented in Tables D.5 and D.6) to be accomplished at run-time. Table D.7 provides an overview of the problems that emerged during the enactment. Some of them were detected by means of the GLUE! logs [EXP2_IT_LOG] and students' attendance to the lab sessions [EXP2_R_OBS], and others were identified reviewing the tool instances [EXP2_IT_LO].

Finally, reviewing the questionnaires to the students [EXP2_S_QUE1, EXP2_S_QUE2, EXP2_S_QUE3], the critical situations identified by the teachers [EXP2_T_QUE2], and the researcher observations [EXP2_R_OBS], we did not find any additional problems unconnected with the patterns constraints.

EXQ_DAT.IT1: What are the required conditions for collecting relevant information of the participants' collaboration in a blended CSCL scenario supported by DLEs?

EXQ_DAT.IT1.1: How can the information available in the technological support be automatically gathered and integrated?

As we already mentioned in Section C.3, the analysis of computer-mediated actions was based on the information provided by GLUE!. GLUE! stores its logs in a file using the W3C Extended Log File Format[4]. Applying this format each registered event is described using the following fields:

- **Date** (YYYY-MM-DD)
- **Time** (HH:MM:SS)
- Client address (IP)
- Remote user identifier
- Server address (IP)
- Server port
- **Method** (GET—POST—...)
- **Resource reference path**
- **Resource reference query**
- Response status code
- Number of bytes sent
- Number of bytes received
- Time to serve the request (in milliseconds)
- Host reference
- Client agent name
- Referrer reference

[4] W3C Extended Log File Format `http://www.w3.org/TR/WD-logfile.html` (Last visit: 10 March 2014)

To automate log analysis, we developed an interpreter for GLUE! logs [EXP2_IT_LOG] compliant with the Extended Log File Format. Concretely, we used 5 of the aforementioned fields: the date and time were the event happened, the method used (i.e., the type of event: a creation -POST-, an access -GET-, a removal -DELETE-, etc.), the resource reference path (i.e., the tool instance that the user is asking for), and the resource reference query (i.e., the user). With this information we could filter all the accesses originated by a participant, to the resources that supported the monitored activity, within the activity timeframe. Since this format is frequently used in RESTlet services, we expect that the interpreter prototype shall be reusable for other tools.

The use of the log interpreter reduced significantly the time devoted to the log analysis. While in the first study we needed 7 hours, in this study we only invested 2,5 hours.

EXQ_DAT.IT1.2: Is the data registered by the learning tools enough to monitor the students participation?

In the previous study we realized that just by monitoring the access to the tool instances, it was possible to offer a general view about the CSCL scenario and to detect a number of critical situations. However, the lack of face-to-face evidence introduced certain amount of noise in the monitoring reports, in the form of false positives. In this scenario we tried to verify whether adding to the computer-mediated actions a very simple evidence from the face-to-face action during the lab sessions, the participants' attendance led to a decrease of false positives.

The results obtained from monitoring the GLUE!'s logs [EXP2_IT_LOG] and the attendance register [EXP2_R_OBS] were compared with the researcher's observation during the face-to-face sessions [EXP2_R_OBS], the learning outcomes of the students in the tool instances [EXP2_IT_LO], the questionnaires to the students about the learning process [EXP2_S_QUE1, EXP2_S_QUE2, EXP2_S_QUE3], and the questionnaire to the teachers about the critical problems that they detected [EXP2_T_QUE2]. Table D.7 shows that 2 false positives and 8 problems went unnoticed.

As it happened in the first study, the problems that were due to students accessing the tools but not performing the tasks that they were expected to (writing the report in activity 1.1 and providing comments in activity 2.1) [EXP2_IT_LO, EXP2_S_QUE1, EXP2_S_QUE2]. However, as we already mentioned in C.6, the solution to this problem is not straightforward. Although some advantage could be gained by using ICT tools that offer monitorable data, evaluating whether the students have properly finished their work frequently requires that a human reviews the learning outputs.

Dealing with the false positives, the number decreased from 71 (in the previous study) to 2. These false positives were due to the unexpected behaviour of one small group, who had accessed the tool instance directly using the URL, instead of going through Moodle, where the request of resources is managed by GLUE!.

Based on the feedback provided by the students in the first questionnaire [EXP2_S_QUE1] and the researcher observation during the first lab session [EXP2_R_OBS], we realized that additional false positives could have appeared. During the first activity the students asked if they could use alternative drawing tools, something that teachers allowed. Indeed, the questionnaire reflects that, among the 34 students that answered, 8,82% only used tools out from the DLE and 23,53% used both the DLE and external tools. This means that our perception of 32,35% of the students was only a partial one. In terms of monitoring, the tools that do not belong to the DLE are out of reach since we do not have access to these tools. One possible way to provide more accurate monitoring reports could be distinguishing between mandatory and optional resources. This approach could help to better contextualize the results obtained. Another solution to increase the information available about the learning process could be involving the students in the monitoring process as another data source.

As we have seen, there were a number of situations that we were not able to detect. Although we can envision certain enhancements that could improve the monitoring evidence to be gathered:

- Collecting more information about computer-mediated actions, creating a DLE with tools that offer more information about the users' actions.
- Distinguishing between optional and mandatory resources in order to understand the impact that the lack of use may have over the rest of the script.
- Involving students in the monitoring process as another data source, in order to provide additional information about the actions that happen out of the DLE.

Final remarks

The findings obtained in this study provide evidence on the capabilities of the presented approach to generate relevant information related to the teachers' concerns: a) part of the problems that the teachers envisioned were related to the pattern constraints; b) all the critical situations that were detected were connected to the pattern constraints.

If we compare this study with the previous one, we can see that the integration of face-to-face evidences contributed to obtain more accurate monitoring reports, reducing drastically the number of false positives. Besides, the development of the log interpreter reduced the amount of time required to the monitoring tasks.

Finally, we identified throughout this study some design decisions that may affect the monitoring results such as the selection of tools or the expected use of learning resources. This fact led us to reflect on how we could support teachers during the design of the CSCL scenario in order to obtain monitoring reports better suited to their needs.

Appendix E

Third exploratory study

Summary: In this appendix, we include the details of the third exploratory study. As part of the second iteration of the DBR process, the study focuses on three main issues: (1) to support teachers in the integration of monitoring concerns in the pattern-based design process of CSCL scripts; (2) to continue with the identification of script information necessary to guide the monitoring process of pattern-based CSCL scenarios; and (3) to find out the required conditions for collecting relevant information about students' participation in a blended CSCL scenario supported by DLEs. The study took place in 2012, within a course of the Master's Degree for Pre-service Secondary Education Teachers, at the University of Valladolid (Spain), involving a expert teacher in CSCL scenarios (*Julia*), and 14 students. During this study, the researcher co-designed with teacher the learning scenario in order to meet both pedagogical and monitoring needs, and supported her in the monitoring process. The following sections describe the context and methodologies, the different stages of the study, and the main data sources collected. To conclude, we present the findings of the exploratory work, including the needs identified to support the teacher at design-time, the script parameters and dimensions that guided the monitoring process, the relevance of using the script constraints for regulating the learning scenario; and finally, we reflect on the suitability of the selected data sources for monitoring the blended CSCL scenario.

E.1 Context and methodologies of the study

The third study lasted from February 17th to March 9th, 2012, and took place within a course on "Learning Methods for Technology and Computer Science", which is part of a Master's Degree for Pre-service Secondary Education Teachers. Fourteen students attended the course, led by an expert teacher in CSCL scenarios. To preserve the participant anonymity, within this document, we will refer to the teacher as *Julia* (T3 in Figures 1.2 and 3.1), and the student names have been replaced by *Student1* to *Student14*.

During this course, students had to analyse different learning methods applicable to secondary education (i.e., lectures, inquiry-based learning, project-based learning, cooperative learning, etc.). In order to help them in understanding and internalizing these topics, they were asked to study a specific context and decide which methods could be the most appropriate. Once they chose the methods, they had to create a poster where they provided an example of the application of the methods to the context. To carry out these activities, the students followed a CSCL script based on the *Jigsaw* and the *Peer-review* CLFPs [HL10a], interleaving face-to-face with distance activities mediated by ICT tools (Mediawiki, Dabbleboard, and Google Forms).

In the previous studies (see Appendices C and D) we realized that certain design decisions, such as the selection of tools and the definition of the activity deadlines, influence the accuracy of monitoring results. Thus, we decided to carry out a new set of studies taking into account the design phase of the learning scenario. Concretely, in this study, teacher and researcher followed the pattern-based design process proposed by Villasclaras et al. [VF09b], with the aim of obtaining a final script that gathered both the pedagogical and the monitoring needs. Later on, the resulting monitoring-aware script was put into practice and the participants' actions were monitored in order to test whether the overall design was being enacted as expected.

As we already mentioned in Chapter 3, this study addressed three main questions: the first question aimed to find ways of supporting teachers to include monitoring issues in the pattern-based design of CSCL scripts [EXQ_DES.IT2]; the second question tried to identify what script information is necessary to guide the monitoring process of pattern-based CSCL scenarios [EXQ_MON.IT2]; and third question attempted to find out what were the required conditions for collecting relevant monitoring data about the students' participation, in a blended scenario supported by a DLE [EXQ_DAT.IT2]. These exploratory questions were split into more specific ones, that are shown in Figure E.1.

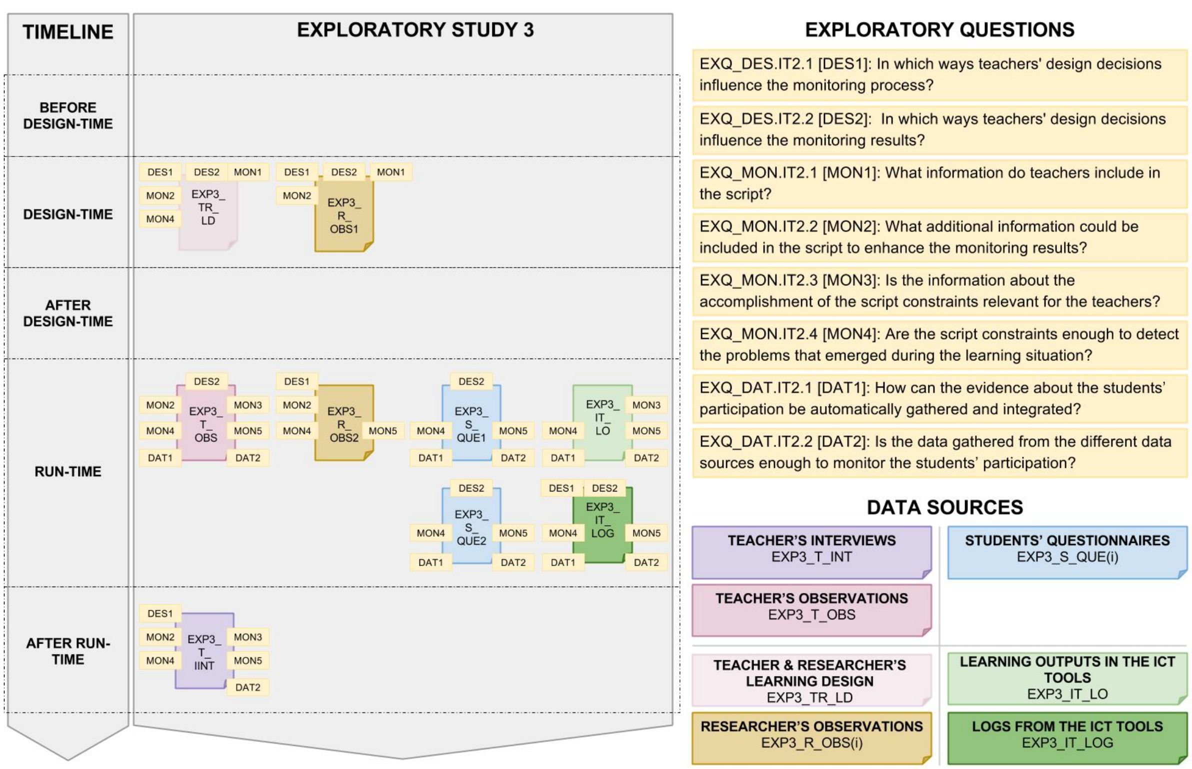


Figure E.1: Third exploratory study: data sources and exploratory questions.

To answer these questions, we gathered data from several sources throughout the study.

At design-time, we collected both the co-designed CSCL script and the researcher observations [EXP3_TR_LD, EXP3_R_OBS1]. During the enactment, the researcher (R) monitored the learning process by means of the logs obtained from the ICT tools [EXP3_IT_LOG] and the teacher's observations of the students' participation during the face-to-face sessions [EXP3_T_OBS]. Our monitoring results were triangulated with data coming from the observations made by the teacher and the researcher [EXP3_T_OBS, EXP3_R_OBS2], and two questionnaires about the learning process sent to the students [EXP3_S_QUE1, EXP3_S_QUE2]. Once the learning scenario finished, the teacher was interviewed about the design and monitoring processes [EXP3_T_INT]. Figure E.1 presents an overview of the data sources, the moment they were collected, and the exploratory questions that they help address.

The following sections of this Appendix describe the work done in the different phases of the study as well as the main findings obtained in relation to the exploratory questions.

E.2 Design-time

The design of the learning scenario consisted of 7 face-to-face collaborative sessions, that lasted altogether 17 hours, working from the conceptualisation of the learning design to its deployment in the learning environment. This design process (actually, a co-design between teacher and researcher) consisted of *two cycles*. First, the teacher designed the learning scenario following the guidelines given by the *pattern-based design process for CSCL scripts* proposed by Villasclaras et al. [VF09b], which has been extensively applied in combination with CLFPs. This pattern-based design process provides teachers with a clear and organised set of steps that guide them during the design process of CSCL scripts. In addition, this process had already been used with success for embedding assessment in the design of CSCL scripts. Therefore, we hypothesised that this process might be used as a framework for integrating monitoring issues in the script.

As Figure E.2 shows, the process begins with the determination of learning objectives and prerequisites, in which the teacher (or designer) must consider carefully the characteristics of the learning scenario (the type of learning activity, learning objectives, and the complexity of the collaboration flow). This analysis must guide the selection of the pattern(s) that will inform the following steps of the process. Then, once the activity flow is structured, each activity should be configured attending to particularities of the learning scenario. This particularisation includes the definition of the activities (tasks that the participants are expected to carry out, time constraints, etc.), and the configuration of roles and groups (for instance to indicate the maximum and minimum number of people needed for each group). Finally, the last step involves the provision of resources - creation and configuration - that support the realisation of the activities planned in the script. It is noteworthy that the pattern chosen in the second step of this process influenced, not only the activity flow, but also the configuration of the activities.

In this first cycle, the researcher contributed with her knowledge on the pattern, observing how the decisions taken by the teacher influenced monitoring, and intervening where necessary to ensure that the resulting technological set-up could provide data about the users' actions. In the second cycle, both teacher and researcher analysed the possibility of including complementary data sources that could provide information about the state of the activities. Table E.1 summarises the main decisions made in both parts of the co-design process.

Table E.1: Overview of the activities included in the script of the third study. Italicised text is used for the elements that were added in the second cycle of the study in order to improve the monitoring process.

Phase	**Activity**	**Social level**	**Interaction**	**Learning**	**Resources & tools for learners**	**Teacher's monitoring support activities**
Individual	1.1 Individual study	Individual	Computer-mediated	Distance	- Documentation on learning methods	
Expert	2.1 Individual summaries	Individual	Computer-mediated	Distance	- 3 wiki pages (1/expert group)	***- Check monitoring report***
	2.2 Expert consensus	Expert groups	Blended	Blended	- 3 Dabbleboards (1/expert group) - 3 wiki pages (1/expert group)	***- Control attendance*** ***- Check monitoring report***
	2.3 Workgroup report	***Expert groups***	***Computer-mediated***	***Distance***	***- 3 Google Forms (1/expert group)***	***- Check monitoring report***
Jigsaw	3.1 Selection of methods	Jigsaw groups	Computer-mediated	Distance	- 4 Google Forms (1/jigsaw group)	***- Check monitoring report***
	3.2 Poster development	Jigsaw groups	Blended	Distance	- 4 wiki pages (1/jigsaw group)	***- Check monitoring report***
	3.3 Peer review	Individual	Computer-mediated	Distance	- 4 wiki pages (1/jigsaw group)	***- Check monitoring report*** ***- Control participation***
	3.4 Posters presentation	Jigsaw groups	Face-to-face	Face-to-face		***- Control attendance*** ***- Control participation***
	3.5 Workgroup report	***Jigsaw groups***	***Computer-mediated***	***Distance***	***- 4 Google Forms (1/jigsaw group)***	***- Check monitoring report***
	3.6 Peer evaluation	Individual	Computer-mediated	Blended	- 14 Google Forms (1/student)	***- Check monitoring report***

TOTAL= 42 instances

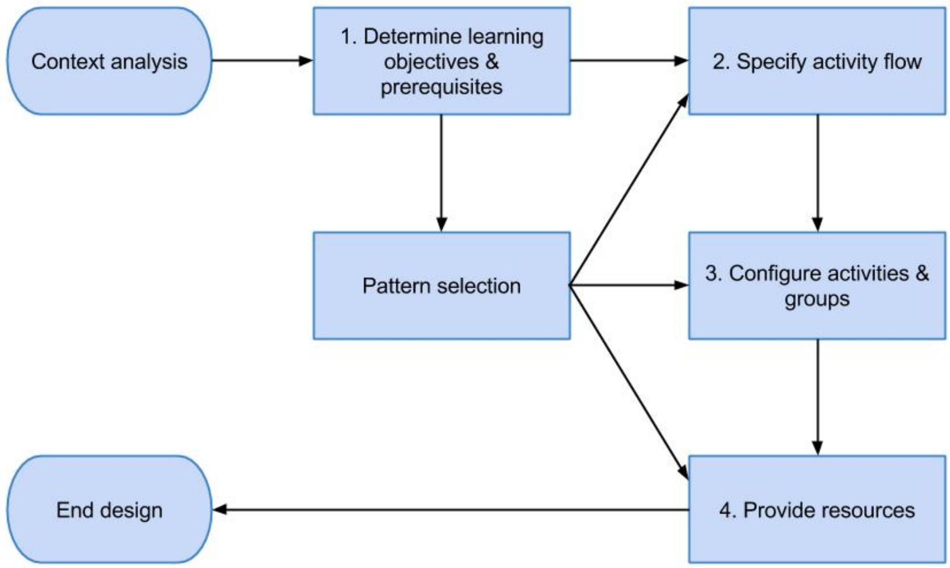


Figure E.2: Pattern-based design process of CSCL scripts proposed by Villasclaras et al. [VF09b].

E.2.1 First Cycle: The Pattern-Driven Co-Design

Two tools were used to facilitate the application of pattern-based learning design process: *Web Collage*[1], an authoring tool that produces IMS-LD [IMS03] compliant formalised scripts; and *GLUE!-PS*[2], a tool that allows practitioners to particularise and deploy IMS-LD scripts (among other learning design languages) into DLEs.

Throughout this cycle, the researcher informed Julia about the impact that the design decisions would have on monitoring, and both agreed on the most convenient approach that satisfied pedagogical and monitoring needs. Here we present how the four steps of the pattern-based learning design process were followed.

1. Determine learning objectives and select pattern(s). The teacher envisioned a learning scenario in which students had to work collaboratively on learning methods. Since the number of participants was small (14 students) and there were several learning methods to analyse, the pattern chosen was the *Jigsaw* CLFP [HL08]. In such context, this pattern provides some guidelines (a collaborative learning flow and a schema for group structuring) devoted to promote the feeling that team members need each other to succeed (positive interdependence), to foster discussion in order to construct student's knowledge, and to ensure that all students must contribute (individual accountability).

The researcher, based on the definition of the patterns [HL08] and on the literature review [Alv09] [PS11b], informed the teacher about the constraints that had to be satisfied to

[1] Web Collage: `http://pandora.tel.uva.es/wic` (Last visit: 16 March 2014)
[2] GLUE!-PS: `http://www.gsic.uva.es/glueps/` (Last visit: 16 March 2014)

Table E.2: List of constraints of the *Jigsaw* CLFP. **X** indicates that the restriction must be satisfied in that specific phase of the pattern (individual, expert and jigsaw).

Structuring constraints	**Individual** (individual)	**Expert** (collaborative)	**Jigsaw** (collaborative)	**Description**
group sizes		**X**	**X**	There must be enough participants to collaborate.
expert group sizes		**X**	**X**	The group sizes must be large enough to provide at least one expert to each jigsaw group.
jigsaw group sizes			**X**	The group sizes must be large enough to gather experts from all areas.
no. of subproblems	**X**	**X**	**X**	There must be at least 2 subproblems but no more than half the number of participants to allow for collaboration in the expert groups.
no. of expert groups	**X**	**X**	**X**	There must be at least one group of experts for each subproblem but no more than half the number of participants to allow for collaboration in the expert groups.
no. of jigsaw groups			**X**	The number of jigsaw groups must be in accordance with the number of experts of each area.
group dependences			**X**	There must be experts of all areas in each jigsaw group.

comply with these patterns. Table E.2 shows the *Jigsaw* constraints that should be monitored in the different phases that constitute the learning flow (further information about the *Jigsaw* and the *Peer-review* are available in Section B.3 and B.4 respectively).

2. **Specify activity flow.** Following the pattern guidelines, Julia defined the concrete tasks that the students had to accomplish during the three phases of the *Jigsaw* (i.e. individual, expert and jigsaw). In the first phase, each participant had to review two learning methods assigned by the teacher. During the second phase, those students that had been working on the same methods joined in expert groups. Each group had to develop an individual summary and design collaboratively a concept map with the main ideas of both methods they had studied. In the third phase, the students worked in their jigsaw groups (conformed by at least one expert on each learning method). The planned activities consisted in the elaboration of a poster where they had to choose two methods out of the six they had studied in the group, and justify their choice, discussing their suitability for the learning

contexts they were working on. The poster was co-evaluated by the rest of the classmates and the teacher in an oral presentation at the end of the activity. The first two columns of Table E.1 show the structure of phases and activities that conformed the activity flow.

Regarding monitoring, identifying the dependences of the activity flow was useful to detect whether the current state of the learning scenario could jeopardise future activities. Certain dependences stemmed from the pattern constraints shown in Table E.2 (e.g., due to the group formation policies), and others appeared on account of the data flow. Both kind of dependences will be illustrated later.

3.a Configure activities. Julia described the tasks to be carried out in each activity. Additionally, the definition was complemented with decisions related to monitoring such as the *duration* (with explicit starting and ending points), the specification of the social level (individually/by groups/whole class), which in some cases was given by the pattern but in others had to be set by the designer (the teacher, in this case), the *interactivity type* (face-to-face, through computers or blended), and the *learning type* (face-to-face, distance or blended). Some of these details have been included in Table E.1.

From the monitoring point of view, the time limits were needed to narrow the period of the analysis. Being aware of which activities had to be carried out individually or in groups -and in which groups- gave information about *which evidence should be gathered* (for instance, identifying collaboration is relevant in those tasks done by groups but not in the individual ones). Besides, the combination between the interaction and learning type of the activity provided information about which evidence was applicable and potentially useful (i.e., presence in a face-to-face activity in groups, or submission of a deliverable in an individual task, etc.) or not (i.e., it may not be meaningful to monitor the number of individual accesses to a tool if only a unique group submission is expected at the end of the task). Finally, Julia reviewed each activity deciding whether she wanted to monitor it or not.

3.b Configure groups. The group formation consisted in distributing students in jigsaw and expert groups. As mentioned in Table E.2, there must be as many expert groups as the number of sub-problems or topics identified. Besides, each expert group had to contain at least one member of each jigsaw group, and viceversa, each jigsaw group had to include at least one member of each expert group. Thus, from the 14 students, Julia configured 4 expert groups and 3 jigsaw groups. 12 students were assigned to these groups in order to ensure the pattern constraints, and the remaining two were allocated to existing groups.

The way groups were structured was essential in terms of monitoring, because it *informed about the expected structures of interaction in a given activity.* Taking into account these constraints defined by the CLFP would, for example, help to foresee whether a particular jigsaw group might miss the contribution of one expert on a subproblem.

4. Provide resources. The design required ICT tools for collaborative drawing and writing, as well as for managing on-line questionnaires. Then, the next step involved the search for tools that satisfied the teacher's needs and, at the same time, offered the possibility to store the users' actions for their latter analysis. Table E.1 specifies the ICT tools used in each activity. Furthermore, Julia posed the restriction of using MediaWiki to support the collaborative writing and to centralise the access to all the resources and activities. Teacher

Table E.3: Description of the software used in the third study in terms of (1) the information provided about the user activity and (2) the way this information is accessible.

Software	**User activity information**	**Retrievable from**
Dabbleboard	None	Not possible
Google Tools	Document revision history: *user, date, time and document version*	User interface
MediaWiki	Event history: *date, time, user name, action, wiki page*	User interface or database
GLUE!	History of accesses to the integrated resources *user, date, time, resource*	Event logs

and researcher agreed using the GLUE! architecture because it allowed the integration of external tools into MediaWiki and besides, it facilitates the collection of information from the different technologies used in the learning scenario. Additionally, the teacher proposed to use Text2MindMap, a web application for development of conceptual maps, and Google Forms for the on-line questionnaires. However, since Text2MindMap did not offer any information about user actions, it was replaced by Dabbleboard[3]. From such technological context it was possible to detect who (and when) accessed Dabbleboard or Google Forms, as well as the editions and uploads done by the users in MediaWiki (see Table E.3). Taking into account this information, the teacher decided which resources and monitorable actions were relevant for monitoring each activity.

Being aware of the *tools and resources* required for each activity influences the data gathering and contributes to the definition of the desired state. The tool type informed us about what information was available and how it could be harvested, and the list of resources determined where we could look for learning evidence.

As we pointed out when describing the step *2. Specify activity flow*, it was also relevant to reflect on the dependences that emerged from the data flow. For instance, if one group of experts did not submit the analysis of the learning methods assigned to them, the activities of the jigsaw phase might fail, since the contribution of these experts would be missing. The identification of these dependences contributed to be aware of the impact that the current state could have over the rest of the activities.

E.2.2 Second Cycle: Enriching the Design to Enhance Monitoring

Up to this point, the co-design process had been driven by the pattern-based design approach. Julia had followed the steps described in it, introducing some aspects in the script that could improve monitoring, based on the knowledge that the researcher had on this topic.

Based on the script description, the researcher obtained the list of constraints and verified whether there existed monitorable evidence for each one of them. Some of these constraints

[3]This tool is no longer available

Table E.4: Constraints derived from the particularization of the group formation policies imposed by the *Jigsaw* in the third study.

- **Number of expert groups** = number of subproblems = 3
- **Number of jigsaw groups** = 4
- **Expert group size** = 4-5 students
- **Jigsaw group size** = 3-4 students
- **Jigsaw members** = at least 1 expert of each subproblem

were obtained from the pattern an others derived from the description of the activities. Table E.4 shows some constraints derived from the adaptation of the *Jigsaw* pattern to the particular context. The list of constraints was shown to the teacher and she detected that the pattern constraints should not be applied to all activities. For instance, *Activity 3.6 Peer evaluation* belonged to the jigsaw phase but the purpose of this activity was not related with the *Jigsaw* , and therefore imposing the group formation policies of this pattern made no sense. Thus, teacher and researcher reviewed the list of constraints specifying when they should be taken into account.

The selection of the indicators used for monitoring students was based on the pattern and the activity constraints. Tables E.5 and E.6 present indicators related to some aspects (activity flow, the collaboration, the group formation policies, and expected use of resources) and how they were used to define the current and desired state of the interaction. For instance, the use of a resource is an indicator measured by the number of participants' actions on involving the resource. If the resource is mandatory, there should be at least one participant working with it.

The researcher identified that there were parts of the design that were difficult (if not impossible) to monitor with such configuration of the activities. For instance, the monitorable evidence was only computer-mediated, therefore there was no chance to monitor face-to-face activities such as the *Posters presentation*. Hence, there was a need of going one step further, looking for new ways on which the design could better inform the monitoring process.

At this point the focus was on how the design could be enriched in order to augment the information given by the ICT tools. It is noteworthy that, in blended settings, there are many actions that are not supported by technology or take place out of the classroom. Therefore, if these activities are to be monitored, additional data sources that capture these actions are necessary.

After an analysis of the factors that affect the usefulness of different types of data sources, we observed that the type of interaction (face-to-face, computer-mediated, or blended) and learning (face-to-face, distance, or blended) have an influence on which data sources can be used to get information about one activity. For example, distance activities where students interact face-to-face can only be informed by the students themselves, while those mediated by computers inside the classroom can be informed by the data collected by the ICT tools, by the teachers in their observations of the class, and by the students themselves. Table E.7 summarises the *informants* that were identified (the technological support, the teacher herself and the students) *depending on the learning and interactivity type* of the specific activity.

Table E.5: Definition of the current state of the interaction according to the indicators related to participation, collaboration and expected use of resources.

Participation: applied to individuals or groups depending on the social level of the activity.

- **Individual participation**: the involvement of each participant in the activity is measured by:
  - *The number of actions (to be monitored) that (s)he performs:* $\{\sum \text{action} | (\text{action.actor.id} = \text{participant.id}) \ \&(\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$
- **Group participation**: the involvement of each group in the activity is measured by:
  - *The number of actions (to be monitored) that the group members perform:* $\{\sum \text{action} | (\text{action.creator} \subseteq \text{group.participants}) \ \& \ (\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$

Collaboration among group members: for each group, the collaboration is measured by the actions (made by individuals or subgroups, depending on the social level) to be monitored according to the teacher's decisions :

- *The actions (to be monitored) that the group members perform:* $\{\sum \text{action} | (\text{action.creator} \subseteq \text{group.participants}) \ \& \ (\text{action.type} \in \text{group.resources\_to\_be\_monitored})\}$

Group formation: for each activity, it is necessary to control the group formation policies, e.g., the group size.

- **Group size**: the size of the groups is measured by the number of group members (individuals or subgroups depending on the social level) that are participating:
  - *The number of individuals who have participated:* $\{\sum \text{participant} | \text{actor.id} = \text{participant.id} \ \& \ \text{action.actor} > 0\}$
  - *The number of subgroups who have participated:* $\{\sum \text{subgroups} | \text{group.id} = \text{subgroup.id} \ \& \ \text{action.group} > 0\}$

Use of monitored resources: for each monitored resource that supports the activity, the use that participants make of it is measured by:

- *The number of actions (to be monitored) made by the participants of the activity*: $\{\sum \text{interaction} | (\text{action.creator} \subseteq \text{activity.participants}) \ \& \ (\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$

Table E.6: Conditions associated to the considered indicators based on their expected values, i.e., the pattern and the activity constraints.

Participation: depending on the social level (individual/group), the expected participation values are:

- **Individual participation**:
  - *for each participant*: If activity.social_level = individual $\rightarrow$ participant.participation ≥ 1
- **Group participation**:
  - *for each expert group*: If activity.social_level = expert_group or whole_class $\rightarrow$ group.participation ≥ 1
  - *for each jigsaw group*: If activity.social_level = jigsaw_group or whole_class $\rightarrow$ group.participation ≥ 1

Collaboration among group members: if the activity is collaborative, for each group the expected collaboration values are:

- *At least two group members participate*: If (activity.social_level $\neq$ individual) $\rightarrow$ $\{\exists \text{participant1, participant2} | \ (\text{participant1.participation} \geq 1) \ \& \ (\text{participant2.participation} \geq 1)\}$

Group formation:

- *for each jigsaw group*: $\{\exists \text{participant1, participant2, participant3} | \ (\text{participant1.participation} \geq 1) \ \& \ (\text{participant1} \in \text{expert\_groupA}) \ \& \ (\text{participant2.participation} \geq 1) \ \& \ (\text{participant2} \in \text{expert\_groupB}) \ \& \ (\text{participant3.participation} \geq 1) \ \& \ (\text{participant3} \in \text{expert\_groupC})\}$

Use of monitored resources:

- *for each activity*: *activity.resource.use* ≥ 1

Table E.7: Data sources needed for the monitoring of a collaborative activity depending on the interaction type (columns) and the learning type (rows).

	Face-to-face	**Blended**	**Computer-mediated**
Face-to-face	students & teachers	students & teachers & ICT support	students & teachers & ICT support
Blended	students & teachers	students & teachers & ICT support	students & teachers & ICT support
Distance	students	students & ICT support	students & ICT support

According to aforementioned analysis of data sources, the learning design built in the previous cycle of the process was complemented with new activities that enabled the collection of data from an appropriate informant for each case (see text in italics in Table E.1). For the collaborative activities planned to happen out of the classroom, the teacher added a new activity where the students had to fill out *a form about the distribution of tasks in their groups* (named 'workgroup reports' in Table E.1). We have called these additional activities: *students' data gathering activities*. For every activity fully or partially located in the classroom, the teacher planned to *control the attendance* (access to the classroom) and *participation* (interaction among participants) in order to take into account what happened during those sessions. We have named these activities *teachers' monitoring support activities*.

E.3 After design-time

After design-time, the researcher iterated several times over the graphical representation of the monitoring report[4] in order to provide Julia with an understandable view of the learning process. For each learning activity, the monitoring report offered certain *contextual information* such as aspects of the activity description (name, social level, learning type, time-frame, participants, groups, and resources) and teacher's monitoring decisions (actions to be monitored and critical situations that might emerge during the enactment). This pieces of information made easier for the teacher to remember the setting and constraints of the different activities, so that she could interpret the results of the data analysis. Since the visualization of the monitoring reports was not yet automated, this preliminary work reduced significantly the time devoted to the generation of the reports. The following section provides an example of monitoring report (see Figure E.3).

E.4 Run-time

The script [EXP3_TR_LD] was put into practice in the context previously described. A prototype of a GLUE! module named *GLUE!-CAS* (GLUE! Collaboration Analysis Support, see Section 4.6.3) was used to collect the participants' actions from the technological support [EXP3_IT_LOG], and from the attendance registers filled out by the teacher during the activities [EXP3_T_OBS]. The participant actions thus collected were analysed taking into account the indicators and conditions obtained from the script constraints using *GLIMPSE* (Group Learning

[4]An anonimized version of the monitoring reports is available in the additional material attached to this document. See Appendix H.

Interaction Monitor for Pedagogical Scripting Environments, described in Section 4.6.2), and a monitoring report was sent to the teacher at the end of each activity as she had planned.

The monitoring reports were validated by comparison with the evidence gathered by the teacher during the enactment [EXP3_T_OBS] (e.g., emails and comments from students), researcher's observations [EXP3_R_OBS2], the learning outcomes [EXP3_IT_LO], and the questionnaires answered by the students at the end of the expert and jigsaw phase [EXP3_S_QUE1][EXP3_S_QUE2]. 112 out of the 113 evaluated conditions[5] (99,12%) were interpreted correctly by the system, while only one was erroneous (one student had accessed a Google Form but he had not answered it, and this was not detected by the system).

In most cases, the monitored reports helped Julia confirm that the students were following properly the script: 97 out of the 113 evaluated conditions (85,84%) were consistent with the script expectations, while the other 16 (14,16%) were unexpected events that made her take regulatory actions (e.g., contacting the students, fixing technological failures, solving students' mistakes, or delaying the deadlines). We describe some of the unexpected events here, in order to illustrate the impact that monitoring had in improving the overall learning situation.

For instance, regarding activity constraints, in three of the activities that were mandatory for each participant -*individual summaries*, *peer review* and *peer evaluation* (see Table E.1)- there was no evidence that some of the students had performed their tasks. In these situations the teacher started by verifying the work done by the students, and in the cases in which the problem was confirmed, she sent a reminder, extending the deadlines in those cases where the individual participation was crucial. Another critical situation linked to an activity constraint arose in the *workgroup report* carried out by expert groups: despite the group submission was mandatory, no evidence of participation was registered from two of the groups. In this case, the cause was a technological problem with the on-line questionnaires supporting the activity, that was easily fixed on the fly, so that the students could submit their answers on time.

Another issue was detected during the *expert consensus* activity that was related to the *Jigsaw* constraints. Figure E.3 displays the monitoring report sent to the teacher at the end of the activity. Coloured icons were used to represent the participants who attended the lab session, and white was used to represent those that did not attend. The labels on the arrows specify how many times each participant accessed the shared board in Dabbleboard. Crosses over participants represent those cases where no evidence of participation could be deduced from the collected data. On the right side of the Figure, the warnings associated to the script constraints are included. As it can be seen, in this specific report no evidence of participation was detected for *Student7* and *Student10*. The lack of participation of *Student7* triggered an additional problem: if this situation continued, *Jigsaw Group 3* would have no expert from *Expert Group A*. Besides, there was no evidence of *Expert Group A* and *Expert Group B* uploading their proposals in the corresponding wiki pages. When Julia saw the monitoring report, she was not worried about *Student7* and *Student10*. *Student7* had notified that he could not participate in that activity and *Student10* had not been involved from the very beginning. To verify what was happening with the submission from *Expert Group A* and *Expert Group B*, she visited the wiki and realized that both groups had uploaded the proposals in the wrong wiki page. To avoid problems in the following phases, the teacher relocated the groups' artefacts and mailed the

[5] Examples of the conditions related to the activities are shown in Table E.6.

students with a reminder about paying attention to include their contributions in the proper wiki page.

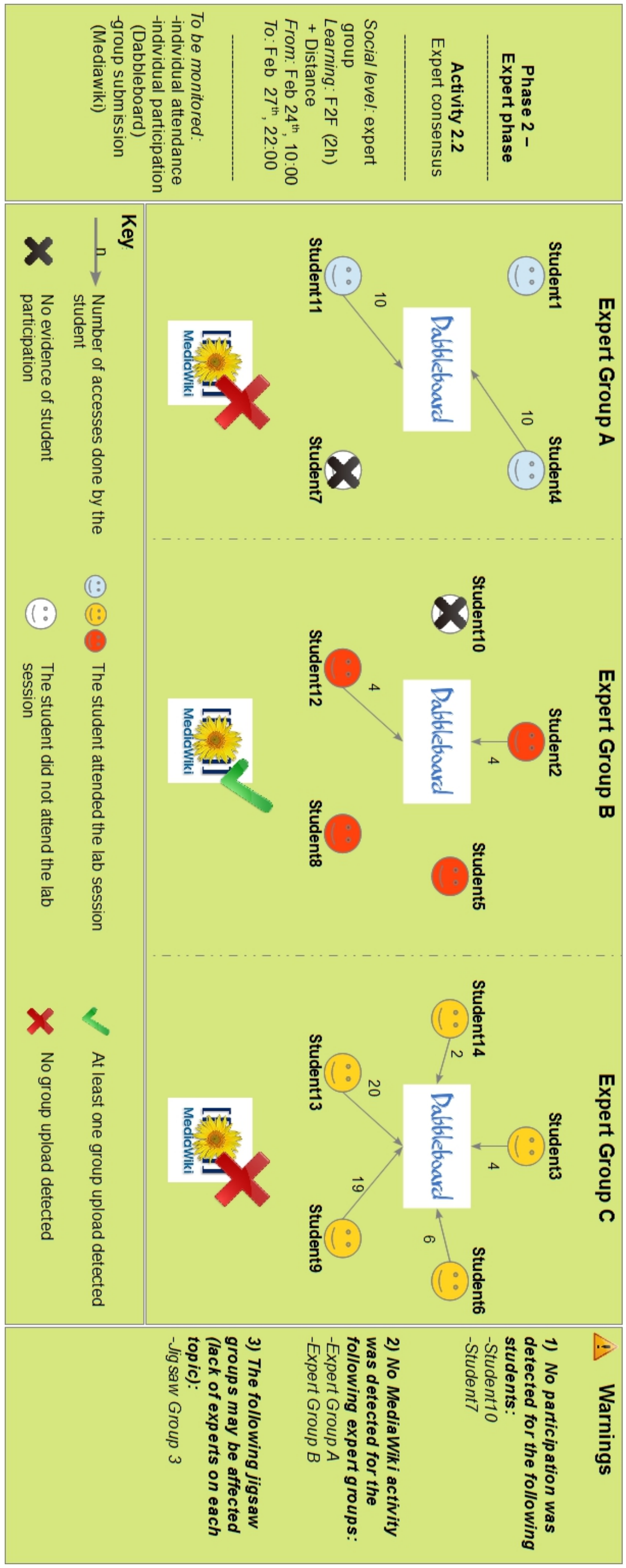


Figure E.3: Example of the information sent in the monitoring report of the *Activity 2.2 Expert consensus*.

A similar critical situation appeared during the *poster development* dealing with the pattern constraints. No evidence of participation was registered from *Jigsaw Group 3* due to the fact that they had uploaded their contributions in the wrong wiki page. In this case, the lack of contributions of this group could have negatively affected the next activity, i.e., the *Peer-review* : if *Jigsaw Group 3* had not submitted its poster, *Jigsaw Group 2* would not have a poster to review. Also in this activity the problem was easily solved relocating the group's work in the proper wiki page before the next activity began.

Overall, the monitoring reports helped Julia confirm that the students were performing as expected; and, in those cases where eventualities happened, the reports were useful to detect the problem and solve it before it became an actual activity breakdown. In addition, according to the teacher's feedback [EXP3_R_OBS2], all this information was received with almost no effort on her part.

E.5 After run-time

Once the learning scenario finished, we interviewed Julia to gather her feedback on the learning design and monitoring processes [EXP3_T_INT]. Table E.8 and Table E.9 collect some teacher comments extracted from the interview.

In the first place, we talked about the impact that monitoring had on the teacher's design decisions (see Table E.8). According to Julia's feedback, reflecting on monitoring aspects was worth the effort for several reasons. First, because it forces the designer to think about important scenario aspects, that a priori may go unnoticed and should be considered during design. For instance, reflecting on the conditions that must be satisfied in order to properly follow the script -and the effect that the violation of these conditions may had- moved her to include new sources to increase the reliability of the monitoring results. Second, reflecting about monitoring at design-time gave her a greater sense of control over the activity (e.g., knowing what must be supervised and when), and made her more confident about how to regulate in case of eventual occurrences.

The only drawback identified by the teacher was related to the selection of tools. Julia stated that the hardest part for designers would be knowing what tools provide monitorable data or not. Thus, she suggested to provide teachers with feedback about whether, under the configuration at that point in time, it would be feasible to obtain relevant information about the script constraints.

In the second place, we talked about the monitoring process (see Table E.9). From Julia's point of view, monitoring reports were easy to interpret and, just devoting some seconds, she got a clear view of the learning situation and helped her trace the progress of the learning scenario. As she mentioned: "Monitoring reports let you focus your attention, be more efficient, and detect problems in a more timely manner". Even if the reports do not eliminate the tasks of searching for causes of the problems and regulating the situation, the reports guide the teacher directly to where the problems may be, saving her the time needed to revise all deadlines exhaustively.

Although almost all data provided in the reports were accessible to the teacher (e.g., the logs of MediaWiki, the learning outcomes in the ICT tools, the attendance register to the lab sessions), seeing them integrated was also time-efficient, and even seeing the history, provided

Table E.8: Third exploratory study: teacher's feedback regarding the design process [EXP3_T_INT].

Topic	Question	Answer
How monitoring influenced the design of the scenario:	1. Was the design modified due to monitorization needs?	Yes. The need to know whether students are doing what they're supposed to, makes it necessary to include activities in the design, [...] which enable the tracing of the process [...] and also, monitoring face-to-face sessions.
	2. Do you consider that the design process has been enriched? If yes, how has it been enriched?	[...] It enables you to avoid a certain group 'getting out of control', or to know which students are more (or less) involved. You obtain a design that lets you do more as a teacher.
	3. Do you consider the cost of integrating monitoring in the design process was high?	Absolutely not[...]. It only forces you to think about something that is really important, and thus it is not perceived as a high cost with no benefit; rather, the opposite.
	4. When you were providing information related to monitoring, did you have the impression of it being a task unrelated to designing the scenario? Or did you perceive it as just another aspect to define about the scenario?	[...] It is something that you may not notice a priori, but once it is mentioned, you realize it is important. Some things I would have not realized by myself, [...] but when they tell you, you perceive clearly the need. When you force yourself to think about it, you realise it is something to consider during design.
The impact of including monitoring from the design phase into the enactment of the scenario:	1. Reflecting about monitoring at design-time, has it helped you have a higher awareness of what eventualities could appear and their potential impact on the learning scenario?	Yes, [...] it helps you start thinking about what consequences such event may have. Knowing that you (as a teacher) have to watch for certain moments to know whether things are being done or not, makes you aware of your own monitoring task[...]
	2. Did the configuration of monitoring during design of the scenario help you have greater control over it?	Having an initial plan about what has to be monitored and what to pay attention to, gives you a greater sense of control over the activity.
	3. Reflecting about monitoring in the design phase, has it helped you be more confident about how to regulate in face of eventual occurrences?	Yes.
Changes and improvements for future versions	1. What changes would you do to improve the design process?	The hardest part is to know whether a tool is going to provide information or not. [...] I might want to monitor an action but I don't know if it is monitorable. It could be useful to tell the teacher if it is possible to obtain relevant information about the aspects she's interested in. When you design an activity you don't know if those are the best conditions so that it can be monitored.

her with a general vision throughout the whole activity flow. Besides, the integration of the data sources from computer-mediated and face-to-face actions was very useful for her because it uncovered situations she was not aware of. Julia highlighted that among the things that would have been difficult to obtain by herself was the impact of a problem in other activities or groups (i.e., the pattern and activity flow constraints). From Julia's perspective, the pattern and the activity constraints are useful for monitoring since teachers are interested in knowing whether their design, their idea of the activities and the flow, is being complied with or not.

The information provided in the monitoring reports made Julia take regulatory measures during the learning scenario and avoid bigger problems. After seeing the report, she checked what had happened and afterwards she took appropriate measures (e.g., contacting the students or directly solving the problem in the case of students' mistakes or technological problems). In order to enhance monitoring and the consequent regulation, Julia proposed to provide a link to the resources in the monitoring reports. For her, maybe the most complex part was to find the origin of the problems detected in the report. Thus, having the access to the resource (instead of having to go the workspace to look for them) could make things easier and could lead to a faster process.

Finally, we reviewed the monitoring reports of the ten activities, classifying which of the 113 results[6] were unknown by Julia (when she received the monitoring report) and whether the

[6]These results come from the validation of the conditions obtained from the script constraints. Some examples

Table E.9: Third exploratory study: teacher's feedback regarding the monitoring process [EXP3_T_INT].

Topic	Question	Answer
The presentation of results:	1. Was it easy to interpret the results of the monitoring reports?	Yes
	2. Approximately how much time did you need to interpret the results of the monitoring report?	To interpret the content of the report, I could dedicate seconds. What they mean can be clearly seen. In that sense it is very fast and very useful.
	3. Do you think that using the pattern and the activity characteristics was useful for the monitoring?	I think it is useful. It is a "top-down" approach: I have a clear idea of what I want, and I try to see whether it is happening or not. I think a teacher is interested in knowing whether what she has designed, her idea of the activities, is being complied with or not.
About the impact that the monitoring results had in the scenario:	1. The monitoring results helped you trace the progress of the learning scenario? or were they already evident?	[...] In general, they helped trace the learning scenario, even if some were evident. [...] Even if the system does not eliminate an insurmountable task, any time saving is relevant because maybe the teacher does not have time to do these tasks (or maybe she is not proactive in seeking this information). [...] When you are guided by the report, you go directly to where the problems may be; if not, you would have to revise all deadlines exhaustively. Monitoring reports let you focus your attention, be more efficient, and detect problems in a more timely manner [...]
	2. From all the data provided in the reports, which ones were you already aware of, and which ones you did not know? In the case of data that you already knew, how did you obtain them?	Among the things that are difficult to obtain is the impact of a problem in other phases or groups (i.e., the dependencies). Almost all of them are data that you can obtain from the ICT tools, but seeing them integrated, and even seeing the history, provides a general vision along the whole activity flow. [...]
	3. Was it useful, the integration of information from the tools with the information from the teacher/observer?	Having the integrated information of the different sources is very useful. [...] the integration with the rest of sources is interesting because it can uncover situations I was not aware of. [...]
	4. The information provided, did it make you take regulatory measures during the learning scenario? Of which kind?	Yes, of course. After seeing the report, I checked what had happened and afterwards I took appropriate measures.[...] it was useful to contact students (to find a solution) or to directly solve the problem.
	5. Having those results helped you avoid bigger problems?	Yes.
	6. Which other data sources would have been interesting to include in the [monitoring] analysis?	The student feedback
The results obtained vs. other information sources:	1. If you had other kinds of data, would you have monitored in a different way (be it automatic or manual)? How?	To get the same information, I would have had to be continuously tracking whether [students] had delivered things or not. In any case, if I had not received the monitoring reports, I would not have been so watchful. [...] I would have noticed many things later on, since a student can write to you saying that he does not find the materials. But this dynamic is much worse, since you force students to detect the problem and report it to you.
	2. Do you think that monitoring has caused you to invest more, or less, time in the tracking of the scenario?	Having a monitoring plan does not imply the investment of more time than it's due. The report is very fast and easy to interpret, and sometimes it leads you to do things that are useful.
	3. About the monitoring process (additional comments)	Supporting the teacher during monitoring is very important. The reminders were very useful, since I forgot some things. You could even monitor the teacher herself.
Changes and improvements for future versions	1. What changes would you do to improve the monitoring process?	Maybe the most complex part is to find the origin of the problems detected in the report. Having the link to the resources (instead of having to go the workspace to look for them) would make things easier and would lead to a faster process.

information was useful for regulation purposes. This analysis helped us identify design parameters linked with the teacher's monitoring interests, as we will see in the following section.

E.6 Findings

In this section, we present the findings of the study attending to the exploratory questions and the data sources presented in Figure E.1. As part of the second iteration, the exploratory

are included in Table E.6.

Table E.10: Third exploratory study: dimensions and parameters as affecting the monitoring process.

Pattern	**Activity**	**Teacher's monitoring decisions**
Activity flow	Deadlines	Monitoring periods
Collaboration	Resources (tools, contents)	Activities to be monitored
Group formation policies	Participants	Actions to be monitored
	Groups	
	Social level	
	Interactivity type	
	Learning type	

questions address three main aspects: a) how to help teachers integrate monitoring concerns in the pattern-based design process of CSCL scripts; b) what script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs; and c) what are the required conditions for collecting relevant information of the students' participation in a blended CSCL scenario supported by DLEs.

EXQ_DES.IT2: How can teachers be supported to integrate monitoring concerns in the pattern-based design process of CSCL scripts?

EXQ_DES.IT2.1: In which ways teachers' design decisions influence the monitoring process?

Analysing the script [EXP3_TR_LD] and taking into account the researcher's observations at design and run-time [EXP3_R_OBS1, EXP3_R_OBS2], we identified a set of dimensions and parameters that influenced the analysis process, especially regarding the data gathering and the representation of the desired state of a CSCL situation. Table E.10 brings together these dimensions and parameters.

Firstly, three configuration parameters of the activities guided the *data gathering of participants' actions*: the activity deadlines, the resources (tools and contents), and the participants involved in each activity. These three parameters allowed to filter out actions performed out of the activity period, on resources or by users not involved in the activity. Moreover, some teacher's decisions affected the data gathering: the monitoring periods, that determined when the monitoring had to be done, and actions to be monitored, that specified which actions registered in the learning environment were considered for the analysis.

Concerning *the representation of the desired state of a CSCL situation*, certain activity features also influenced. The interactivity type determined how students were expected to participate (face-to-face, through computers or blended); the social level (individually or in groups) defined whether the participants or groups involved in the activity should collaborate. Furthermore, the pedagogical design patterns (*Jigsaw* and *Peer-review*) contributed to the definition of the desired state, by means of the constraints that had to be verified during the enactment in order to accomplish the pedagogical objectives. For instance, the activity flow provided sequencing dependences (finish-to-start, start-to-start, finish-to-finish, start-to-finish) between activities or phases that could jeopardise the script purposes, and the collaboration and group formation policies had to be satisfied in order to verify the script's collaborative purposes.

Additionally, during the co-design process we identified two more parameters with a collateral impact on monitoring. First, the selection of tools that satisfied the pedagogical and monitoring needs, called for a list of ICT tools describing their monitoring affordances, in particular their monitorable actions. Second, when analysing the data sources needed for monitoring an activity, together with the interactivity type, the learning type of the activity (face-to-face, distance, or blended) turned out to be relevant. Although this parameter was not used in the analysis process, it was necessary for the reflection on the data sources that could inform about the activity progress. Thus, we have included the monitorable actions and the learning type as design parameters that affected (indirectly) the monitoring process.

In order to understand how the teacher was supported to integrate the monitoring issues, we compile the main researcher's contributions to the co-design process [EXP3_R_OBS1]:

- When Julia specified the learning objectives, the patterns, and the activity flow, the researcher *extracted the script constraints* that helped define the desired state and detect whether the current state of the learning situation might risk future activities. As the teacher said: "some things I would have not realized by myself, [...] but when they tell you, you perceive clearly the need. When you force yourself to think about it, you realise it is something to consider during design" [EXP3_T_INT].

- When the teacher configured the activities, the researcher *asked her for some additional parameters that influenced monitoring* such as the duration, the specification of the social level, the interactivity and the learning type. In relation to this, Julia mentioned that : "[...] it is something that you may not notice a priori, but once it is mentioned, you realize it is important" [EXP3_T_INT].

- When Julia was selecting the tools that made up the DLE, the researcher *informed about the monitoring affordances of the ICT tools* to find options that satisfied the pedagogical needs and, at the same time, allowed us to harvest data about the users' actions. According to the teacher's feedback: "The hardest part is to know whether a tool is going to provide information or not. [...] I might want to monitor an action but I don't know if it is monitorable. It could be useful to tell the teacher if it is possible to obtain relevant information about the aspects she's interested in. When you design an activity you don't know if those are the best conditions so that it can be monitored" [EXP3_T_INT].

- Finally, in order to enrich the design to enhance monitoring, the researcher *identified the monitorable evidence for each constraint* according to the script definition. In connection with this point, Julia added that: "the need to know whether students are doing what they're supposed to, makes it necessary to include activities in the design, [...] which enable the tracing of the process [...] and also, monitoring face-to-face sessions"[EXP3_T_INT].

EXQ_DES.IT2.2: In which ways teachers' design decisions influence the monitoring results?

As it is shown in the co-design of the CSCL script [EXP3_TR_LD, EXP3_R_OBS1], the teacher had a crucial role in the enhancement of the monitoring results, not only adjusting the conditions to be evaluated, but also improving and enriching the monitorable data sources [EXP3_TR_LD].

It is noteworthy that selection of pattern constraints that should be taken into account in each activity did not obey to any specific rule. It was the teacher who decided in which cases the pattern constraints should be applied [EXP3_TR_LD]. This task was crucial in order to avoid the appearance of false positives in the monitoring reports.

Regarding the data sources, the teacher adapted the selection of ICT tools in order to include those offering further information about the users' actions. This decision improved the quantity and the quality of monitorable computer-mediated evidence. In addition, the fact of including additional data sources coming from the teacher herself [EXP3_T_OBS] and the students [EXP3_S_QUE1, EXP3_S_QUE2] enriched the variety of evidence and, therefore, contributed to obtain less biased monitoring results not only based on computer-mediated actions [EXP3_IT_LOG]. And finally, the teacher's selection of resources and actions to be monitored focused the analysis on the elements most relevant for her.

EXQ_MON.IT2: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?

EXQ_MON.IT2.1: What information do teachers include in the script?

Table E.10 summarises the information included in the script [EXP3_TR_LD] [EXP3_R_OBS1]. Firstly, the teacher defined the pedagogical patterns, and from this information it was possible to obtain some guidelines about the group formation policies, the expected collaboration and the activity flow. Secondly, the teacher defined the main elements that usually appear in CSCL scripts (such as participants, groups, roles, activities and resources). And finally, she included, with the help of the researcher, certain information necessary to guide the monitoring process. For instance, there were some details that Julia had to specify about the activities (deadlines, social level, interaction and learning type) and her own monitoring decisions (monitoring periods, activities and actions to be monitored).

EXQ_MON.IT2.2: What additional information could be included in the script to enhance the monitoring results?

Apart from the new parameters identified in Table E.10 during the co-design process [EXP3_TR_LD] [EXP3_R_OBS1], no additional design element was extracted from the observations during the enactment [EXP3_T_OBS][EXP3_R_OBS2], nor from the interview to the teacher [EXP3_T_INT].

EXQ_MON.IT2.3: Is the information about the accomplishment of the script constraints relevant for the teachers?

As we mentioned in Section E.5, during the teacher interview [EXP3_T_INT], we reviewed the monitoring reports obtained from the analysis of the logs and the attendance to the face-to-face sessions [EXP3_IT_LOG, EXP3_T_OBS]. Based on the feedback obtained from the teacher interview [EXP3_T_INT], the monitoring reports "helped trace the learning scenario, even if some were evident". Out of the 113 evaluated conditions, 94 (83,19%) were considered relevant by Julia for regulating the scenario, and 64 (56,64%) were unknown to her when she received the monitoring report. Besides, the emerging critical situations could not have been detected in advance by her without the monitoring report, or without a thorough review of the DLE, which would be a more demanding task. As Julia mentioned: "to get the same information, I would have had to be continuously tracking whether students had delivered things or not. In any case, if I had not received the monitoring reports, I would not have been so watchful. [...] I would have noticed many things later on, since a student can write to you saying that he does not find the materials. But this dynamic is much worse, since you force students to detect the problem and report it to you".

Based on the teacher's feedback on the usefulness and the novelty of the monitoring results, we carried out a first analysis taking into account the type of learning (distance, face-to-face, or blended), interaction (computer-mediated, face-to-face, or blended), and social level (individual, expert group, jigsaw group, whole-class) of each activity. Figure E.4 provides an overview of these characteristics throughout the activity-flow and Figures E.8, E.9, and E.10 summarize the teacher's answers.

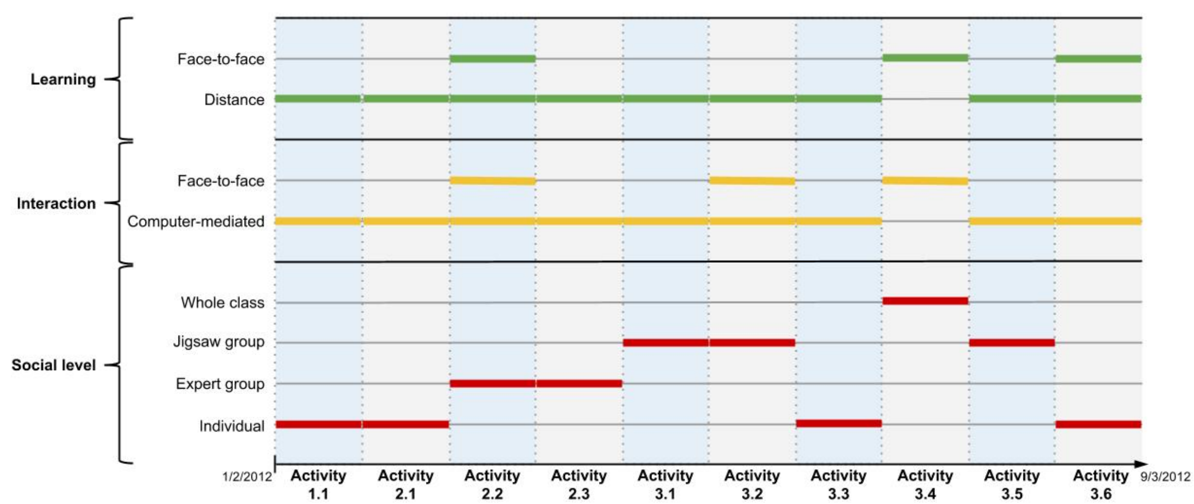
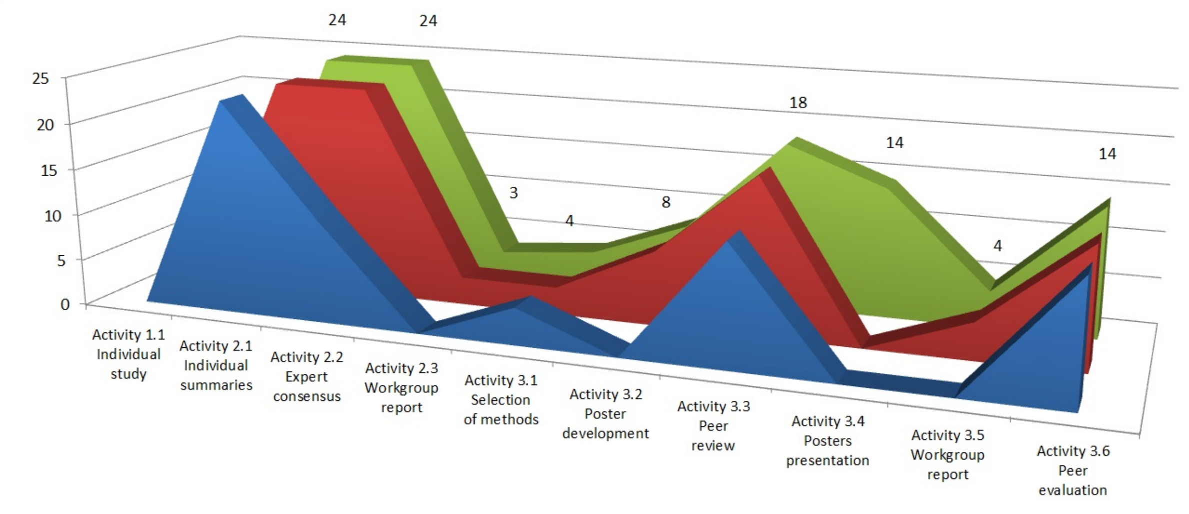
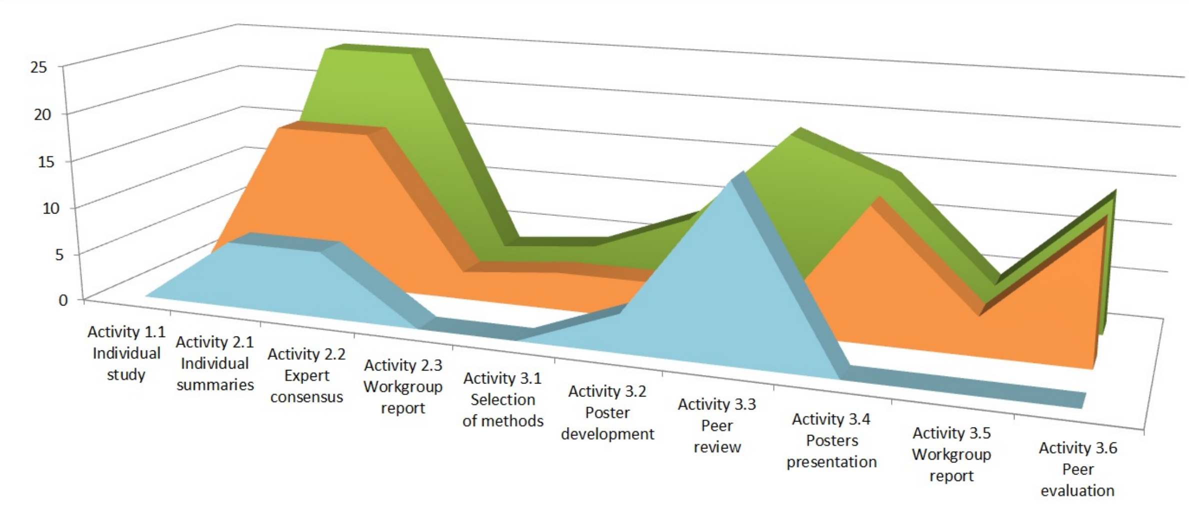


Figure E.4: Third exploratory study: overview of social level, interaction and learning type throughout the activity-flow.



	Activity 1.1 Individual study	Activity 2.1 Individual summaries	Activity 2.2 Expert consensus	Activity 2.3 Workgroup report	Activity 3.1 Selection of methods	Activity 3.2 Poster development	Activity 3.3 Peer review	Activity 3.4 Posters presentation	Activity 3.5 Workgroup report	Activity 3.6 Peer evaluation
Unknown results	0	23	11	0	4	0	13	0	0	13
Useful results	0	23	23	3	3	8	17	0	4	13
Results obtained per activity	0	24	24	3	4	8	18	14	4	14

Figure E.5: Third exploratory study: comparison among the total amount of monitoring results obtained in each activity and the number of results that were unknown and useful for the teacher when she received the report.



	Activity 1.1 Individual study	Activity 2.1 Individual summaries	Activity 2.2 Expert consensus	Activity 2.3 Workgroup report	Activity 3.1 Selection of methods	Activity 3.2 Poster development	Activity 3.3 Peer review	Activity 3.4 Posters presentation	Activity 3.5 Workgroup report	Activity 3.6 Peer evaluation
Pattern constraints	0	7	7	0	0	4	18	0	0	0
Activity constraints	0	17	17	3	4	4	0	14	4	14
Results obtained per activity	0	24	24	3	4	8	18	14	4	14

Figure E.6: Third exploratory study: breakdown of the total amount of monitoring results obtained in each activity attending to the nature of the associated constraint (pattern or activity).

Teacher awareness about the learning process (before receiving the monitoring report) was in part influenced by the stage within the activity-flow: as the script progresses, there are less chances of the current state affecting the remaining activities. This means that, as the activities go by, the monitoring information has less impact on regulation, and may be less useful for the teacher, especially in complex learning scenarios with multiple dependences between activities. Figure E.5 shows the teacher's feedback per activity regarding the unknown and useful results.

Looking at Figure E.5 and Figure E.6, we can detect that, according to the teacher's perspective, the most useful and unknown results appeared in those activities with higher number of pattern constraints.

Besides, we carried out a similar analysis relating the type of constraint that imposed each evaluated condition with the teacher's feedback on the usefulness and the novelty of the monitoring results (see Figure E.7). Throughout the learning scenario, the teacher saw the students work during the face-to-face sessions and received comment from the students. Therefore, when Julia had a look to the monitoring reports, often, she already had an idea of what was going on in the current activity (51,95% of the results related to activity constraints were already known and 76,62% turned to be useful). However, as the teacher mentioned during the interview, one of the most difficult parts for her was to realize of the impact that the current state of the learning situation might have on the following activities (25,00% of the results coming from pattern constraints were known and 97,22% were considered useful for regulation purposes).

In general terms, the analysis shows that the teacher considered the results were useful (over 94%) mainly in cases of distance or blended learning activities as well as those activities including computer-mediated or blended interaction (see Figure E.8 and Figure E.9). Conversely, in activities with purely face-to-face learning or interaction the teacher considered that the results were unnecessary for regulation purposes. It is noteworthy that, from these activities, there was no further evidence out of Julia's observations (the attendance registers), and therefore she was already aware of the results. However, according to the teacher's comments during the interview, the results obtained from these kind of activities should not be left out since they were very useful in order to have an overview of the students involvement over the whole scenario. In addition, the teacher highlighted the importance of integrating evidence from face-to-face participation in those activities carried out partially in the lab session. The combination of computer-mediated and face-to-face evidence helped to avoid false positives and to uncover problems that would have remained hidden.

Regarding the social level (see Figure E.10), while the information was useful (over 93%) in those activities where the students work individually or by groups, curiously in the whole-class activity the number of useful results came down to 0%. This drastic difference is justified because the whole-class activity was carried out face-to-face and, as we already mentioned, the teacher collected the information used in that monitoring report.

From the aforementioned analyses we can deduce that the type of learning, interaction and constraints may shed some light on the teacher's monitoring needs. At least in this study, those activities that involve distance learning and computer-mediated interaction, as well as the activities with impact on future ones tended to draw teacher's attention. On the contrary, the social level did not seem to have a clear impact since it was often conditioned by the rest of the parameters.

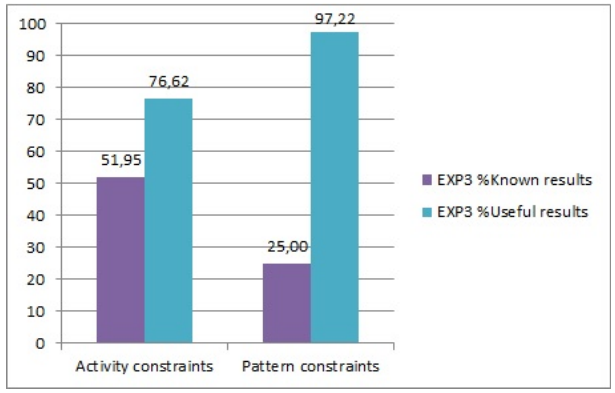


Figure E.7: Percentage of known and useful monitoring results according to the scripts constraints they come from (activity or pattern constraints).

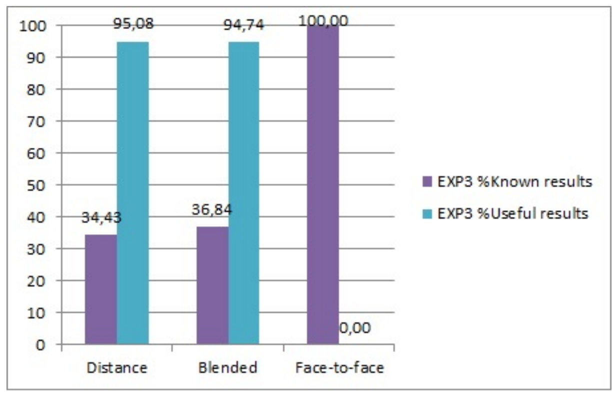


Figure E.8: Percentage of known and useful monitoring results attending to the learning type (distance, blended, face-to-face).

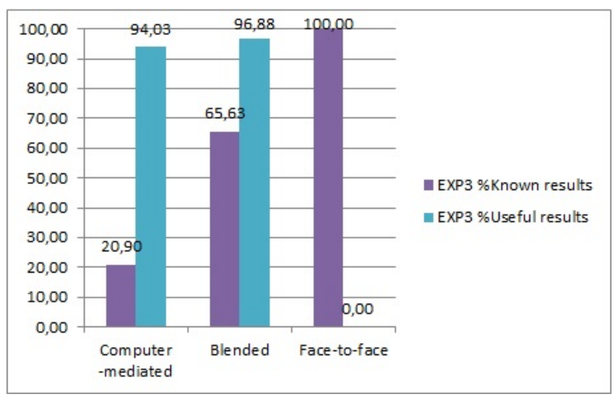


Figure E.9: Percentage of known and useful monitoring results in terms of interaction type (computer-mediated, blended, face-to-face).

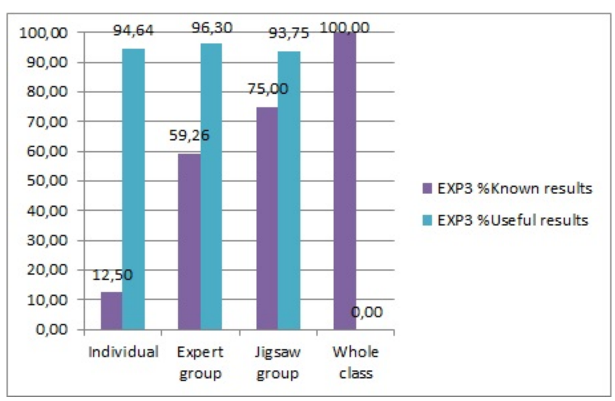


Figure E.10: Percentage of known and useful monitoring results according to the social level (individual, expert group, jigsaw group, whole class).

EXQ_MON.IT2.4: Are the script constraints enough to detect the problems that emerged during the learning situation?

The list of script constraints was based on the constraints derived from the configuration of each activity (e.g., participants, groups, social level, resources, deadlines, etc.) and the constraints imposed by the *Jigsaw* and the *Peer-review* patterns (e.g., group formation policies, general activity flow, dependences between phases/activities, etc.). The analysis of these constraints eased the identification of indicators and conditions (as the ones presented in Tables E.5 and E.6) that led us to detect 16 emerging problems during the enactment. 15 of these problems were recognized by the system and the remaining one was discovered by the teacher while reviewing the students work. Apart from the problems related to the activity and the pattern constraints (13 and 3 respectively), we did not identify any other critical situation from the analysis of the GLUE! logs [EXP3_IT_LOG], the researchers' observation [EXP3_R_OBS2], the learning outcomes in the ICT tools [EXP3_IT_LO], the teacher's feedback [EXP3_T_OBS, EXP3_T_INT], and the workgroup reports [EXP3_S_QUE1, EXP3_S_QUE2]. Thus, we can state that the script constraints were enough to detect the problems that emerged during the learning situation.

EXQ_DAT.IT2: What are the required conditions for collecting relevant information about the students' participation in a blended CSCL scenario supported by DLEs?

EXQ_DAT.IT2.1: How can the evidence about the students' participation be automatically gathered and integrated?

As we already mentioned in Section E.2, Dabbleboard did not provide any kind of information about the users' actions and, at that moment, Google Forms offered some information exclusively through the web application's graphical user interface. Regarding Mediawiki, it was possible not only to review the history of changes via the user interface, but also to query the database to analyse how students interacted with the wiki pages. Thus, we focused the analysis of computer-mediated actions on the information provided by Mediawiki and GLUE!.

Regarding face-to-face data sources, we provided Julia with a Google Spreadsheet document to register the students' attendance to the face-to-face sessions [EXP3_T_OBS] and to enable the subsequent data gathering and interpretation. Regarding the information provided by the students in the workgroup reports [EXP3_S_QUE1] [EXP3_S_QUE2], we agreed with the teacher not to integrate this data source in the analysis because the purpose of these questionnaires was to gain insight into how groups had organized the work and what had been the contributions of each one of the members, not to gather information about the script constraints. Thus, the answers to the questionnaires were delivered to the teacher complementing the information presented in the monitoring reports.

A prototype of a GLUE! module named *GLUE!-CAS* (see Section 4.6.3) was used to collect the participants' actions from the technological support [EXP3_IT_LOG], and from the attendance registers filled out by the teacher during the activities [EXP3_T_OBS]. To automate the data gathering of computer-mediated actions, we developed an adaptor for querying the Mediawiki database in addition to the interpreter already implemented for GLUE! logs. Similarly, we created a new adaptor to collect and interpret the evidence gathered by the teacher in the attendance registers.

To facilitate the integration of the three data sources, the adaptors translated the data gathered into the *Common Format* proposed by Kaleidoscope [Har09]. This format was created to promote the data sharing between technological learning environments and analysis tools, and allowed as to represent the information required for the monitoring process (i.e., the action type, the user who performed the action, the timestamp, and the resources involved in the action).

The evidence gathered by the adaptors was analysed taking into account the indicators and conditions obtained from the script constraints using *GLIMPSE* (see Section 4.6.2). The results obtained by the tool were represented manually in the graphical templates agreed with the teacher, and the monitoring reports were sent to her at the end of each activity, as she had planned.

Finally, it is noteworthy that the use of *GLUE!-CAS* and *GLIMPSE* reduced significantly the time devoted to the data gathering and analysis from 2,5 hours (in the previous study) to 5 minutes [EXP3_R_OBS2]. This drop in time costs allowed us to provide Julia with monitoring reports whenever she needed them within a small timeframe.

EXQ_DAT.IT2.2: Is the data gathered from the different data sources enough to monitor the students' participation?

Unlike the previous studies, in this case the teacher decided at design-time the data sources to be monitored. First, she adapted the list of ICT tools that made up the DLE to those ones that could offer more information about the students' actions. Besides, she included new sources (such as the attendance registers and the workgroup reports) that enriched the information obtained from the technological support, involving herself and the students in the data gathering. We have shown in Section E.4 that this combination of data sources in the monitoring process helped Julia detect and solve emerging problems during the learning process. As the teacher explicitly mentioned during the interview [EXP3_T_INT]: "Having the integrated information of the different sources is very useful [...] because it can uncover situations I was not aware of [...] and provides a general vision along the whole activity flow".

In order to estimate the **reliability** of the monitoring process, the results obtained from monitoring the Mediawiki and GLUE!'s logs [EXP3_IT_LOG] and the attendance register [EXP3_T_OBS] were compared with the learning outcomes of the students in the tool instances [EXP3_IT_LO], the questionnaires to the students about the learning process [EXP3_S_QUE1, EXP3_S_QUE2], and the information gathered by the teacher about the problems that the students had experienced during the learning process [EXP3_T_OBS]. This analysis revealed that 112 out of the 113 evaluated conditions (99,12%) were interpreted correctly by the system, while only one was erroneous. As it happened in previous studies, the error was caused because of a student accessing a tool and not performing the task he was expected to. In order to avoid this kind of mistakes, it would be necessary to extract further information from the ICT tools about the users' performance.

Final remarks

In this study we have seen certain benefits of integrating monitoring in the design of CSCL scripts. Regarding the teacher practice, this 'new' task in the design made her more confident ("having an initial plan about what has to be monitored and what to pay attention to, gives you a greater sense of control over the activity"), and pushed her to envision the potentially critical situations ("it helps you start thinking about what consequences such event may have [...]") and how to proceed in case of appearance.

Making the teacher aware of the impact of her decisions on monitoring moved her to improve the monitorable data sources (creating a DLE that offered more information about the users' actions, and including complementary data sources). Besides, she also participated in the configuration of the monitoring process, identifying the conditions to be evaluated in each activity, choosing the resources and actions to be monitored, defining the moments when she would need the information. Such teacher involvement in the configuration of the monitoring process contributed to better satisfying the teacher's monitoring needs.

During enactment, the monitoring process helped the teacher regulate the learning situation. As Julia mentioned: "monitoring reports let you focus your attention, be more efficient, and detect problems in a more timely manner". Furthermore, the reception of monitoring reports in the moments identified as 'relevant' for the monitoring (according to the teacher decisions at design-time) caused Julia to look at the students' work even if no problem was detected ("if I had not received the monitoring reports, I would not have been so watchful").

We have also shown that it was feasible to involve teachers and students in the monitoring data gathering. This integration of different data sources enabled the analysis of evidence from the face-to-face and distance part of the activities. However, in order to integrate the students feedback in the script-aware monitoring process, it would be necessary to link their feedback to the accomplishment of the script constraints.

Based on the lessons learnt from this study, we extracted a list of considerations to be taken into account in the future:

- To support teachers in the integration of monitoring concerns at design-time, it is crucial to provide teachers with descriptions of the ICT tools, specially regarding the user's actions that are monitorable. Such information is meaningful for pedagogical reasons since it informs the selection of tools. Julia said: "I might want to monitor an action but I don't know if it is monitorable. It could be useful to tell the teacher if it is possible to obtain relevant information about the aspects she's interested in."

- The teacher may not realize of the impact that her design decisions have on monitoring, or whether it is possible to obtain information from the current definition of the script ("When you design an activity you don't know if those are the best conditions so that it can be monitored."). Thus, it is necessary to provide teachers with feedback on their design decisions.

- The integration of monitorable data sources from teachers and students creates a need for tools that support them in this endeavour and, at the same time, allow the automation of the data gathering and integration.

Finally, it is worth mentioning that this study led to a first proposal of the monitoring-aware design process (see Section 4.3) with the aim of supporting teachers in the integration of monitoring aspects in the design of CSCL scenarios. Likewise, the study also guided us towards the definition of a monitoring-aware model of CSCL scripts (see Section 4.2), which establishes the connections between the design and the monitoring processes needed to automatize the data flow between them. Moreover, the co-design process entailed certain improvements on the script-aware monitoring process (such as the new script parameters that were included in the definition of the desired model) and the teacher's feedback contributed to the refinement of the monitoring reports.

Appendix F

Fourth exploratory study

Summary: In this appendix, we include the details of the third exploratory study. As part of the second iteration of the DBR process, the study focuses on three main issues: (1) to support teachers in the integration of monitoring concerns in the pattern-based design process of CSCL scripts; (2) to continue with the identification of script information necessary to guide the monitoring process of pattern-based CSCL scenarios; and (3) to find out the required conditions for collecting relevant information about students' participation in a blended CSCL scenario supported by DLEs. The study took place in 2012, within a similar context than in the third study: a course of the Master's Degree for Pre-service Secondary Education Teachers, at the University of Valladolid (Spain), involving the same teacher (*Julia*) and students. During this study, the researcher supported the teacher in both the design and the enactment phases in order to link pedagogical and monitoring purposes. To achieve that aim, the researcher provided the teacher a set of new design instruments aimed at scaffolding the design activities (e.g., activity forms and the description of the ICT tools monitoring capabilities) and the already know monitoring reports. The following sections describe the context and methodologies, the different stages of the study, and the main data sources collected. To conclude, we present the findings of the exploratory work.

F.1 Context and methodologies of the study

The fourth study involved a learning scenario that took place from March 26th to April 26th, 2012, within a course dealing with "Research in Education", in the same Master's Degree and with the same participants as in the previous study (see Appendix E). As we did in the third study, the teacher will be renamed *Julia* (T3 in Figures 1.2 and 3.1) and the students' name will be substituted by *Student1* to *Student14* to keep their identity anonymous.

This course followed a project-based learning strategy, where the students had to define in groups an educational research project, based on the principles of Action Research [Sus78]. To perform this task, the students followed a blended CSCL script based on two CLFPs: the *Pyramid* and the *Peer-review* [HL10a]. The script combined activities at different social levels (individual, group, and whole-class), with different types of learning (face-to-face, distance, and blended), interaction (face-to-face, computer-mediated, and blended), and tools (MediaWiki, Google Documents, and Google Forms).

In this exploratory study, teacher and researcher co-designed the learning scenario to integrate pedagogical and monitoring concerns. In this case, the teacher used a set of new design instruments aimed at scaffolding the design activities (activity forms, the pattern constraints, the description of the ICT tools monitoring capabilities, and the analysis of the activity constraints). The study reported in this Appendix was meant, among other goals, to explore whether the use of these instruments was affordable for the teacher, and to verify whether the output of such design process could guide the monitoring process.

As we already mentioned in Chapter 3, in this study we explored three different dimensions: first, we tried to identify how we can support teachers to integrate monitoring concerns in the pattern-based design process of CSCL scripts [EXQ_DES.IT2]; second, we aimed at determining what script information was necessary to guide the monitoring process in this pattern-based CSCL scenario [EXQ_MON.IT2]; and third, we aimed to detect the required conditions so as to collect relevant information of the participants' actions in this scenario, taking into account that it was blended and supported by a DLE [EXQ_DAT.IT2]. These dimensions were de-composed into more concrete questions, that are shown in Figure F.1.

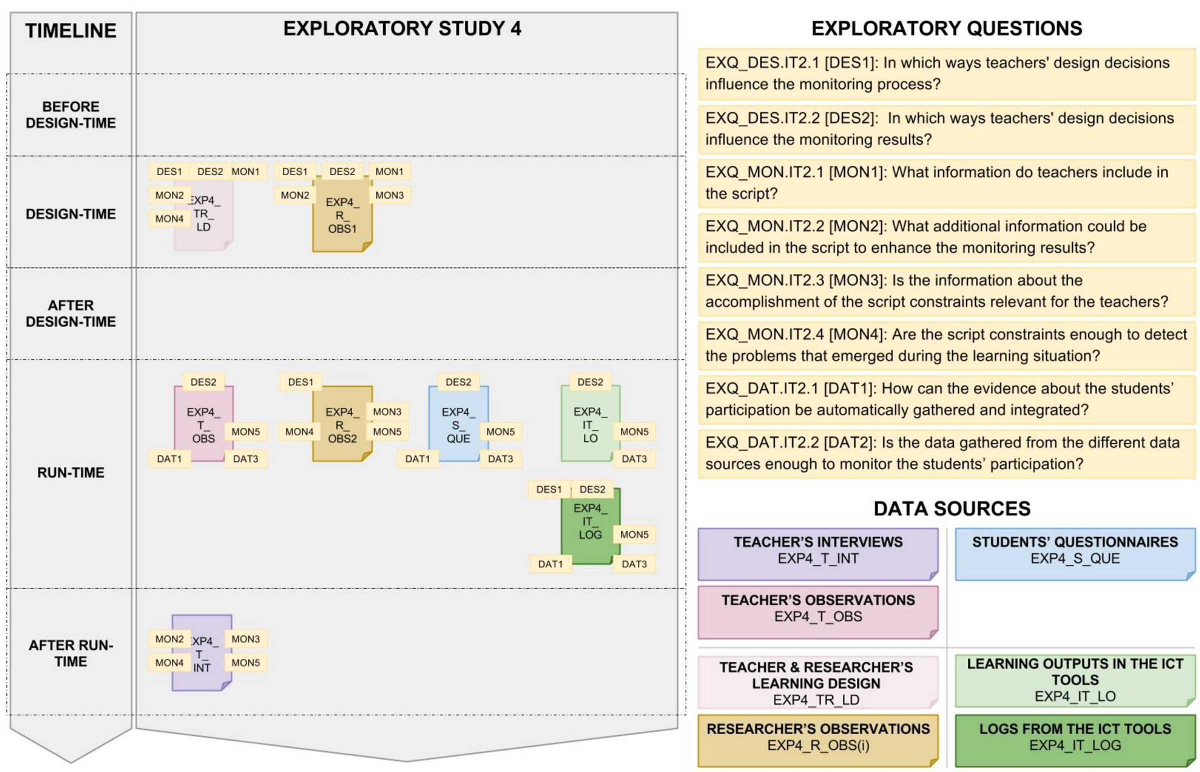


Figure F.1: Fourth exploratory study: data sources and exploratory questions.

To answer these questions, we collected several data sources throughout the study. At design time, the author of this dissertation co-designed with the teacher the learning scenario [EXP4_TR_LD], and registered the problems and difficulties identified by the teacher

[EXP4_R_OBS1]. During the enactment, in order to obtain evidence from the learning process, the teacher registered the attendance to the face-to-face sessions [EXP4_T_OBS], reviewed the learning outcomes [EXP4_IT_LO], and wrote down the problems that she herself detected [EXP4_T_OBS]; the students answered a questionnaire explaining how they had worked [EXP4_S_QUE]; and the researcher analysed the logs obtained from the ICT tools [EXP4_IT_LOG] together with the attendance register [EXP4_T_OBS]. Once the learning scenario finished, we interviewed the teacher in order to collect her impressions about the design and monitoring process [EXP4_T_INT]. Figure F.1 relates the data sources, the phases of the study when they were collected, and the exploratory questions that they helped to answer. The following sections of this Appendix describe the work done in the different phases of the study as well as the main findings obtained in relation to the exploratory questions.

F.2 Design-time

The co-design of the learning scenario required 5 face-to-face sessions, that lasted altogether around 8 hours, involving from the conceptualisation of the learning design to its deployment in the technological learning environment. To support the design and deployment tasks, the teacher used the tools *Web Collage* and *GLUE!-PS*, as in the previous study. In order to integrate the monitoring issues throughout the *pattern-based design process for CSCL scripts* [VF09b], we used *paper-based activity forms* that represented the elements to take into account in the configuration of the monitoring issues of each activity. Figure F.2 illustrates one activity form.

The design process was organized in two cycles. In the first cycle, the teacher and researcher designed the learning scenario following the guidelines given by the pattern-based design process for CSCL scripts, and also filled out the activity forms with the monitoring configuration. Then, the researcher analysed the constraints of the design and introduced them in the activity forms. With this information, the teacher faced the second cycle, where she included new data gathering and monitoring support activities in the scenario. The following subsections describe the main decisions made in the two cycles of the co-design process (summarised in Table F.1) and how the teacher used the activity forms.

F.2.1 First Cycle: Monitoring-Aware Design Driven by the Pattern

This subsection illustrates how the teacher defined the initial version of the script using the activity forms. Besides, some examples are included to explain how the researcher extracted the constraints, the indicators and conditions to be accomplished during the enactment of the learning scenario.

1. **Determine learning objectives and select pattern(s).** The collaboration script implemented a four-level *Pyramid* , including a *Peer-review* in one of the *Pyramid* 's phases [HL08]. The researcher analysed the definition of these patterns and obtained the constraints that must be verified during the enactment (see Sections B.4 and B.5). These constraints were visualised throughout the different forms of the activities in the fields *Pattern and Activity constraints* (see Figure F.2).

Table F.1: Fourth exploratory study: overview of the activities included in the script. Italicised text is used for the elements that were added in the second cycle of the study in order to improve the monitoring process.

Phase	Activity	Social level	Interaction	Learning	Resources & tools for learners	Teacher's monitoring support activities
Level 1	1.1 Individual research proposal	Individual	Computer-mediated	Distance	- 14 Google Docs (1/student)	*- Check monitoring report*
Level 2	2.1 Initial research proposal	Small groups	Blended	Blended	- 6 Google Docs (1/small group)	*- Check monitoring report* *- Control attendance*
Level 3	3.1 Final research proposal	Super groups	Blended	Blended	- 3 wiki pages (1/super group)	*- Check monitoring report* *- Control attendance*
	3.2 Development of the research plan	Super groups	Blended	Blended	- 3 wiki pages (1/super group)	*- Check monitoring report* *- Control attendance*
	3.3 Peer review	Individual	Computer-mediated	Distance	- 3 wiki pages (1/super group)	*- Check monitoring report*
	3.4 Improvement of the proposals	Super groups	Blended	Blended	- 3 wiki pages (1/super group)	*- Check monitoring report* *- Control attendance*
Level 4	4.1 Presentation of proposals & plans	Whole class	Face-to-face	Face-to-face		*- Control attendance*
	4.2 Peer evaluation	Individual	Computer-mediated	Distance	- 14 Google Forms (1/student)	*- Check monitoring report*
	4.3 Workgroup report	*Super groups*	*Computer-mediated*	*Distance*	*- 3 Google Forms (1/super group)*	*- Check monitoring report*
					TOTAL= 49 instances	

<table>
<tr><td>Activity name:</td><td colspan="3">Activity 3.2 Development of the research plan</td><td>Phase:</td><td>Level 3</td></tr>
<tr><td>Beginning:
(YYYY-MM-DD hh:mm:ss)</td><td colspan="2">2012/04/03 11:30:00</td><td>End:
(YYYY-MM-DD hh:mm:ss)</td><td colspan="2">2012/04/04 22:00:00</td></tr>
<tr><td>Enable monitoring:
(yes / no)</td><td colspan="2">yes</td><td>Monitoring dates:
(YYYY-MM-DD hh:mm:ss)</td><td colspan="2">2012/04/04 22:15:00</td></tr>
<tr><td>Social level:
(Individual / by groups / whole class)</td><td colspan="2">By groups</td><td>Interaction type:
(Face-to-face / computer mediated / blended)</td><td colspan="2">Blended</td></tr>
<tr><td>Participation:
(Optional / mandatory for individuals / mandatory for groups)</td><td colspan="2">Mandatory for individuals</td><td>Learning type:
(Face-to-face / distance / blended)</td><td colspan="2">Blended</td></tr>
<tr><td rowspan="3">Groups formation:</td><td>Group name:</td><td>Big-group 1</td><td>Participants:</td><td colspan="2">Student1, Student2, Student3, Student4, Student5</td></tr>
<tr><td>Group name:</td><td>Big-group 2</td><td>Participants:</td><td colspan="2">Student6, Student7, Student8, Student9, Student10</td></tr>
<tr><td>Group name:</td><td>Big-group 3</td><td>Participants:</td><td colspan="2">Student11, Student12, Student13, Student14</td></tr>
<tr><td rowspan="3">ICT Tools & Additional data sources :</td><td>Tool name</td><td colspan="2">Expected use
(optional/mandatory, individual/by groups)</td><td colspan="2">Actions to be monitored</td></tr>
<tr><td>Media Wiki</td><td colspan="2">mandatory, by groups</td><td colspan="2">Editions, uploads</td></tr>
<tr><td>Attendance register</td><td colspan="2">optional, individual</td><td colspan="2">Attendance</td></tr>
<tr><td>Activity constraints:
(Derived from the analysis of the activity features)</td><td colspan="5">1) Individual participation (Every participant must be involved in the activity)
2) Expected use of resources (Every group must use its MediaWiki resources)</td></tr>
<tr><td>Pattern(s) constraints:
(Derived from the analysis of the pattern(s))</td><td colspan="5">3) [Pyramid] Collaboration (In every big group all the conforming small groups from the previous level must participate)
4) [Peer review] Flow (If any group does not carry out the activity, there may be groups that during the "Peer review" activity will have no document to review)</td></tr>
<tr><td>Additional constraints:
(Specified by the teacher)</td><td colspan="5">--</td></tr>
</table>

Figure F.2: Fourth exploratory study: example of activity form filled with the information of the *Activity 3.2 Development of the research plan*. The area surrounded with a dashed line represents the constraints provided to the teacher, derived from the analysis of the pattern and the activity description.

2. Specify activity flow. The *Pyramid* pattern guided the main structure of the activity flow, made up by four phases, corresponding with the four levels of the *Pyramid* . At level-1, students proposed a research question suitable for a participatory research project. At level-2, small groups agreed on a research question inspired by their previous work. At level-3, the *Peer-review* pattern was applied. Super groups at this level had to (1) agree a research question based on the ones formulated by each small group, (2) propose a research plan, (3) review and provide feedback on at least one of the proposals produced by the other super groups, and (4) refine the proposal taking into account the received comments. Finally, at the fourth level of the *Pyramid* , super groups (1) performed an oral presentation about their proposal and (2) evaluated the presentations of the other super groups. The two first columns of Table F.1 show the structure of the activities.

This sequence of activities presents several flow constraints. For instance, the *Peer review* activity depends on *Development of the research plan*. The *Peer-review* pattern prescribes that every group must review at least one document (see third row in Table B.3). Thereby, if there are groups that do not submit the plan, other groups will have no document to review during the *Peer review* activity. Figure F.2 illustrates how this constraint set by the pattern was included in the activity forms (see *[Peer Review] Constraint* under *Pattern constraints*).

3.a Configure activities. For each activity, the teacher specified, using the activity forms, the following data: starting and finishing dates, social levels, interactivity types, expected participation, and learning type, as well as the monitoring periods (part of this information appears in Table F.1). From this configuration, new constraints could be derived. For example, the description of the *Development of the research plan* was to be carried out in groups, combining face-to-face and computer-mediated interaction, both inside and outside the classroom (blended learning). Besides, all students had to participate in the activity and the teacher wanted to receive the monitoring report 15 minutes after the finishing date. One of the constraints derived from this configuration was the need of keeping track of individual participation (see section *Activity constraints* in Figure F.2).

3.b Configure groups. The *Pyramid* pattern guided the students' grouping. At level-1, students worked individually. At level-2, the teacher created 6 small-groups of 2 to 3 participants. At level-3, the groups merged to conform 3 super groups (composed of 2 small groups). And finally, at the fourth level of the *Pyramid* there was a whole-class activity. The information related to the groups in each level was included in each activity form, as shown in Figure F.2. According to the group configuration and the collaboration constraints set by the *Pyramid* CLFP, in the activity *Development of the research plan* it was mandatory that the small groups that conformed the super groups participated actively to enable interchange of ideas (see fourth row in Table B.4). This constraint can also be observed in the *Pattern constraint* section of Figure F.2.

4. Provide resources. In this scenario the technological needs were similar to the first study. Then, the teacher already knew which tools could be used to satisfy both pedagogical and monitoring purposes, and chose them according to this criteria. MediaWiki was used to centralise the access to all resources and activities. Students had at their disposal Google Documents and MediaWiki pages for the writing tasks, and Google Forms for the on-line questionnaires. In addition, the GLUE! architecture allowed the integration of the external tools into MediaWiki.

For each activity the teacher, using the monitoring information about the ICT tools provided in Figure F.3, decided which actions would be monitored. For instance, in the example shown in Figure F.2 for the tool MediaWiki, editions and uploads were taken into account. The specification of the expected use of the tool (mandatory and by groups) generated a new activity constraint: *Every group must use its MediaWiki resources.*

Data sources	***Suitable locations***	***Tools***	***Monitorable actions***
ICT Tools	Inside /outside	Media Wiki	accesses, editions, uploads
		G Documents	accesses
		G Forms	accesses
Teachers / Observers	Inside	Attendance register	attendance

Figure F.3: Fourth exploratory study: description provided to the teacher about the monitoring capabilities of the tools involved in the learning scenario.

Based on the script description, the researcher obtained the list of constraints and verified whether there was monitorable evidence for each one of them. Some of these constraints were obtained from the pattern and others were derived from the description of the activities. Table F.2 shows some constraints derived from the adaptation of the *Pyramid* pattern to the particular context. The list of constraints was shown to the teacher in order to decide which pattern constraints should be applied in each activity.

Table F.2: Fourth exploratory study: constraints derived from the particularization of the group formation policies imposed by the *Pyramid* .

- **Number of small groups** = 6
- **Number of super groups** = 3
- **Small group size** = 2-3 students
- **Super group size** = 2 small groups (4-5 students)
- **Super group members** = at least 1 member from two different small groups

As we did in the previous studies, the selection of the indicators used for monitoring students was based on the pattern and the activity constraints. Tables F.3 and F.4 present indicators related to certain aspects (activity flow, the collaboration, the group formation policies, and expected use of resources) and how they were used to define the current and desired state of the interaction.

Table F.3: Definition of the current state of the interaction according to the indicators related to participation, collaboration and expected use of resources.

Participation: applied to individuals or groups depending on the social level of the activity.

- **Individual participation**: the involvement of each participant in the activity is measured by:
  - *The number of actions (to be monitored) that (s)he performs:* $\{\sum \text{action}|$ $(\text{action.creator.id} = \text{participant.id})\ \&(\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$
- **Group participation**: the involvement of each group in the activity is measured by:
  - *The number of actions (to be monitored) that the group members perform:* $\{\sum \text{action}|$ $(\text{action.creator} \subseteq \text{group.participants})\ \&\ (\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$

Collaboration among group members: for each group, the collaboration is measured by the actions (performed by individuals or subgroups, depending on the social level) to be monitored according to the teacher's decisions :

- **Small groups**: the collaboration is measured by:
  - *The actions (to be monitored) that the group members perform:* $\{\sum \text{action}|$ $(\text{action.creator} \subseteq \text{group.participants})\ \&\ (\text{action.type} \in \text{group.resources\_to\_be\_monitored})\}$
- **Super groups**: the collaboration is measured by:
  - *The number of actions (to be monitored) that the small groups perform:* $\{\sum \text{action}|$ $(\text{action.creator} \subseteq \text{subgroup.participants})\ \&(\text{subgroup.id} \subseteq \text{group.subgroups})$ $\&\ (\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$

Group formation: for each activity, it is necessary to control the group formation policies, e.g., the group size.

- **Group size**: the size of the groups is measured by the number of group members (individuals or subgroups depending on the social level) that are participating:
  - *The number of individuals who have participated:* $\{\sum \text{participant}|\text{actor.id} = \text{participant.id}\ \&$ $\text{action.actor} > 0\}$
  - *The number of subgroups who have participated:* $\{\sum \text{subgroups}|\text{group.id} = \text{subgroup.id}\ \&\ \text{action.group} > 0\}$

Use of monitored resources: for each monitored resource that supports the activity, the use that participants make of it is measured by:

- *The number of actions (to be monitored) performed by the participants of the activity*: $\{\sum \text{interaction}|$ $(\text{action.creator} \subseteq \text{activity.participants})\ \&\ (\text{action.type} \in \text{resource.actions\_to\_be\_monitored})\}$

Table F.4: Application of the constraints to the indicators presented in Table F.3.

Participation: depending on the social level (individual/group), the expected participation values are:

- **Individual participation**:
  - *for each participant*: If activity.social_level = individual $\rightarrow$ participant.participation ≥ 1
- **Group participation**:
  - *for each small group*: If activity.social_level = small_group $\rightarrow$ group.participation ≥ 1
  - *for each super group*: If activity.social_level = big_group or whole_class $\rightarrow$ group.participation ≥ 1

Collaboration among group members: if the activity is collaborative, for each group the expected collaboration values are:

- *At least two group members participate*: If (activity.social_level $\neq$ individual) $\rightarrow$ $\{\exists$participant1, participant2$|$ (participant1.participation ≥ 1) & (participant2.participation ≥ 1)$\}$

Group formation:

- *for each super group there there must be at least two members from different small groups*: $\{\exists$participant1, participant2$|$ (participant1.participation ≥ 1) & (participant1 $\in$ small_groupA) & (participant2.participation ≥ 1) & (participant2 $\in$ small_groupB)$\}$

Use of monitored resources:

- *for each activity*: $activity.resource.use \geq 1$

F.2.2 Second Cycle: Enriching the Design to Enhance Monitoring.

During the second cycle of the co-design process, the teacher reviewed the constraints of each activity and compared them with the information that the technological context could offer. This review led to the enrichment of the learning design with new activities and resources (see italicised text in Table F.1). This subsection describes how the teacher made such decisions.

Using the relation between data sources, interaction and learning type (see previous study, Table E.7), the teacher analysed whether the current configuration of activities could generate enough evidence to inform about the constraints. This analysis moved her to add new data gathering activities (students had to elaborate a workgroup report at the end of the activity flow), and monitoring support activities (the teacher registered the attendance in those activities that happened partially or completely face-to-face in the classroom, see text in italics in Table F.1).

Focusing on the activity *Development of the research plan*, there were several constraints to be informed related to the individual participation, the expected use of resources, the collaboration, and the activity flow. Although MediaWiki provided evidence about computer-supported actions, there was no data source about face-to-face actions (necessary to inform about the individual participation and the collaboration). Therefore, the teacher decided to control the attendance to the lab sessions. Outside the lab sessions, students normally collaborated via MediaWiki. Thus, the teacher decided not to gather information about face-to-face interactions outside the classroom.

F.3 After design-time

As it happened in the previous study, the visualization of the monitoring reports was not yet automated. Thus, we prepared a template of the monitoring reports *a priori*, to minimize the time required in the generation of the reports at run-time. The researcher refined the monitoring reports integrating the teacher's suggestions that emerged during the previous study (e.g., including student names and links to the activities to ease the access and review of the learning environment). The graphical proposal was discussed with Julia to ensure the understandability of the reports. For each learning activity, the monitoring report offered certain *contextual information* such as aspects of the activity description (name, social level, learning type, time-frame, participants, groups, and resources) and teacher's monitoring decisions (actions and resources to be monitored as well as critical situations that might have emerged during the enactment). This information made it easier for the teacher to remember the setting and constraints of the different activities, and to interpret the results of the data analysis. The following section provides an example of a monitoring report[1] (see Figure F.4).

F.4 Run-time

During the enactment, a monitoring report was sent to the teacher in the moments specified by her (generally, 15 minutes after the deadline of each activity). For that purpose, we used a *GLUE!-CAS* prototype (see Section 4.6.3) to automatically gather and integrate the monitorable data sources, and *GLIMPSE* (described in Section 4.6.2) to analyse the participants' actions according to the indicators and conditions obtained from the script constraints.

The monitoring reports were compared for its validation with the evidence gathered by the teacher herself during the enactment [EXP4_T_OBS] (e.g., emails and comments from students), researcher's observations [EXP4_R_OBS2], the learning outcomes [EXP4_IT_LO], and the workgroup reports sent by the students at the end of the scenario [EXP4_S_QUE]. From this validation we obtained that 219 of the 226 evaluated conditions (96,90%) were interpreted correctly by the system. The remaining cases corresponded to 7 false positives, 6 of them caused by the students carrying out their tasks before the expected activity timeframe, and the remaining one was due to a student accessing the activity resources using a groupmate's user account.

As it happened in the previous study, monitoring reports helped the teacher to confirm that the students were following properly the script: out of 226 evaluated elements, 196 (86,72%) were consistent with the script expectations, while 30 corresponded to unexpected events, requiring the teacher's intervention. Out of the 226 (60,62%) evaluated elements, 137 were unknown by the teacher and 150 (66,37%) were considered relevant for regulating the learning scenario. Some of the situations requiring intervention are presented here to illustrate the impact that monitoring had in supporting the management of the learning situation.

Eventualities were detected regarding the activity constraints, such as lack of participation by some individuals or groups. Sometimes these problems were known in advance (e.g., Student6 was not involved in the learning situation from the very beginning) or did not require intervention

[1] An anonimized version of the monitoring reports is available in the additional material attached to this document. See Appendix H.

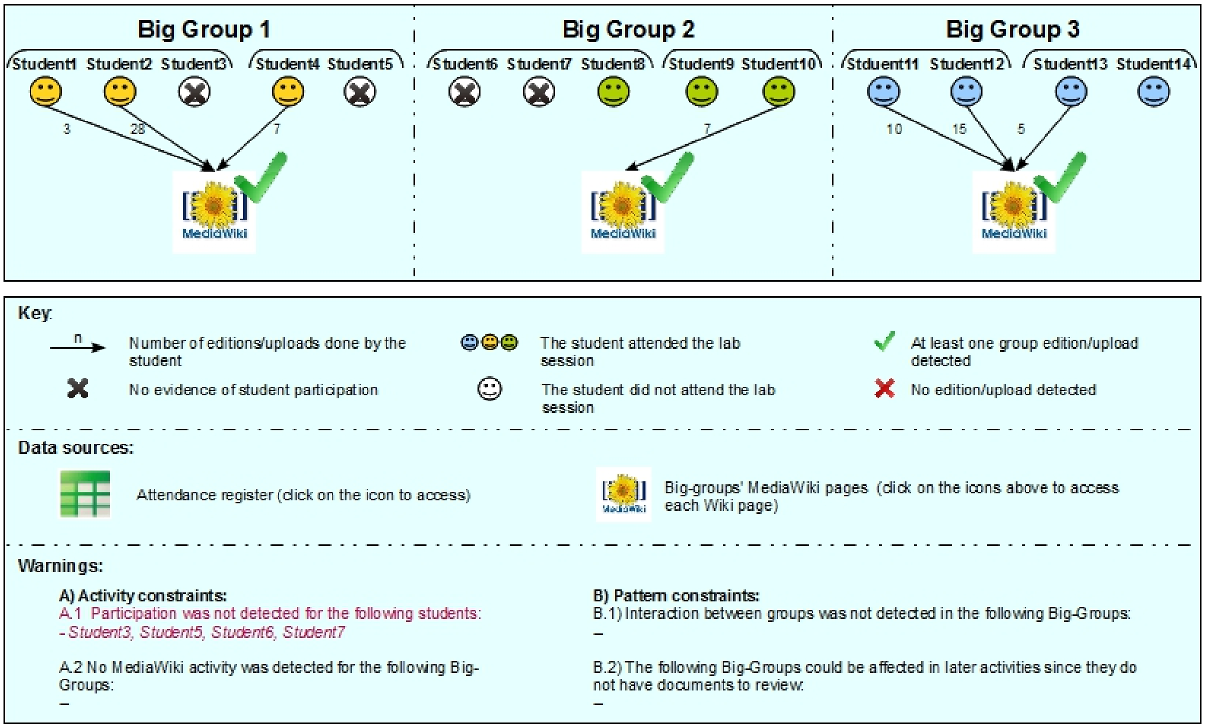


Figure F.4: Example of the information sent in the monitoring report of the *Activity 3.2 Development of the research plan.*

(e.g., activities in which the lack of participation of one student did not entail any additional problem). However, in those activities with lack of group participation, the teacher reviewed the wiki pages and realised that the students had included their contributions in the wrong place and could fix it on time (as it happened with Small Group 1.1 during Activity 2.1).

Related to the pattern constraints, two problems appeared that could have affected the success of the *Pyramid* pattern. During *Activity 1.1 Individual research proposal*, two out of three students that conformed a group in the second level of the *Pyramid* were not participating. This situation could imply that during the second phase of the *Pyramid* , one student would be isolated with no option of collaboration. To face this problem, the teacher contacted the students and extended the deadline. Moreover, during the second activity, which was supposed to be collaborative, no interaction was detected between the members of three groups. The teacher contacted them and the students confirmed that they had used different communication media (phone calls, emails, or face-to-face meetings) to interact within the activity.

Figure F.4 displays a fragment of the monitoring report sent to the teacher at the end of the *Activity 3.2 Development of the research plan*. Coloured icons were used to represent the participants who attended the lab session, and white was used to represent those that did not attend. The labels on the arrows specify how many times each participant edited or upload a file in MediaWiki. Crosses over participants represent those cases where no evidence of participation could be deduced from the collected data. At the bottom of the figure, the warnings associated to the constraints (see Figure F.2) were included. As it can be seen, in this specific report there was no evidence of participation from four of the students.

F.5 After run-time

Once the learning scenario finished, we interviewed Julia to gather her feedback on the learning design and monitoring processes [EXP4_T_INT]. Table F.5 and Table F.6 collect some of the teacher's comments extracted from the interview.

The first topic addressed was how the integration of monitoring at design time influenced the teacher's design decisions (see Table F.5). From Julia's perspective, this 'enriched' design process contributed, without a significant extra effort, to a more detailed description of the script that enabled monitoring later on. The design process encourage the teacher to explicitly state aspects "that you should anyway have in mind, such as the dates, the dependencies among activities, or what is expected of each activity". Besides, the fact of involving herself and the students in the monitoring process was considered beneficial not only for the teacher (who could reflect on their own learning process) but also for the students, who reflected on their own learning process. In addition, reflecting on monitoring issues at design-time increased the teacher's awareness of potential incidents that could impact on the learning scenario, and contributed to think *a priori* about possible solutions.

Table F.5: Fourth exploratory study: teacher's feedback regarding the design process [EXP4_T_INT].

Topic	Question	Answer
How monitoring influenced the design of the scenario:	1. Was the design modified due to monitorization needs?	Yes. The description of the design has varied, to be more detailed, and activities and resources for the teacher related to the monitorization (attendance lists, monitoring reports) have been included. Furthermore, on the student side, they have been asked to fill in a groupwork report, in order to trace the online activities.
	2. Do you consider that the design process has been enriched? If yes, how has it been enriched?	Yes, and also it has enabled monitoring later on.
	3. Do you consider the cost of integrating monitoring in the design process was high?	No. Although it does entail an extra effort, the amount of time is not significative. Furthermore, it helps you notice about design aspects that you should anyways have in mind, such as the dates, the dependencies among activities, or what is expected of each activity.
	4. When you were providing information related to monitoring, did you have the impression of it being a task unrelated to designing the scenario? Or did you perceive it as just another aspect to define about the scenario?	It is an issue which is very related to the tasks that the teacher has to do. Furthermore, asking students to do a report about their own work has helped students to reflect about how they have participated.
The impact of including monitoring from the design phase into the enactment of the scenario:	1. Reflecting about monitoring at design-time, has it helped you have a higher awareness of what eventualities could appear and their potential impact on the learning scenario?	Yes, it makes you be more aware and lets you anticipate.
	2. Did the configuration of monitoring during design of the scenario help you have greater control over it?	Yes
	3. Reflecting about monitoring in the design phase, has it helped you be more confident about how to regulate in face of eventual occurrences?	Yes. Being aware of what can happen helps you think about possible 'solutions'.
Changes and improvements for future versions	1. What changes would you do to improve the design process?	In general it is difficult to know which tool to choose and what monitoring opportunities it affords. Also it is difficult to know when it is necessary and/or relevant to gather data from students. It would be interesting a higher 'automation' of the process.

Asking for potential improvements, Julia pointed out two main difficulties in the design process: she stated that teachers need advice on which tool to choose and what monitoring opportunities it affords; besides, she mentioned that it is difficult to know when it is necessary and/or relevant to gather additional data for monitoring. Therefore, the teacher proposed "a higher 'automation' of the process" in order to support these design tasks.

The second topic tackled during the interview was the monitoring process (see Table F.6). From Julia's point of view, monitoring reports were easy and "almost immediate" to interpret, and helped her trace the activities "in a faster and simpler way". Regarding the content of the monitoring reports, Julia considered that they were useful, even though there had been relatively few problems to detect. Besides, the teacher pointed out that the use of pattern and activity constraints to guide the monitoring process offered more precise results.

Table F.6: Fourth exploratory study: teacher's feedback regarding the monitoring process [EXP4_T_INT].

Topic	Question	Answer
The presentation of results:	1. Was it easy to interpret the results of the monitoring reports?	Yes.
	2. Approximately how much time did you need to interpret the results of the monitoring report?	It was almost immediate! Having a report helps you trace the activities in a faster and simpler way. In any case, since you need to revise the reports, documents and wiki pages to know what has happened, it can be very useful to have the links to the resources in the report.
	3. Do you think that using the pattern and the activity characteristics was useful for the monitoring?	Yes, although in this case there were not many events to detect. It lets the results be more precise.
About the impact that the monitoring results had in the scenario:	1. The monitoring results helped you trace the progress of the learning scenario? or were they already evident?	Having a report helps you keep track of the scenario in an easier way. Even in the cases where evidence could have been gathered manually, it saved time. It was very useful in the peer-review, to know who had done what, since doing that manually would have been very costly.
	2. From all the data provided in the reports, which ones were you already aware of, and which ones you did not know? In the case of data that you already knew, how did you obtain them?	No, the report arrived before I had any evidence of my own (before I revised the students' work). Furthermore, there was a predominance of online work.
	3. Was it useful, the integration of information from the tools with the information from the teacher/observer?	Yes. In the case of the student questionnaires we should think about how to integrate them to check their reliability.
	4. The information provided, did it make you take regulatory measures during the learning scenario? Of which kind?	It supported, especially, the opposite. The fact that the report pointed out that students were performing the activities correctly, meant that I did not have to revise the students'/groups' work exhaustively.
	5. Having those results helped you avoid bigger problems?	Detecting deviations from the design enabled the resolution of problems as soon as possible. However, in this case there were no "big problems" to solve.
	6. Which other data sources would have been interesting to include in the [monitoring] analysis?	Students [as a source of data], either with work reports or minutes (indicating who has worked in the activity, how have they done that, face-to-face, through email, ...).
The results obtained vs. other information sources:	1. If you had other kinds of data, would you have monitored in a different way (be it automatic or manual)? How?	In a manual fashion, I could revise the change history of the wiki. However, I wouldn't do it, due to time constraints.
	2. Do you think that monitoring has caused you to invest more, or less, time in the tracking of the scenario?	Less time, definitively. Knowing that the assessment was positive (indicating that students were performing the activities correctly) allowed to avoid the exhaustive review of the work of each student.
	3. About the monitoring process (additional comments)	It has many advantages such as time savings, systematization and accomplishment of the monitoring tasks. This has prompted a greater control over the evolution of the learning scenario.
Changes and improvements for future versions	1. What changes would you do to improve the monitoring process?	To diminish the apparition of 'false positives', since they require reviewing what has happened. [...] It would be especially useful to be able to modify the reports with my own information. For example, in some cases the students sent the deliverable to me, or I already knew that they had delivered beyond the deadline. [...] To include student feedback.

Comparing the monitoring reports versus alternative data sources, and despite the fact that in some cases the evidence offered by the reports could have been gathered manually (e.g., revising the change history in Mediawiki), the teacher stated that she would have not done it, since that approach would have been very costly. Indeed, when Julia received the monitoring reports, often she had no evidence of student progress, mainly because there was a predominance of online work. Thus, we can state that the monitoring reports favoured the tracking of the learning activities.

Additionally, the monitoring reports eased the regulation process: knowing that the evidence was positive (indicating that students were performing the activities correctly) avoided an exhaustive review of the students' work. Besides, the teacher confirmed that, despite the lack of 'serious problems' throughout the scenario, detecting deviations from the design enabled the resolution of potentially critical situations as soon as possible.

In order to enhance monitoring and the consequent regulation, Julia highlighted three main aspects to deal with: first, to diminish the apparition of 'false positives', since they require a careful reviewing of what has happened; second, to be able to modify or complete the reports with her own observations (in addition to the attendance register); and third, to integrate students' own feedback to triangulate the different perspectives.

Finally, in order to delve into what information helps the teacher regulate the learning process, we reviewed the monitoring reports classifying which of the 226 results were unknown by Julia (when she received the monitoring report) and whether they were useful for her. The following section presents the outcomes of this analysis.

F.6 Findings

This section aims at discussing in detail the evidence gathered in the study, following the exploratory questions presented in Figure F.1. As part of the second iteration, the exploratory questions address three main aspects: a) how to help teachers integrate monitoring concerns in the pattern-based design process of CSCL scripts; b) what script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs; and c) what are the required conditions for collecting relevant information of the students' participation in a blended CSCL scenario supported by DLEs.

EXQ_DES.IT2: How can teachers be supported to integrate monitoring concerns in the pattern-based design process of CSCL scripts?

EXQ_DES.IT2.1: In which ways teachers' design decisions affect the monitoring process?

Throughout the co-design process [EXP4_TR_LD] [EXP4_R_OBS1] and the researcher's observations during run-time [EXP4_R_OBS2], we identified new parameters that influenced the monitoring process. Table F.7 collects these parameters specifying whether they conditioned the data gathering or the representation of the desired state of a CSCL situation. For instance, offering to the teacher the possibility of choosing which activities and resources must be monitored, not only affects the data gathering but also reduces irrelevant information for monitoring purposes. Besides, taking into account how the teacher expects that resources will be used contributes to fine-tune the representation of the desired state. In addition, we realised that certain parameters

Table F.7: Fourth exploratory study: dimensions and parameters that a) contribute to enhance the monitoring process at design time and b) guide the data gathering and representation of the desired state. Parameters in *italics* emerged in this scenario, the rest of them were already taken into account in the previous study.

Dimension	**Parameter**	**Script design**	**Data gathering**	**Desired state representation**
Pattern Constraints	Activity flow			X
	Collaboration			X
	Group formation policies			X
Activity Configuration	Timeframes		X	
	Resources (tools, contents)		X	
	Participants		X	X
	Groups			X
	Social level	X		X
	Interaction type	X		X
	Learning type	X		
	Participation			X
Teacher's monitoring decisions	Monitoring periods		X	
	Activities to be monitored		X	
	Resources to be monitored		X	
	Actions to be monitored		X	
	Expected use of resources			X
ICT tools	*Monitorable actions*	X	X	

also affected the analysis at design-time. For instance, the monitorable actions guided the selection of ICT tools in the first cycle; and the analysis of the social level, interactivity type, learning type, and the monitorable actions were used to detect which activities might need additional data sources to be included in the second design cycle.

Since the teacher had designed the scenario of the third exploratory study, she had already internalized many of the monitoring-related tasks. For instance, using the activity forms she was able to describe on her own the activity parameters that affected monitoring. However, there were two aspects that required additional help from the researcher: the selection of tools ("it is difficult to know which learning tool to choose and what monitoring opportunities it affords") and the identification of situations that could require further data sources ("it is difficult to know when it is necessary and/or relevant to gather data from students.") [EXP4_R_OBS1] [EXP4_T_INT].

EXQ_DES.IT2.2: In which ways teachers' design decisions affect the monitoring results?

Teacher involvement in the monitoring configuration enhanced the monitoring results [EXP4_TR_LD, EXP4_R_OBS1,EXP4_R_OBS2]. The selection of constraints to be applied in each activity focused the analysis on questions relevant for teacher and reduced the appearance of false positives. Besides, the inclusion of monitorable data sources [EXP4_T_OBS, EXP4_S_QUE] complementary to the ICT tools [EXP4_IT_LOG], increased the accuracy of the results. And finally, the specification of activities, resources and actions to be monitored filtered the evidence relevant for the teacher.

EXQ_MON.IT2: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?

EXQ_MON.IT2.1: What information do teachers include in the script?

Table F.7 summarises the information included in the script [EXP4_TR_LD]. According to the researcher observations [EXP4_R_OBS1], first, the teacher defined the pedagogical patterns followed by the main elements that usually appear in CSCL scripts (participants, groups, roles, activities and resources). Then, she included the information necessary to guide the monitoring process (deadlines, social level, interaction, learning type, etc.) and her own monitoring decisions (monitoring periods, activities, resources and actions to be monitored).

EXQ_MON.IT2.2: What additional information could be included in the script to enhance the monitoring results?

Apart from the new parameters identified in Table F.7 during the co-design process [EXP4_TR_LD] [EXP4_R_OBS1], no additional design element emerged from the observations during the enactment [EXP4_T_OBS][EXP4_R_OBS2], nor from the interview to the teacher [EXP4_T_INT].

EXQ_MON.IT2.3: Is the information about the accomplishment of the script constraints relevant for the teachers?

Based on Julia's feedback during the review of the monitoring reports [EXP4_T_INT], we analysed the relevance of script constraints. Out of the 226 evaluated conditions, 150 (66,37%) were considered relevant for the regulation of the learning scenario, and 137 (60,62%) were unknown to her before receiving the monitoring report: "the report arrived before I had any evidence of my own". Besides, the reports contributed to save teacher's time, independently of the number of problems detected: "although in this case there were not many events to detect [...] the fact that the report pointed out that students were performing the activities correctly, afforded that I did not have to revise the work of each group or student exhaustively".

We used certain script parameters that influenced the monitoring process (namely, social level, learning and interaction type of each activity, and the sort of constraints) to analyse teacher's answers about the novelty of the monitoring information. Figure F.5 provides an overview of these parameters and Figure F.6 summarizes the teacher's answers throughout the activity flow. Looking at Figure F.6, the most useful and unknown results appeared in those activities that involved computer-mediated interaction and distance learning (Activity 1.1, Activity 3.4 and Activity 4.2). Conversely, the monitoring reports provided less useful information in cases of face-to-face interaction during the lab sessions (Activity 4.1).

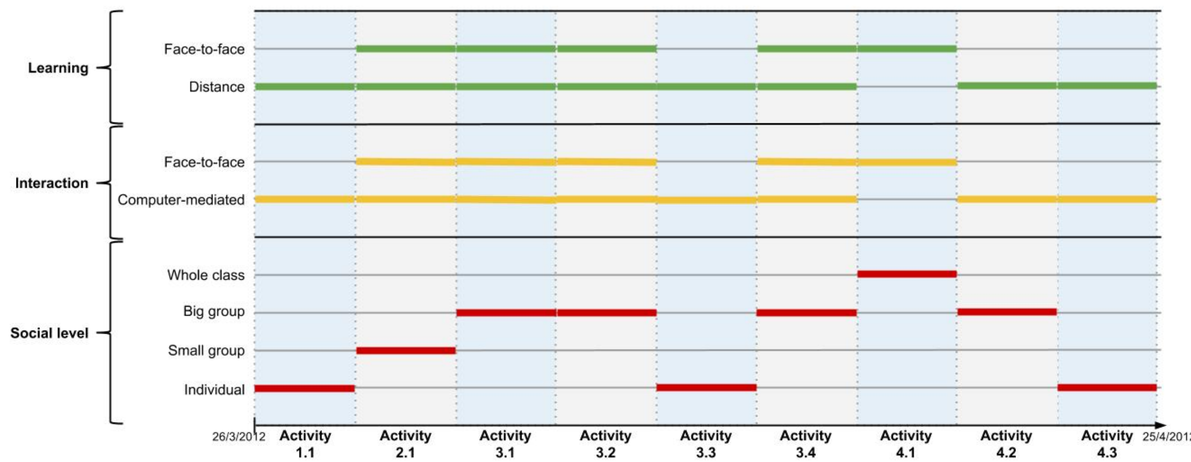
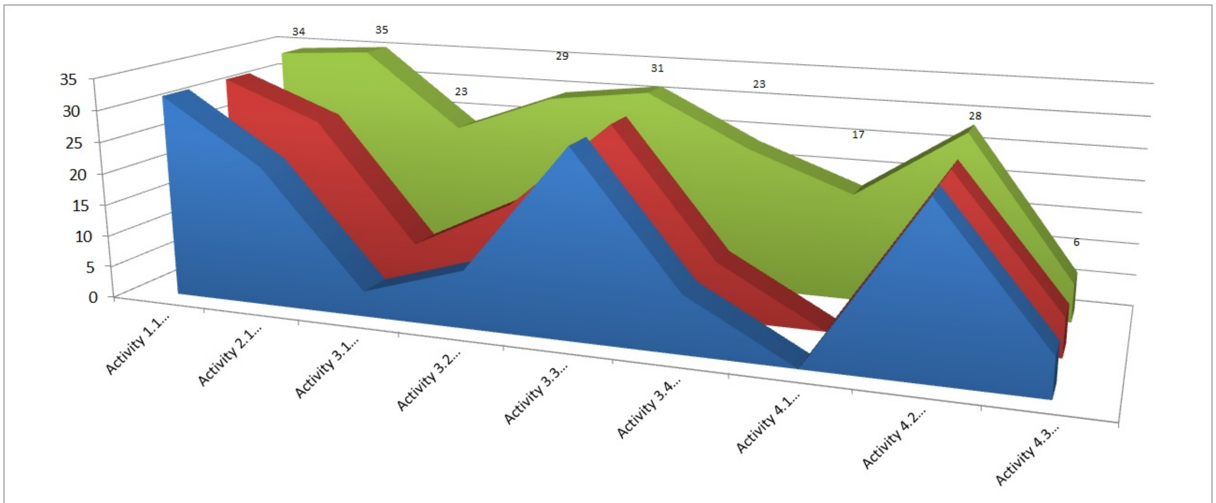


Figure F.5: Fourth exploratory study: overview of social level, interaction and learning type throughout the activity-flow.



	Activity 1.1 Individual research proposal	Activity 2.1 Final research proposal	Activity 3.1 Final research proposal	Activity 3.2 Development of the research plan	Activity 3.3 Peer review	Activity 3.4 Improvement of the proposals	Activity 4.1 Presentation of research proposals & plans	Activity 4.2 Peer evaluation	Activity 4.3 Workgroup report
Unknown results	32	22	4	9	29	9	0	26	6
Useful results	32	26	7	15	29	9	0	26	6
Results obtained per activity	34	35	23	29	31	23	17	28	6

Figure F.6: Fourth exploratory study: comparison among the total amount of monitoring results obtained in each activity and the number of results that were unknown and useful for the teacher when she received the report.

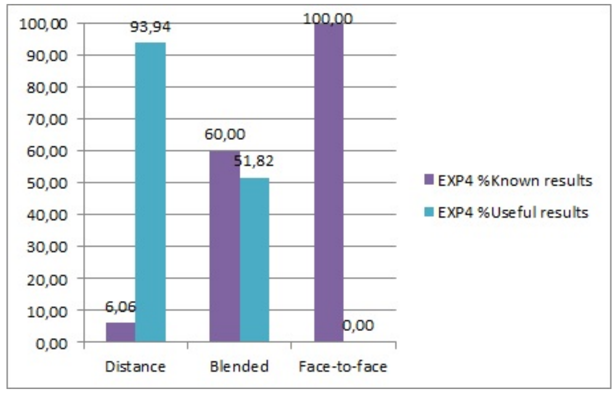


Figure F.7: Fourth exploratory study: percentage of known and useful monitoring results attending to the learning type (distance, blended, face-to-face).

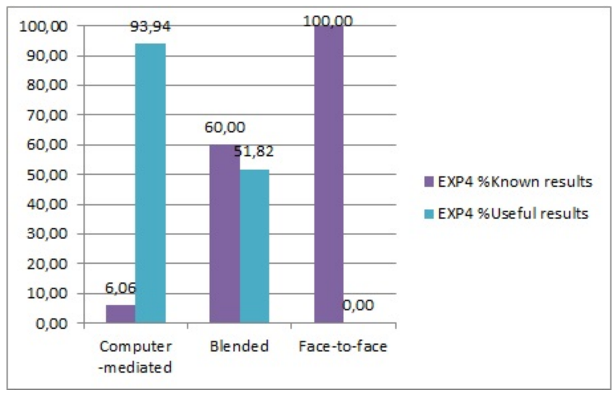


Figure F.8: Fourth exploratory study: percentage of known and useful monitoring results in terms of interaction type (computer-mediated, blended, face-to-face).

Looking at Figure F.5, we can observe that there is a coincidence between the description of the learning type and the interaction type: all distance activities were computer-mediated, activities involving blended interactions also combined blended learning, and the only activity carried out exclusively during the lab session entailed face-to-face interactions. Thus, when analysing whether the monitoring results were useful and already known by Julia, the values obtained were the same for learning and interaction type (see Figure F.7 and Figure F.8). From these analysis we can infer that face-to-face activities offered more awareness opportunities to the teacher. However, in activities with more computer support and performed out of the classroom, she would have received little or no contextual information.

Regarding the social level (see Figure F.9), it seems that the monitoring results were specially useful in individual tasks (93,55%) and their relevance decreased as the group size increased. However, we should notice that these results were influenced by the learning and interaction type: all 3 individual activities involved computer-mediated interactions and distance learning; 4 out of 5 activities carried out in small and super groups were blended in terms of learning and interaction; and the single whole-class activity was held during a lab session with just face-to-face interaction (see Figure F.5).

Dealing with the type of constraint that imposed each evaluated condition, Figure F.10 shows the percentages of useful and known information based on Julia's feedback. Despite the fact that the amount of results known in advance was similar in both cases (around 39%), the usefulness is larger in those cases were the results are related to pattern constraints. The teacher herself emphasized this fact during the interview: "it was very useful in the peer-review, to know

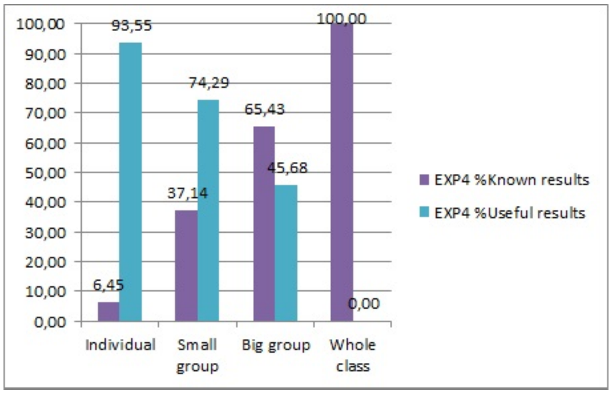


Figure F.9: Fourth exploratory study: percentage of known and useful monitoring results according to the social level (individual, expert group, jigsaw group, whole class).

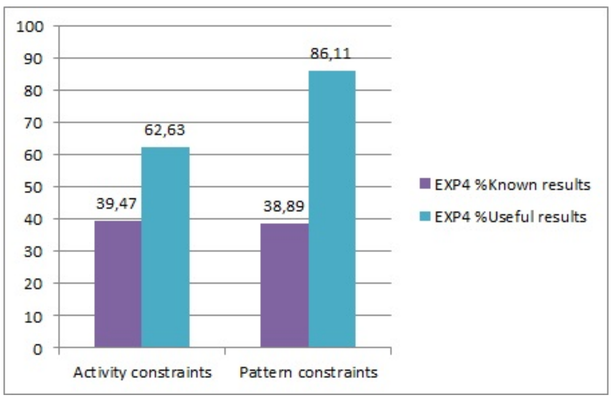


Figure F.10: Fourth exploratory study: percentage of known and useful monitoring results according to the scripts constraints they come from (activity or pattern constraints).

who had done what, since doing that manually would have been very costly".

Aligned with the results obtained in the previous exploratory study (see Section E.6), we can deduce that the type of learning, interaction and constraints may be related to the teacher's monitoring needs. As we have seen in this study, those activities that involve distance learning and computer-mediated interaction, as well as the activities with impact on future ones were especially relevant for the teacher. The impact of social level, however, is not so obvious since it was often conditioned by the rest of the parameters.

EXQ_MON.IT2.4: Are the script constraints enough to detect the problems that emerged during the learning situation?

The list of script constraints was based on the constraints derived from the configuration of each activity (e.g., participants, groups, social level, resources, deadlines, etc.) and the constraints imposed by the *Pyramid* and the *Peer-review* patterns (e.g., group formation policies, general activity flow, dependences between phases/activities, etc.). The analysis of these constraints eased the identification of indicators and conditions (such as those presented in Tables F.3 and F.4). This analysis led us to detect 37 potentially critical situations during the enactment. Thirty of these situations were real problems and the other 7 were false positives. Aside from the problems related to the activity and the pattern constraints (26 and 4 respectively), we did not identify any other critical situation from the analysis of the GLUE! logs [EXP4_IT_LOG], the researchers' observation [EXP4_R_OBS2], the learning outcomes in the ICT tools [EXP4_IT_LO], the teacher's feedback [EXP4_T_OBS, EXP4_T_INT], and the workgroup reports [EXP4_S_QUE]. Thus, we can state that the script constraints were enough to detect the problems that emerged during the learning situation.

EXQ_DAT.IT2: What are the required conditions for collecting relevant information about the students' participation in a blended CSCL scenario supported by DLEs?

EXQ_DAT.IT2.1: How can the evidence about the students' participation be automatically gathered and integrated?

As we already mentioned in Section F.2, the monitorable actions from the DLE were the accesses to the Google applications (obtained from the GLUE! logs) as well as the editions and uploads made in Mediawiki. The face-to-face data sources, we automated the data gathering and analysis of the Google Spreadsheet filled out by Julia about the students' attendance to the face-to-face sessions [EXP4_T_OBS]. We did not to integrate the students' feedback [EXP4_S_QUE] in the analysis because the workgroup reports had been designed to gain insight into how groups had organized the work and what had been the contributions of each one of the members (not to gather information about the script constraints). Thus, the students' feedback was directly interpreted by the teacher, complementing the information presented in the monitoring reports.

The monitoring process was supported by *GLIMPSE* (see Section 4.6.2). This tool performed the monitoring process, by means of the script instantiation details provided by GLUE!-PS (an XML file compliant with the *Lingua Franca* [Pri11a]) and the monitoring configuration (a translation of the activity form in XML format). Based on this information, *GLIMPSE* used the *GLUE!-CAS* prototype (see Section 4.6.3), to gather and integrate the actions to be monitored from the DLE [EXP4_IT_LOG, EXP4_T_OBS]. Finally, the results obtained by the tool were represented manually in the graphical templates agreed with the teacher, and the monitoring reports were sent to her at the end of each activity as she had planned. The time required for collecting data, analysing the evidence, and generating the graphical representation of the report was around 5 minutes per activity [EXP4_R_OBS2].

EXQ_DAT.IT2.2: Is the data gathered from the different data sources enough to monitor the students' participation?

In order to estimate the **reliability** of the monitoring process, the results obtained from monitoring the Mediawiki database, GLUE!'s logs [EXP4_IT_LOG] and the attendance register [EXP4_T_OBS] were compared with the learning outcomes of the students in the tool instances [EXP4_IT_LO], the workgroup reports [EXP4_S_QUE], and the information gathered by the teacher about the problems that the students had during the learning process [EXP4_T_OBS]. This analysis revealed that 219 out of the 226 evaluated conditions (96,90%) were interpreted correctly by the system, while 7 were false positives (caused because students submitted their works sooner than expected and used their group mates' user accounts). Extracting further information from the ICT tools about the user performance could contribute to reduce the number of false positives and to obtain more reliable results.

F.6.1 Final remarks

The integration of monitoring aspects at design-time, according to the teacher's point of view, enriched the design process, enabled monitoring, and improved the quality of the monitoring reports without a significant extra effort. In addition, reflecting on monitoring issues at design-time increased the teacher's awareness of potential incidents that could impact on the learning scenario, and contributed to think *a priori* about possible solutions.

Also in this case, providing the teacher with monitoring reports dealing with the script constraints helped her to follow the students' performance with low effort: when monitoring reports confirmed that students were accomplishing properly the activities, the teacher was not obliged to review in detail the students' work to obtain the same information; and, when the report announced potential problems, it facilitated solving them before becoming a real breakdown in the course. Indeed, the benefits of the monitoring process were highlighted by Julia during the interview: "It has many advantages such as time savings, systematization and accomplishment of the monitoring tasks. This has prompted a greater control over the evolution of the learning scenario". Besides, involving herself and the students in the monitoring process was considered convenient not only for the teacher but also for the students, who could so reflect on their own learning process.

Based on the lessons learnt from this study, we extracted two main considerations to be taken into account in the future. First, using the activity forms to collect the teacher decisions, the unique tasks of the design process that required additional support from the researcher were the selection of tools and the analysis of constraints versus monitorable data sources. Thus, we need to pay special attention to support teachers in these two tasks. And second, the integration of participants' feedback (e.g., students) in the monitoring process requires resources, aligned with the monitoring purposes, that support them in the data gathering and enable an automated analysis.

Appendix G

Fifth exploratory study

Summary: In this appendix, we include the details of the fifth exploratory study. As part of the second iteration, we explored three different dimensions: a) how to support teachers in the integration of monitoring concerns in the pattern-based design process; b) what script information was necessary to guide the monitoring process; and c) what were the required conditions for collecting relevant information of the participants' actions in this blended CSCL scenario supported by a DLE. The study took place in 2012, within a course of the Kindergarten Degree on Primary Education, at the University of Valladolid (Spain), involving a non-expert teacher in CSCL scenarios (*Carmen*) and 60 students. During this study, the researcher co-designed the learning scenario with teacher in order to meet both pedagogical and monitoring needs, and supported her in the monitoring process. The following sections describe the work done in the different phases of the study as well as the main findings of the exploratory work: the needs identified to adapt our proposals to be feasible not only for experts on CSCL; the script parameters and dimensions that guided the monitoring process; the relevance of using the script constraints for regulating the learning scenario; and the suitability of the selected data sources for monitoring the blended CSCL scenario.

G.1 Context and methodologies of the study

The fifth study focuses on a learning scenario that took place in Valladolid (Spain) from May 17th to June 4th, 2012. The learning scenario was framed within a course on "Guidance and mentoring for students and families" of a Degree in -early- Childhood Education involving a teacher with little experience in CSCL scenarios and 60 students enrolled in the course. From now on, we will refer to the teacher as *Carmen* (T4 in Figures 1.2 and 3.1) and the students will be labelled from *Student1* to *Student60*, to preserve their anonymity.

During this course, students learnt different techniques to face controversial situations that arise in real educational practice in order to support the students and their families. To encourage the internalization of these situations, Carmen proposed students to define a problematic situation where they had to apply the interview technique (for gathering data from parents, children and other educational experts). In this scenario, students worked in a blended CSCL setting mediated by several ICT tools (Moodle, Google Documents, Google Forms, and online videos).

In the previous studies, we had worked with teachers who were experts in CSCL. However, in this case Carmen had short experience in CSCL. This particularity would allow us to adapt our proposals to be feasible for less experienced teachers, not only for exceptional ones. Besides, the number of students to monitor was higher than in the previous scenarios, and therefore monitoring the students progress could probably prove even more complex. This aspect would allow us to verify whether our monitoring results were suitable to larger classroom sizes. Finally, dealing with the pedagogical patterns implemented, the teacher wanted to apply a *Role-playing* . Applying our proposal to a scenario based on a different pattern, would be useful to validate whether the constraints of a different pattern could also be relevant for the monitoring process.

As we did in the rest of the studies that belong to the second iteration (see Chapter 3), we explored three main exploratory questions: a) how could we support teachers to integrate monitoring concerns in the pattern-based design process of CSCL scripts? [EXQ_DES.IT2]; b) what script information was necessary to guide the monitoring process in this pattern-based CSCL scenario [EXQ_MON.IT2]; and c) what were the required conditions for collecting relevant information of the participants' actions in this blended CSCL scenario supported by a DLE? [EXQ_DAT.IT2]. These questions were split into more concrete ones, that are shown in Figure G.1.

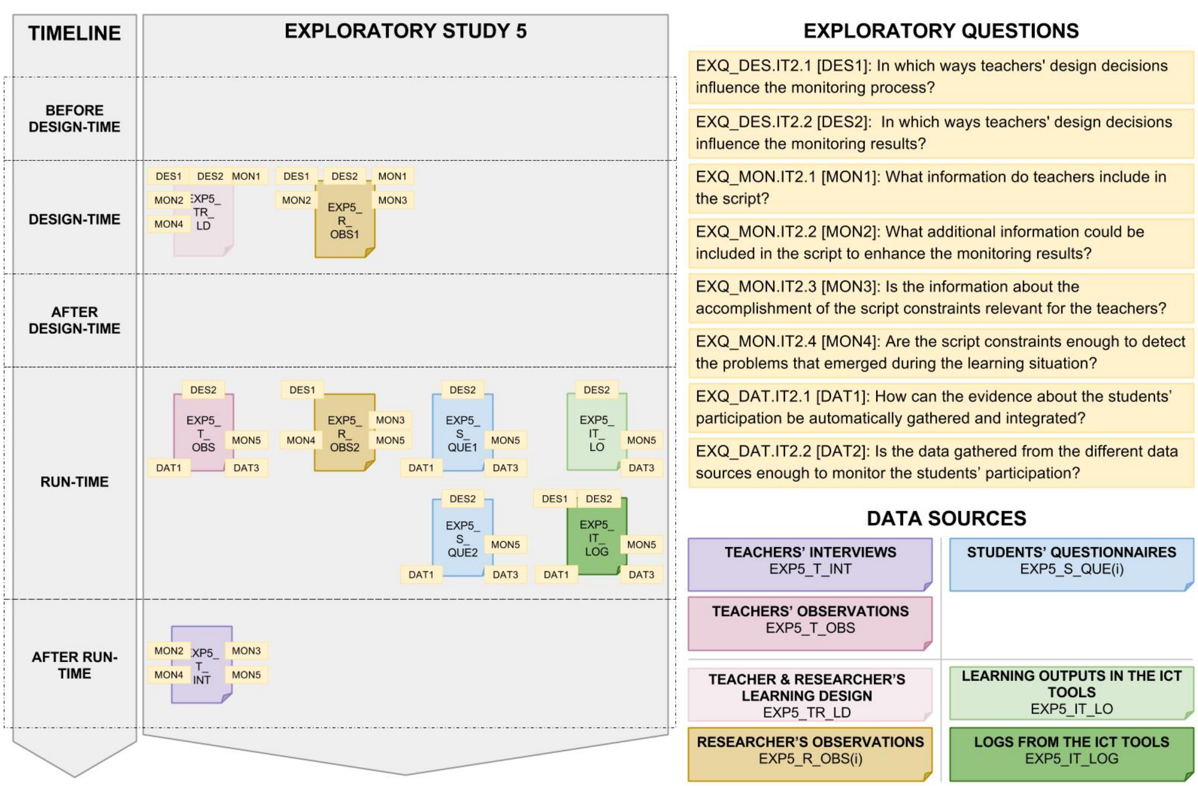


Figure G.1: Fifth exploratory study: data sources and exploratory questions.

To answer these questions, we collected several data sources throughout the study. At design-time, teacher and researcher co-designed the learning scenario [EXP5_T_LD], while the researcher registered problems and difficulties identified by Carmen [EXP5_R_OBS1]. During the enactment, in order to obtain evidence from the learning process, the teacher provided her observations including the student attendance to the face-to-face sessions and the review of the learning outcomes [EXP5_T_OBS, EXP5_IT_LO], students answered two questionnaires explaining how they had worked [EXP5_S_QUE1, EXP5_S_QUE2], and the researcher analysed the logs obtained from the ICT tools [EXP5_IT_LOG] and integrated them with the additional monitoring data sources [EXP5_T_OBS, EXP5_S_QUE1, EXP5_S_QUE2]. Finally, we interviewed Carmen to collect her impressions about the whole study [EXP5_T_INT]. Figure G.1 offers an overview of the data sources, the moments when they were collected, and the exploratory questions that they answer.

The following sections of this Appendix describe the work done in the different phases of the study as well as the main findings obtained in relation to the exploratory questions.

G.2 Design-time

The design process spanned from the initial conceptualization of the script to the deployment in the learning environment. In contrast to the previous cases, the script was deployed in 3 stages due to the particularities of the learning scenario: one before the beginning of learning activities, and the other two, iteratively during the enactment. To carry out these tasks, teacher and researcher held 4 collaborative sessions for a total of 7,5 hours. To support the design and deployment tasks, Carmen used the tools *Pedagogical Pattern Collector*[1] and *GLUE!-PS*.

The design of the script was organized in two cycles. In the first cycle, the teacher designed the learning scenario following the guidelines given by the *pattern-based design process for CSCL scripts* [VF09b], and using the activity forms, provided the information relevant for monitoring. During this first cycle, the researcher explained to the teacher about the impact of her decisions on the monitoring process. Then, the researcher analysed the script constraints and introduced them in the activity forms (simulating an automated process). With this information, Carmen faced the second cycle, wherein she included new data gathering and monitoring support activities. The following subsections describe the main decisions made in the two cycles of the co-design process (summarised in Table G.1) and how the activity forms were used.

G.2.1 First Cycle: Monitoring-Aware Design Driven by the Pattern

During the first cycle, the teacher defined the initial version of the script using the activity forms and the researcher extracted the constraints, the indicators and conditions to be accomplished during the enactment of the learning scenario. This subsection summarizes the design decisions and presents some examples of the conditions inferred from the script constraints.

1. **Determine learning objectives and select pattern(s).** The collaborative script combined two pedagogical patterns, a *Role-playing* and a *Peer-review* [HL08]. The former

[1]Pedagogical Pattern Collector: `http://web.lkldev.ioe.ac.uk/PPC/live/ODC.html` (Last visit: 16 March 2014)

Activity name:	Activity 1.1 Role-playing preparation	**Enable monitoring:** * (yes / no)	yes
Beginning: * (YYYY-MM-DD hh:mm:ss)	2012-05-17 17:00:00	**End:** * (YYYY-MM-DD hh:mm:ss)	23/05/12 17:00
Social level: * (individual / by groups / whole class)	by groups	**Interaction type:** * (face-to-face / computer-mediated / blended)	blended
Participation: * (optional / mandatory for individuals / mandatory for groups)	mandatory for individuals	**Learning type:** * (face-to-face / distance / blended)	blended

Group formation:	Group name:	Group A	Participants:	Student01, Student02, Student03, Student04
	Group name:	Group B	Participants:	Student05, Student06, Student07, Student08
	Group name:	Group C	Participants:	Student09, Student10, Student11, Student12
	Group name:	Group D	Participants:	Student13, Student14, Student15
	Group name:	Group E	Participants:	Student16, Student17, Student18
	Group name:	Group F	Participants:	Student19, Student20, Student21, Student22
	Group name:	Group G	Participants:	Student23, Student24, Student25, Student26
	Group name:	Group H	Participants:	Student27, Student28, Student29, Student30
ICT Tools, expected use[1] & actions to be monitored: * [1](optional / mandatory, individual / by groups)	Tool 1:	Reference material: the interview technique manuals (optional, individual)	Actions:	--
	Tool 2:	Google Documents (mandatory, by groups)	Actions:	Access
Additional data sources & actions to be monitored:	Tool 1:	Attendance register	Actions:	Attendance
	Tool 2:	Workgroup report	Actions:	Interaction and learning type

Script constraints: (check the ones relevant for the monitoring process)	X	Activity	*A.1) Participation:* Each student has to participate
	X	Activity	*A.2) Expected use of resources:* Each group has to use its Google Docs
	X	Pattern (role-playing)	*B.1) Collaboration:* There must be interaction between group memebers
	X	Pattern (role-playing)	*B.2) Group size:* The must be at least one student for each role
		Pattern (role-playing)	*B.3) Number of roles:* The must be at least one role assigned to each student
		Pattern (role-playing)	*B.4) Number of groups:* The must be at least two groups to discuss about the simulation
		Pattern (peer-review)	*B.5) Group size:* The must be at least one student in each group
		Pattern (peer-review)	*B.6) Number of groups:* The must be at least two groups to carry out the review process
		Pattern (peer-review)	*B.7) Reviewer assignment:* There must be at least one role-playing performance assigned to each reviewer
		Pattern (peer-review)	*B.8) Reviewer assignment:* There must be at least one reviewer assigned to each role-playing performance
Additional constraints: (Specified by the teacher)			
Monitoring dates: * (YYYY-MM-DD hh:mm:ss)	(Date 1) 2012-05-20 24:00:00 (Date 2) 2012-05-23 24:00:00		

Figure G.2: Fifth exploratory study: example of activity form filled with the information of the *Activity 1.1 Role-playing preparation*. Students' names have been modified to ensure their privacy.

Table G.1: Fifth exploratory study: overview of the activities included in the script. Italicised text is used for the elements that were added in the second cycle of the study in order to improve the monitoring process.

Phase	Activity	Social level	Interaction	Learning	Resources & tools for learners	Resources & tools for teachers
1.1	Role-playing preparation	Group	Blended	Blended	- 16 Google Docs *- 1 Google Forms*	*Monitoring report* *Attendance register*
1.2	Role-playing presentation	Whole-class	Face-to-face	Face-to-face		*Monitoring report* *Attendance register*
2.1	Peer review	Group	Computer-mediated	Distance	- 16 Google Docs - 16 Videos	*Monitoring report*
2.2	Answer to the reviewers	Group	Computer-mediated	Distance	- 16 Google Docs - 16 Videos	*Monitoring report*
2.3	*Workgroup report*	*Group*	*Computer-mediated*	*Distance*	*- 1 Google Forms*	*Monitoring report*
					TOTAL= 82 instances	

was applied to foster the students' internalization of the different roles that may intervene when facing controversial situations that arise in a real educational practice (mainly, students, teachers, and families), and to get used to the interview technique. *Peer-review* pattern was included to promote analytical thinking and critical assessment (by means of the review task) as well as to foster reasoning and argumentation (in the students' answer to the reviews of their peers). The researcher analysed the definition of these patterns and obtained the constraints that must be verified during the enactment (see Sections B.4 and B.6). These constraints were visualised throughout the activity forms in the area *Script constraints* (see Figure G.2).

2. **Specify activity flow.** The script was made up by two phases as it is shown in Table G.1: the first focused on the *Role-playing* and the second devoted to the *Peer-review* . In the first phase, each group had to review reference material about the interview technique and formulate a controversial situation that later would be played to the whole class. The teacher video recorded students' performances and uploaded the videos for later use in the *Peer-review* . In the second phase, each group had to review and provide feedback on two performances made by their classmates, and finally, reflect and make a report considering the comments they had received from their peers.

   This sequence of activities presents several flow constraints. For instance, the learning outcomes of the *Role-playing* phase conditioned the *Peer-review* phase. The *Peer-review* pattern prescribes that every group must review at least one peer document (see third row in Table B.3). Thereby, if there are groups that do not submit their work, other groups will have no document to review during the *Peer review* activity. Figure G.2 illustrates how this constraint set by the patterns were included in the activity forms (see *[Peer-review]*

Table G.2: Fifth exploratory study: constraints imposed by the *Role-playing* CLFP.

Structuring constraints	Description
$\forall group : size >= 2$	There must be enough participants to collaborate in each group.
$\forall group : \forall rol \exists student$	There must be at least one role for each student.
$\forall group : \forall student \exists rol$	There must be at least one student for each role.
$\|groups\| >= 2$	There must be at least two groups to discuss about the simulation.

constraints under *Script constraints*).

3.a Configure activities. For each activity Carmen specified, using the activity forms, the following data: time-frame, social level, interactivity type, expected participation, and learning type, as well as the monitoring periods (some of these elements are shown in Table G.1). From this configuration, new constraints could be derived. For example, the *Role-playing preparation* was a blended activity to be carried out by groups both inside and outside the classroom, and the participation was mandatory for all the students. This description implies that there should be evidence of participation from each student among the actions gathered from the DLE, the attendance register and the students' feedback (see *[Activity] constraints* under *'Script constraints'* in Figure G.2).

3.b Configure groups. Students were distributed in small groups of 3 to 4 people to accomplish the *Role-playing* guidelines (see Table G.2). Thus, in each group there was at least one person playing the roles of 'student', 'teacher/school member', 'tutor/family member'. This group distribution was maintained throughout the whole scenario. The information related to the group distribution as well as the group configuration and the collaboration constraints were included in each activity form (see Figure G.2).

4. Provide resources. Regarding the technological support, Carmen wanted to use the institutional VLE (Moodle) to centralize the access to all the resources and activities, and GLUE! to integrate the third-party tools into the VLE. Besides, it was necessary to provide some manuals about the interview technique, on-line documents for collaborative writing, and access to the videos recorded during the *Role-playing presentation* activity. Looking at the tools available in GLUE! and their monitoring affordances (see Figure G.3), she chose Google Documents to support the explanation, peer-review and discussion on the role-playing, and decided to offer the videos as a 'web-content' to be able to monitor the access to them. In addition, for each activity, the teacher specified the expected usage of the resources (optional/mandatory, individual/by groups) and decided which tools should be monitored and which were the actions relevant for her.

In relation to the resources that supported the learning scenario, new constraints emerged. For instance, the on-line documents created for the first activity (*Activity 1.1 Role-playing*

Data sources	*Learning type*	*Interaction type*	*Tools*	*Monitorable actions*
ICT Tools	Face-to-face / Blended / Distance	Blended / Computer-mediated	Media Wiki	accesses, editions, uploads
			Dabbleboard	accesses
			Google Documents	accesses
			Google Forms	accesses
			Google Presentations	accesses
			Other tools integrated via GLUE!	accesses
Teachers / Observers	Face-to-face / Blended	Face-to-face / Blended	Attendance register	attendance
Students	Blended / Distance	Blended / Computer-mediated	Students report	interaction type (face-to-face / computer-mediated / blended), learning type (face-to-face / distance / blended)

Figure G.3: Fifth exploratory study: description provided to the teacher about the monitoring capabilities of the tools involved in the learning scenario.

preparation) were reused in Activity 2.1 and Activity 2.2. Therefore, if the outcome of the first activity was now properly achieved, it could affect the rest of the script.

Based on the script description, the researcher obtained the list of constraints and showed them to the teacher in order to decide which ones should be applied in each activity. Many of them were ignored due to their being redundant or unnecessary for this specific context. For instance, the first activity was *mandatory for groups* and *the use of group Google Document was mandatory*. Although both constraints are slightly different (groups could participate face-to-face and through computers), verifying whether *all groups had used their resources as expected* and verifying whether *all groups had participated* was unnecessary taking into account that this document was the unique resource to be used during the activity. Therefore, the second constraint was ignored since it was a bit more general and did not provide additional information. The list of constraints considered relevant for the teacher were included in the activity form (see those constraints under *Script constraints* marked with a 'X' in Figure G.2).

G.2.2 Second Cycle: Enriching the Design to Enhance Monitoring.

During the second cycle of the co-design process, the teacher and the researcher reviewed the constraints of each activity and compared them with the information that the technological context could offer. This review led to the enrichment of the learning design with new resources/activities (elaboration of workgroup reports in the first activity and at the end of the second phase) and data sources (involving the teacher and the students to gather data about the face-to-face interactions). Table G.1 shows the contributions of the second cycle in italics. In this case, the researcher supported the teacher in the definition of the questionnaire addressed to the students about the work in groups. Apart from several descriptive questions defined by the teacher, questions related to the script constraints were included to better understand how students had interacted.

G.3 After design-time

Following the approach of the previous studies, to minimize the time required in the generation of the reports in run-time, the researcher prepared a template with the graphical version of the monitoring reports[2] before the enactment began. This graphical proposal was discussed with Carmen to ensure the understandability of the reports. An example of monitoring report is included in the following section (see Figure G.4).

G.4 Run-time

The script [EXP5_TR_LD] was put into practice in the context previously described, and throughout the different activities we provided Carmen with monitoring reports. To obtain the data analysis we used the *GLIMPSE* and *GLUE!-CAS* prototypes (see Section 4.6.2 and Section 4.6.3). By means of the script and the activity forms the *GLIMPSE* prototype automated the analysis process. First, based on the activity description (time-frames, participants, resources, and actions to be monitored), *GLIMPSE* launched the data gathering, using *GLUE!-CAS* to collect the participants' actions from the different data sources [EXP5_IT_LOG, EXP5_T_OBS, EXP5_S_QUE1, EXP5_S_QUE2]. Then, *GLIMPSE* analysed the collected evidence taking into account the indicators and conditions obtained from the script constraints. The results were represented in the monitoring report templates, and the information was sent to the teacher in the moments she had planned (at the end of each activity and at the middle of Activity 1.1).

The monitoring reports were validated by comparison with the evidence gathered by the teacher during the enactment [EXP5_T_OBS] (e.g., emails and comments from students), the learning outcomes [EXP5_IT_LO], and the questionnaires answered by the students at the end of the each phase [EXP5_S_QUE1, EXP5_S_QUE2]. Out of the 448 evaluated conditions, 100% were interpreted correctly by the system.

In most cases, the monitored reports helped Carmen confirm that the students were following properly the script: out of the 448 evaluated conditions, 431 (96,21%) were consistent with the script expectations, while the other 17 (3,79%) were unexpected events mainly caused by students having problems in the access to their resources.

Figure G.4 displays the monitoring report sent to the teacher at the end of the first activity (just half of the class has been included for space reasons). Coloured icons were used to represent the participants who attended the lab session, and white was used to represent those that did not attend. The labels on the arrows specify how many times each participant accessed the shared Google Document. Crosses over participants represent those cases where no evidence of participation could be deduced from the collected data. On the right side of the Figure, the warnings associated to the script constraints are included. As it can be seen in this figure, in this specific report no evidence of participation was detected for *Student17* and *Student19*. The lack of participation by *Student17* triggered an additional problem: if this situation continued, *Group E* would not have enough students to perform each role. The information gathered from the ICT tools and from the attendance register was completed with the feedback obtained from

[2]An anonimized version of the monitoring reports is available in the additional material attached to this document. See Appendix H.

the students. Figure G.4 shows the results obtained. Each group described how its members had been involved during the activity: face-to-face during the class, face-to-face after the class, or in a computer-mediated way. Base on the students' answers, the teacher verified that *Student17* and *Student19* had worked with their group mates, and therefore there would be no problem in the following activities.

G.5 After run-time

After the learning scenario, we interviewed Carmen to gather her feedback on the learning design and monitoring processes [EXP5_T_INT]. Some of her comments have been included in Table G.3 and Table G.4.

Regarding the design phase, the teacher perceived the relations between scripting and monitoring decisions ("The reflections we have made about the monitoring have a pedagogical logic within the design"). Indeed, she highlighted that reflecting on monitoring improved the script, since the design considered "not only what students have to do, but also how they should do it, and how we can follow the progress of students", without a notable additional effort. Besides, the design process helped Carmen be aware of potential eventualities and how the apparition of problems could affect the different activities. The teacher stated that in the design of future scenarios she would take those lessons learnt into account.

One of the most difficult tasks of the design process dealt with the selection of tools. The teacher mentioned that, without the researcher's help, she would not have known what were the ICT tools' affordances in terms of monitoring. Also, she had problems to identify whether her monitoring needs could be satisfied with the script and considered that she could not do it on herself. To address these issues, she suggested that it would be useful to have a tool or a guide that helps the teacher design taking monitorization into account.

Concerning the enactment, the monitoring reports helped Carmen trace the progress of the learning situation. Although during the scenario no important problem arose, the reports triggered some regulatory actions by the teacher (e.g., checking the email and contacting the students), which in turn eased the detection and solution of technical problems.

According to the teacher's opinion, the monitoring reports were clear and easy to interpret "at a glance". Without depending on receiving students' feedback on the problems they faced, and before she checked the students' work, the reports provided Carmen with information not easily collectable for her in terms of time ("doing this manually would have taken a time that I do not have") and content (in the absence of monitoring reports "I would not have had the slightest idea of who has participated in the classroom, or outside, or how they had done it, etc.").

In relation to the report content, she considered that using the pattern and the activity characteristics was very interesting since "you can see not only the problems of the current activity, but also how they effect on the following ones". Also, integrating evidence gathered from the DLE, the teacher and the students turned out to be useful: "Having all the information compiled and integrated is very useful. It's magic! You manage to see things that you would not be aware of by yourself". In the case of the evidence gathered from the face-to-face session, though it was provided by Carmen, she considered that it was convenient to take it into account in the

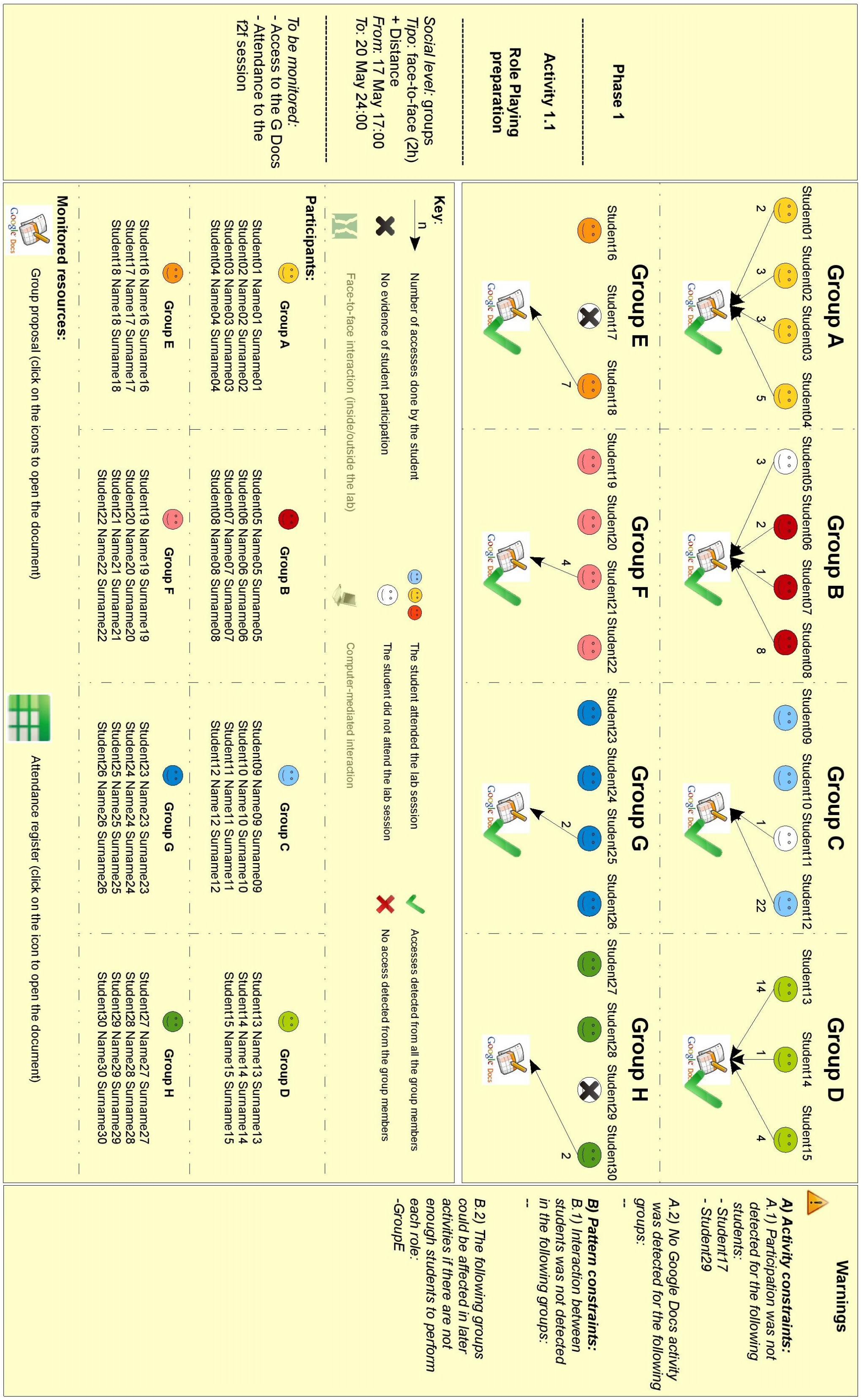


Figure G.4: Fifth exploratory study: monitoring report sent to the teacher at the end of *Activity 1.1 Role-playing preparation*.

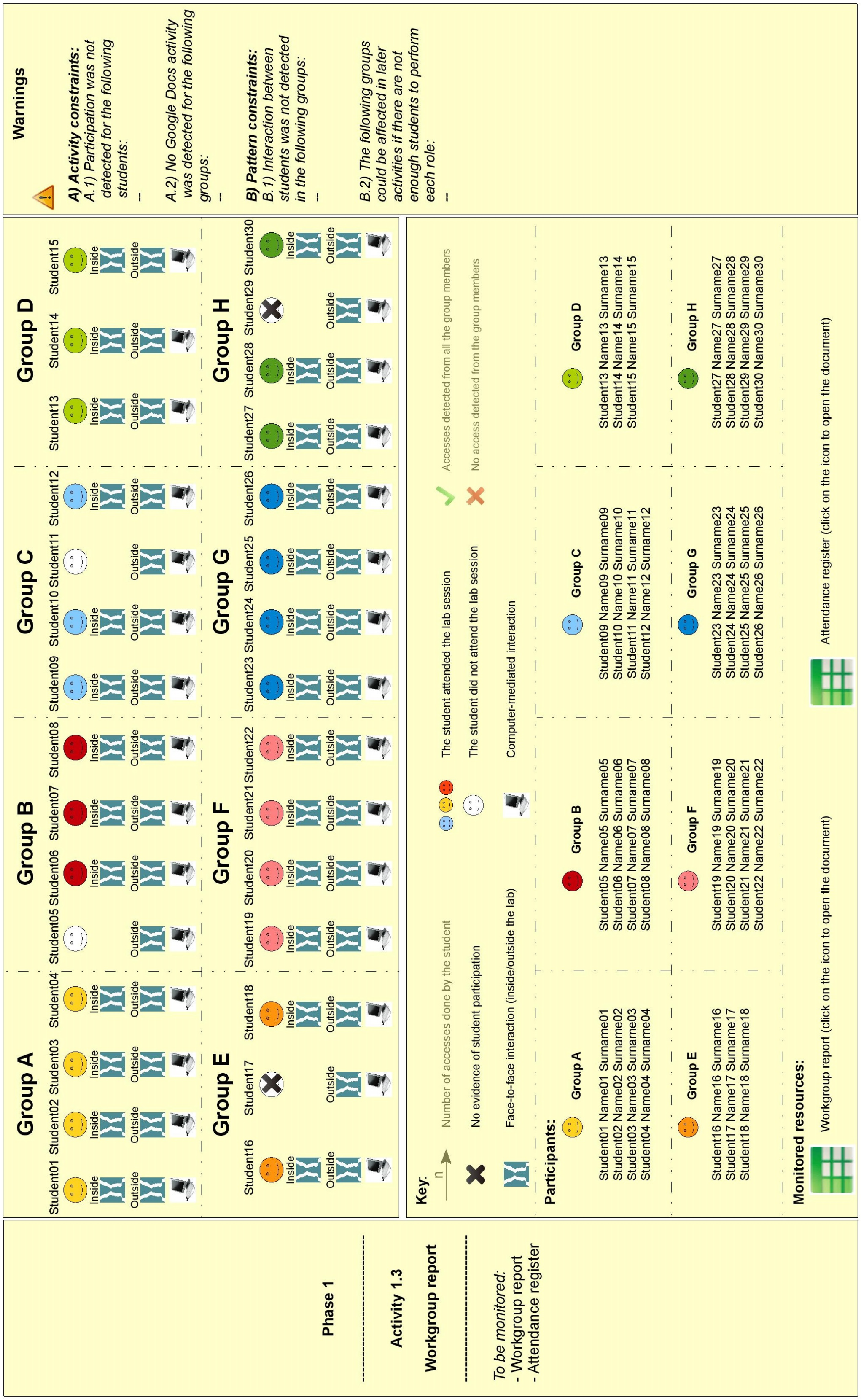


Figure G.5: Fifth exploratory study: analysis of the students feedback at the end of *Activity 1.1 Role-playing preparation*.

Table G.3: Fifth exploratory study: teacher's feedback regarding the design process [EXP5_T_INT].

Topic	Question	Answer
How monitoring influenced the design of the scenario:	1. Was the design modified due to monitorization needs?	Yes, there were things I had not [initially] thought about. For instance, I had not thought about including questionnaires, because I was not fully aware of the relevance of knowing how students had worked.
	2. Do you consider that the design process has been enriched? If yes, how has it been enriched?	Yes, the current design considers not only what students have to do, but also how they should do it, and how we can follow the progress of students. When we were designing there were many things I had not even thought about. I did not know what evidence could be gathered (or not) at a technological level. If I had to do a scenario again, I now know what information I could get and I would take that into account during design. It has been very enriching at a pedagogical level when designing the learning experience.
	3. Do you consider the cost of integrating monitoring in the design process was high?	No, it has helped me reflect and improve the design. In fact, I have taken into account aspects that would have otherwise gone unnoticed (e.g., who interacts and who doesn't, how the teamwork is done, ...). If I had to do the scenario again, it would take me much less time to design it. These things are harder the first time but, once you understand the process and how things work, the it is a breeze.
	4. When you were providing information related to monitoring, did you have the impression of it being a task unrelated to designing the scenario? Or did you perceive it as just another aspect to define about the scenario?	In my opinion, it is totally related. The reflections we have made about the monitoring have a pedagogical logic within the design. [...]
The impact of including monitoring from the design phase into the enactment of the scenario:	1. Reflecting about monitoring at design-time, has it helped you have a higher awareness of what eventualities could appear and their potential impact on the learning scenario?	Yes. They are evident issues, but I would not have stopped to consider those dependencies beforehand. You understand better how the apparition of problems can affect the different activities.
	2. Did the configuration of monitoring during design of the scenario help you have greater control over it?	Yes, because I would not have had the slightest idea of who has participated in the classroom, or outside, or how they have done it, etc. [...] It is yet another aid in the evaluation, even if it is not 100% trustworthy, since you do not know the causes of the detected problems (you cannot be sure even if you ask students, since they also can lie), or the quality of the evidence.
	3. Reflecting about monitoring in the design phase, has it helped you be more confident about how to regulate in face of eventual occurrences?	In this case I thought about the problem resolution once they had already occurred, and I did not reflect enough about what could be the best way to face them. I would have needed a contingency plan [...]
Changes and improvements for future versions	1. What changes would you do to improve the design process?	(1) The hardest part is to know which tools you can use and what do they offer in terms of monitoring.(2) I would give a schema with the teacher needs and potential technological solutions so that [teachers] know what can be done (e.g., If I want to know who has edited a document, then the most appropriate tools are A, B, and C; If I want to know who has participated in an activity, then I have to monitor P, Q and R). That is, to offer different solutions to hypothetical situations. (3) Another option would be to provide teachers with feedback about the impact of the design decisions. It would be useful to have a tool or a guide that helped you design taking monitorization into account.

analysis ("once you exit the classroom, you do not remember what had happened, especially in a long scenario with many students, as this one").

Among the benefits of this monitoring, the teacher put special emphasis on "the quickness of seeing the results and interpreting them at a glance", the time savings, the integration and organization of the evidence in a single report, and the usefulness not only for regulation but also for assessment purposes ("monitoring reports have helped me a lot to remember what had happened"). Lastly, she concluded that, thanks to the prior thinking about the monitoring, she got much more awareness evidence about the students' work, than she would have had otherwise.

In order to enhance monitoring and the consequent regulation, the teacher proposed several ideas. To enhance the monitorable evidence she considered that new questions could be included in the student questionnaire (e.g., dealing the problems found and the time dedicated to the activities), and she would have integrated her own notes to explain some situations ("In the end,

Table G.4: Fifth exploratory study: teacher's feedback regarding the monitoring process [EXP5_T_INT].

Topic	Question	Answer
The presentation of results:	1. Was it easy to interpret the results of the monitoring reports?	Yes, they are very clear. The icon system, the report structure, etc. make the reports very easy to interpret.
	2. Approximately how much time did you need to interpret the results of the monitoring report?	At a glance. It is super-fast.
	3. Do you think that using the pattern and the activity characteristics was useful for the monitoring?	Yes, it is very interesting, since you can see not only the problems of the current activity, but also how they effect on the next ones. [...] In any case, it would be very useful to have a tool that let you modify certain aspects (e.g., the deadlines), since during the learning scenario the need for changing them may arise.
About the impact that the monitoring results had in the scenario:	1. The monitoring results helped you trace the progress of the learning scenario? or were they already evident?	Yes, since the results were not already known. When I received the reports, I had not had time to review the students' work. Regarding the first phase, as it was (partially) face-to-face, I was more aware of what had happened. However, in the second phase, I had no idea of what they were doing. In the second phase I would have had to revise each document, check who had commented, identify which group the reviewers belonged to... Doing this manually would have taken a time that I do not have. In that sense, it has been a great help.
	2. From all the data provided in the reports, which ones were you already aware of, and which ones you did not know? In the case of data that you already knew, how did you obtain them?	The data from the face-to-face sessions were already known, but they are nevertheless useful. Once you exit the classroom, you do not remember what had happened, especially in a long scenario with many students, as this one.
	3. Was it useful, the integration of information from the tools with the information from the teacher/observer?	Undoubtedly. Having all the information compiled and integrated is very useful. It's magic! You manage to see things that you would not be aware of by yourself. It is very useful the complementing of the information from the technology usage and the student questionnaires and attendance lists from the face-to-face sessions.
	4. The information provided, did it make you take regulatory measures during the learning scenario? Of which kind?	Yes, I checked my email to see if I had any news from the students, and then I contacted them. If you see a group not working, it is possible to contact them and solve the problem on time, easing the detection and solution of technical problems.
	5. Having those results helped you avoid bigger problems?	Although during the scenario no big problem arose, when I saw the reports, I contacted the students and we could thus solve certain technical problems that did arise (e.g., permissions/access to the Google Documents).
	6. Which other data sources would have been interesting to include in the [monitoring] analysis?	The teacher's own comments but the information provided is more than enough.
The results obtained vs. other information sources:	1. If you had other kinds of data, would you have monitored in a different way (be it automatic or manual)? How?	The students. I would have had the students inform me of the problems they faced [...]
	2. Do you think that monitoring has caused you to invest more, or less, time in the tracking of the scenario?	During the enactment, it has saved me a lot of time, and it has provided me with evidence that I would not have had otherwise. Then, I reviewed the student reports, one by one, when I have time.
	3. About the monitoring process (additional comments)	I have identified many benefits: (1) The quickness of seeing the results and interpreting them at a glance, the good integration, the completeness. (2) Having all the information gathered and organized in a single report has been incredible. Maybe I am too disorganized, but I would not have been able to have it all under control in only 4 pages. (3)Furthermore, I was not able to remember who had come and who hadn't, and why. (4) When doing assessment, monitoring reports have helped me a lot to remember what had happened. It even gave you hints about which students within a group could have higher or lower marks. (5) Thanks to the prior thinking about the monitoring, I have had much more evidence about the students' work, than I would have had otherwise.
Changes and improvements for future versions	1. What changes would you do to improve the monitoring process?	[Additional evidence] In the Google Docs I'd have liked to get some information about the editions [...] I would have included in the student questionnaire a question for students to indicate whether they had found any problem, and which one [...] and a question about the time dedicated [...]. I would have liked to integrate my own comments. In the end, what I did was print out the reports and add my notes over them, to have a complete overview of what had happened. [Indicators] (1) To see the progress, e.g., with percentage bars. (2) That students can confirm when they have finished the activity. (3) Differentiate between evidence gathered within the deadline (green), out of the deadline (red) and partially out of the deadline (orange). (4) It would be useful to create warnings associated to 'mismatches' between student feedback and the evidence gathered by technology and by the teacher. [Functionalities] (1) Being able to modify some design aspects, such as the delivery deadlines of activities. (2) Being able to get the monitoring information at any moment (in order to see the progress).

what I did was print out the reports and add my notes over them, to have a complete overview of what had happened"). In addition, she mentioned that, even if the information collected was "more than enough", it would have been useful to have some insight about the editions in the Google Documents. Dealing with the information included in the reports, the teacher suggested that it could be also relevant to see student progress (e.g., with percentage bars), to provide a certain information about the evidence gathered out of the deadline, and to create warnings associated to "mismatches" between student feedback and the evidence gathered by technology and by the teacher. Carmen also pointed out some functionalities that would be nice to have, such as being able to modify some design aspects (e.g., deadlines) and to get the monitoring information at any moment.

Finally, we reviewed the monitoring reports along with the teacher to analyse which of the 448 results were unknown and useful for her. The result of these analyses are presented the following section.

G.6 Findings

This section aims at discussing the evidence gathered in the study in relation to the exploratory questions presented in Figure G.1. As part of the second iteration, these questions address three main aspects: a) how to help teachers integrate monitoring concerns in the pattern-based design process of CSCL scripts; b) what script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs; and c) what are the required conditions for collecting relevant information of the students' participation in a blended CSCL scenario supported by DLEs.

EXQ_DES.IT2: How can teachers be supported to integrate monitoring concerns in the pattern-based design process of CSCL scripts?

EXQ_DES.IT2.1: In which ways teachers' design decisions affect the monitoring process?

Among the different decisions made at design-time [EXP5_TR_LD], some of them influenced the data gathering (e.g., the definition of activity timeframes, participants and resources) and others contributed to model the desired state of the learning situation (e.g., the conditions derived from the expected participation, social level, or the expected use of resources). In addition, there were some specific parameters included in the script in order to enhance monitoring, either for filtering the data gathering (e.g., activities, resources and actions to be monitored) or to have a wider variety of data sources (e.g., the monitorable actions or the interaction and learning type). Table G.5 compiles the identified parameters, specifying whether they conditioned the data gathering or the representation of the desired state of a CSCL situation.

Throughout the co-design process of the learning scenario, Carmen was able to specify most of the parameters on her own. However, there were some issues that required the participation of the researcher [EXP5_R_OBS1] [EXP5_T_INT]. First of all, a monitoring-aware selection of tools could not have been done without the description of monitoring affordances provided on Figure

G.3 ("the hardest part is to know which tools you can use and what do they offer in terms of monitoring"). Moreover, the teacher mentioned that she would not have being able to infer by herself the impact of the design decisions on the monitoring process. In both cases, it would be useful to provide teachers with a tool or a guide that helps them design taking monitorization into account (e.g., recommending learning tools or deducing the data sources available for each constraint).

Table G.5: Fifth exploratory study: dimensions and parameters that a) contribute to enhance the monitoring process at design time and b) guide the data gathering and representation of the desired state. Parameters in *italics* emerged in this scenario, the rest of them were already taken into account in the previous studies.

Dimension	**Parameter**	**Script design**	**Data gathering**	**Desired state representation**
Pattern Constraints	Activity flow			X
	Collaboration			X
	Group formation policies			X
Activity Configuration	Timeframes		X	
	Resources (tools, contents)		X	
	Participants		X	X
	Groups			X
	Social level	X		X
	Interaction type	X		X
	Learning	X		
	Participation			X
Teacher's monitoring decisions	Monitoring periods		X	
	Activities to be monitored		X	
	Resources to be monitored		X	
	Actions to be monitored		X	
	Constraints to be monitored	X		X
	Expected use of resources			X
ICT tools	Monitorable actions	X	X	

EXQ_DES.IT2.2: In which ways teachers' design decisions affect the monitoring results?

Carmen's involvement in the monitoring configuration made that the monitoring results better suited to her needs. The accuracy of the monitoring results was increased due to her choices of ICT tools and her decisions on the data sources and actions to be monitored. Besides, her selection of constraints to be taken into account had a positive influence on the usefulness of the monitoring reports: 86,61% out of 448 results were useful for regulation purposes and the remaining 13,39% was relevant for assessment purposes [EXP5_T_INT]. Table G.6 presents the initial list of constraints obtained from the activity and the patterns, and the subset applied during the monitoring process according to the teacher's decisions.

Table G.6: Fifth exploratory study: constraints obtained from the analysis of the activities and the patterns. Those marked with an **X** were selected by the teacher to be taken into account in the monitoring process.

Activity	Constraint type	Constraint description	Selected by the teacher	Elements to be evaluated
Activity 1.1 Role-playing preparation	Activity	A.1) Participation: Each student has to participate	X	60 students
	Activity	A.2) Expected use of resources: Each group has to use its Google Docs	X	16 resources
	Role-playing	B.1) Collaboration: There must be interaction between group members	X	16 groups
	Role-playing	B.2) Group size: The must be at least one (active) student for each role	X	16 groups
	Role-playing	B.3) Number of roles: The must be at least one role assigned to each student		
	Role-playing	B.4) Number of groups: The must be at least two (active) groups to discuss about the simulation		
	Peer-review	B.5) Group size: The must be at least one (active)student in each group		
	Peer-review	B.6) Number of groups: The must be at least two (active) groups to carry out the review process		
	Peer-review	B.7) Reviewer assignment: There must be at least one role-playing performance assigned to each reviewer		
	Peer-review	B.8) Reviewer assignment: There must be at least one (active) reviewer assigned to each role-playing performance		
Activity 1.2 Role-playing presentation	Activity	A.1) Participation: Each student has to participate	X	60 students
	Role-playing	B.1) Collaboration: There must be interaction between group members		
	Role-playing	B.2) Group size: The must be at least one (active) student for each role		
	Role-playing	B.3) Number of roles: The must be at least one role assigned to each student		
	Role-playing	B.4) Number of groups: The must be at least two (active) groups to discuss about the simulation		
	Peer-review	B.5) Group size: The must be at least one (active) student in each group		
	Peer-review	B.6) Number of groups: The must be at least two (active) groups to carry out the review process		
	Peer-review	B.7) Reviewer assignment: There must be at least one role-playing performance assigned to each reviewer	X	16 groups
	Peer-review	B.8) Reviewer assignment: There must be at least one (active) reviewer assigned to each role-playing performance	X	16 resources
Activity 2.1 Peer-review	Activity	A.1) Participation: Each group has to participate	X	16 groups
	Activity	A.2) Expected use of resources: Each group has to use the Google Docs	X	16 resources
	Activity	A.3) Expected use of resources: Each group has to see the Videos	X	16 resources
	Peer-review	B.1) Group size: The must be at least one (active) student in each group		
	Peer-review	B.2) Number of groups: The must be at least two (active) groups to carry out the review process		
	Peer-review	B.3) Reviewer assignment: There must be at least one role-playing performance assigned to each reviewer		
	Peer-review	B.4) Reviewer assignment: There must be at least one review for to each role-playing performance	X	16 resources
Activity 2.2 Answer to the reviewers	Activity	A.1) Participation: Each participant has to participate	X	60 students
	Activity	A.2) Expected use of resources: Each group has to use the Google Docs	X	16 resources
	Activity	A.3) Expected use of resources: Each group has to see the Videos	X	16 resources
	Activity	A.4) Collaboration: There must be interaction between group members	X	16 groups
	Peer-review	B.1) Group size: The must be at least one (active) student in each group		
	Peer-review	B.2) Number of groups: The must be at least two (active) groups to carry out the review process		
	Peer-review	B.3) Reviewer assignment: There must be at least one role-playing performance assigned to each reviewer		
	Peer-review	B.4) Reviewer assignment: There must be at least one (active) reviewer assigned to each role-playing performance		
Activity 2.3 Workgroup report	Activity	A.1) Participation: Each student has to participate	X	60 students
	Activity	A.2) Collaboration: There must be interaction between group members	X	16 groups
	Peer-review	B.1) Group size: The must be at least (active) one student in each group		
	Peer-review	B.2) Number of groups: The must be at least two (active) groups to carry out the review process		
	Peer-review	B.3) Reviewer assignment: There must be at least one role-playing performance assigned to each reviewer		
	Peer-review	B.4) Reviewer assignment: There must be at least one (active) reviewer assigned to each role-playing performance		
			TOTAL =	**448**

EXQ_MON.IT2: What script information is necessary to guide the monitoring process of pattern-based CSCL scenarios supported by DLEs?

EXQ_MON.IT2.1: What information do teachers include in the script?

According to the researcher observations [EXP5_R_OBS1], at the beginning of the design process (in the first cycle) Carmen just specified the patterns that she wanted to implement, the learning objectives of each activity, and the type of technological support needed for the scenario. Later, with the aid of the activity forms and the researcher, she completed the remaining parameters. Table G.5 summarises the information included in the script [EXP5_TR_LD].

EXQ_MON.IT2.2: What additional information could be included in the script to enhance the monitoring results?

Apart from the new parameters identified in Table G.5 during the co-design process [EXP5_TR_LD] [EXP5_R_OBS1], no additional design element emerged from the observations during the enactment [EXP5_T_OBS][EXP5_R_OBS2], nor from the interview to the teacher [EXP5_T_INT].

EXQ_MON.IT2.3: Is the information about the accomplishment of the script constraints relevant for the teacher?

Based on Carmen's feedback during the review of the monitoring reports [EXP5_T_INT], we analysed the relevance of script constraints. Out of the 448 evaluated conditions, 338 (86,61%) were considered relevant for the regulation of the learning scenario and the remaining results (13,39%) turned out to be useful for assessment purposes. Although the teacher was aware of part of this information ("regarding the first phase, as it was (partially) face-to-face, I was more aware of what had happened"), 255 results (56,92%) were unknown to her before receiving the monitoring report ("when I received the reports, I had not had time to review the students' work" [...]). Besides, teacher asserted that the reports contributed to save her time, independently of the number of problems detected: "during the enactment, it has saved me a lot of time, and it has provided me with evidence that I would not have had otherwise".

We used certain script parameters that influenced the monitoring process (namely, social level, learning and interaction type of each activity, and the sort of constraints) to analyse teacher's answers about the novelty of the monitoring information. Figure G.6 provides an overview of these parameters and Figure G.7 summarizes the teacher's answers throughout the activity flow. Looking at Figure G.7, we can detect that the most useful and unknown results appeared in the second phase, when the activities required computer-mediated interaction and distance learning. Conversely, the monitoring reports provided less useful information (for regulation purposes) in *Activity 2.1 Role-playing presentation*, which entailed face-to-face interaction during the lab session.

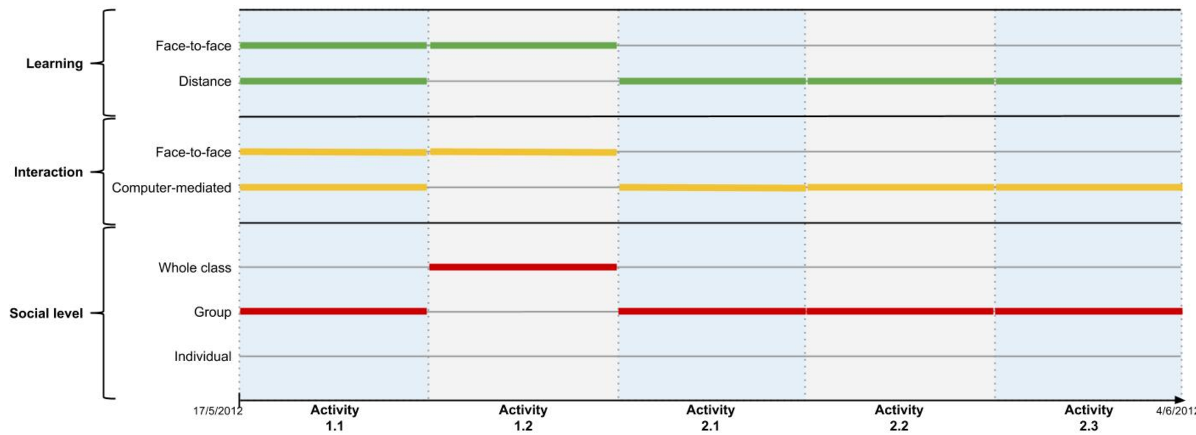
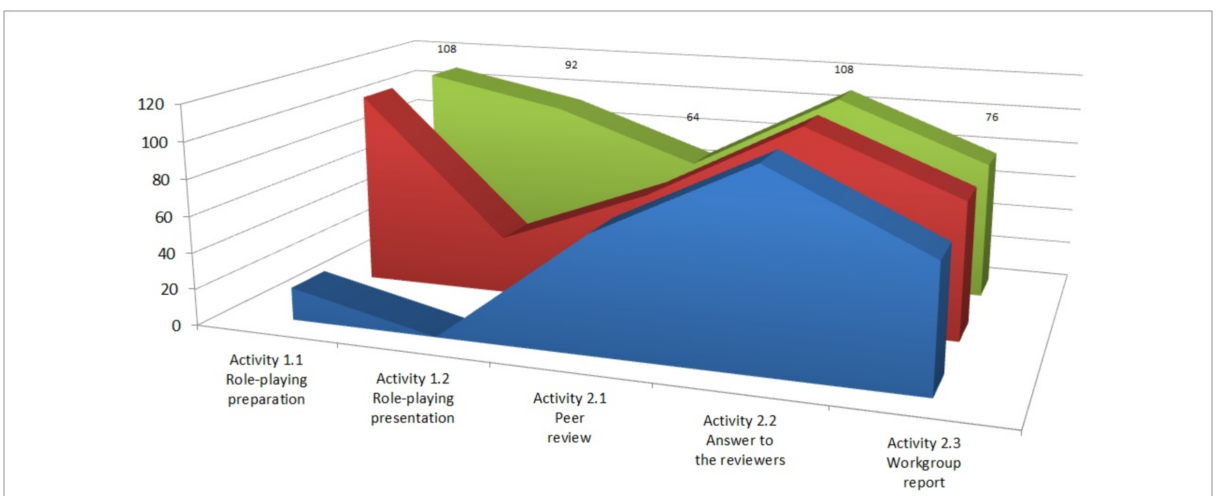


Figure G.6: Fifth exploratory study: overview of social level, interaction and learning type throughout the activity-flow.



	Activity 1.1 Role-playing preparation	Activity 1.2 Role-playing presentation	Activity 2.1 Peer review	Activity 2.2 Answer to the reviewers	Activity 2.3 Workgroup report
Unknown results	18	0	64	106	67
Useful results	108	32	64	108	75
Results obtained per activity	108	92	64	108	76

Figure G.7: Fifth exploratory study: comparison among the total amount of monitoring results obtained in each activity and the number of results that were unknown and useful for the teacher when she received the report.

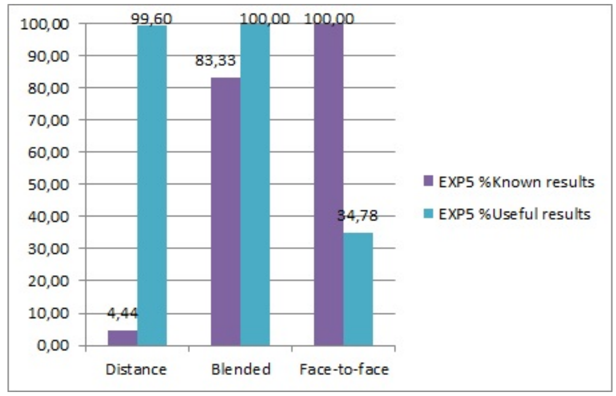


Figure G.8: Fifth exploratory study: percentage of known and useful monitoring results attending to the learning type (distance, blended, face-to-face).

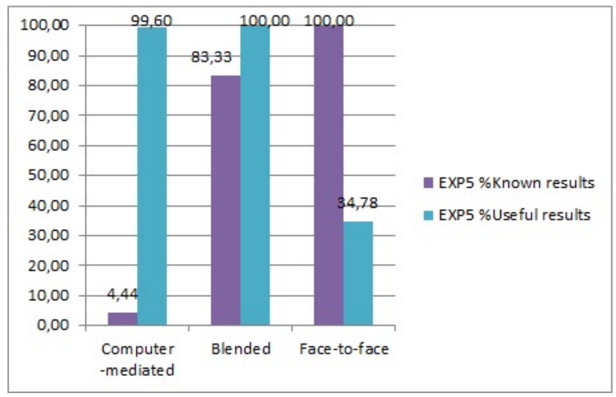


Figure G.9: Fifth exploratory study: percentage of known and useful monitoring results in terms of interaction type (computer-mediated, blended, face-to-face).

As it happened in the previous study, there was one-to-one relationship between the description of the learning type and the interaction type (see Figure G.6): distance activities were computer-mediated, activities involving blended interactions also combined blended learning, and the only activity carried out exclusively during the lab session entailed face-to-face interactions. Thus, as it is shown in Figure G.8 and Figure G.9, the analysis of useful and known results returned the same values for both learning and interaction type. The rates of useful and known information items ratify the teacher's comments during the interview: activities held in the classroom (totally or partially) offered more (non-computer-mediated) awareness opportunities to the teacher (over 83%). However, in activities with more computer support and performed out of the classroom the chances of perceiving contextual information (without specialized computer support) were under 5% ("in the second phase, I had no idea of what the students were doing").

Regarding the social level, the activity-flow was mainly carried out in groups, except one whole-class activity. Although apparently Figure G.10 shows that the monitoring results were more useful in group activities tasks (99,72%), these results are biased by the learning and interaction type: the single whole-class activity took place during a lab session with just face-to-face interaction.

Dealing with the type of constraint that imposed each evaluated condition, Figure G.11 presents the percentages of useful and known information based on Carmen's feedback. Even if the number of results known in advance was higher in the case of results related to pattern constraints (80% versus 35,05%) these results seemed to be 100% useful. In connection to the

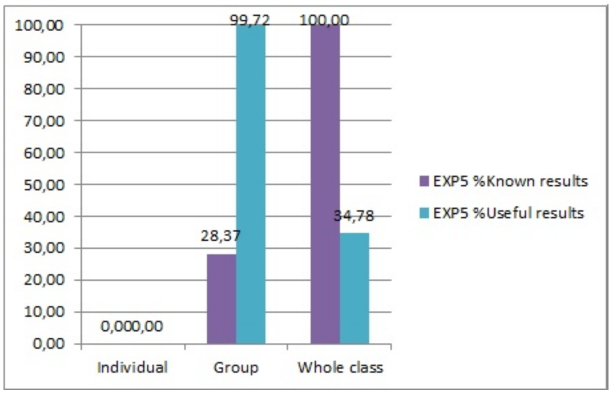


Figure G.10: Fifth exploratory study: percentage of known and useful monitoring results according to the social level (individual, expert group, jigsaw group, whole class).

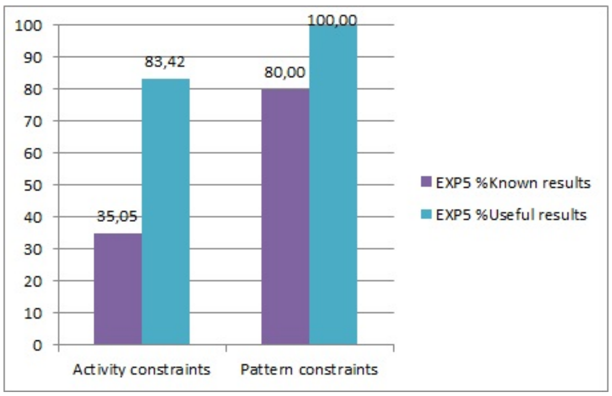


Figure G.11: Fifth exploratory study: percentage of known and useful monitoring results according to the scripts constraints they come from (activity or pattern constraints).

idea of focusing the monitoring process on the script constraints the teacher argued that: "it is very interesting, since you can see not only the problems of the current activity, but also how they effect on the next ones". However, we should notice that the ratios of useful results were condition by the decisions made by the teacher at design-time. Since the teacher decided what constraints should be taken into account [EXP5_R_OBS1], we could assume that they would be more likely relevant for the teacher (either for regulation or assessment purposes).

EXQ_MON.IT2.4: Are the script constraints enough to detect the problems that emerged during the learning situation?

The list of script constraints used in the monitoring process were a subset of the constraints derived from the configuration of each activity and the constraints imposed by the *Role-playing* and the *Peer-review* patterns (see Table G.6). During the monitoring process, 448 conditions were evaluated pointing at 17 potentially critical situations. These critical situations matched with the problems identified by the teacher [EXP5_T_OBS, EXP5_T_INT], the researcher [EXP5_R_OBS2], and students [EXP5_S_QUE1, EXP5_S_QUE2]. Thus, we can state that the script constraints were enough to detect the problems that emerged during the learning situation.

EXQ_DAT.IT2: What are the required conditions for collecting relevant information about the students' participation in a blended CSCL scenario supported by DLEs?

EXQ_DAT.IT2.1: How can the evidence about the students' participation be automatically gathered and integrated?

In addition to the data sources integrated in the previous studies (computer-mediated interactions coming from the DLE, and face-to-face interactions registered by the teacher), in this scenario we also considered the workgroup reports filled out by students [EXP5_S_QUE1, EXP5_S_QUE2]. As we had already done with the teacher-generated attendance registers, we created an interpreter for those questions specifically devoted to inform about script constraints. The integration of the 3 sources was very well appreciated by the teacher: "Having all the information compiled and integrated is very useful. It's magic! You manage to see things that you would not be aware of by yourself. It is very useful the complementing of the information from the technology usage and the student questionnaires and attendance lists from the face-to-face sessions."

The monitoring process was partially supported by *GLIMPSE* and *GLUE!-CAS* prototypes (see Section 4.6.2 and Section 4.6.3), that automatically gathered, integrated and analysed the evidence coming from DLE, teacher and students [EXP5_IT_LOG, EXP5_T_OBS, EXP5_S_QUE1, EXP5_S_QUE2]. Finally, the results obtained by the tool were represented manually in the graphical templates agreed with the teacher. The generation of the reports demanded in total around 5 minutes per activity [EXP5_R_OBS2].

EXQ_DAT.IT2.2: Is the data gathered from the different data sources enough to monitor the students' participation?

In order to estimate the *reliability* of the monitoring process, the results obtained from monitoring GLUE!'s logs [EXP5_IT_LOG], the attendance register [EXP5_T_OBS], and the the workgroup reports [EXP5_S_QUE1, EXP5_S_QUE1] were compared with the learning outcomes of the students in the tool instances [EXP5_IT_LO] and the information gathered by the teacher about the problems that the students had during the learning process [EXP5_T_OBS]. This analysis revealed that 100% of the evaluated conditions were interpreted correctly by the system without falling into errors or false positives. Nevertheless, the teacher suggested two ways of improving the monitoring process: extracting further information from the ICT tools (e.g., about editions in Google Documents), gathering more feedback from the students (e.g., problems found, time devoted to the activities) and including additional teacher comments ("what I did was print out the reports and add my notes over them, to have a complete overview of what had happened.").

Final remarks

One of the main purposes of this study was to adapt our proposal of linking scripting and monitoring for teachers not expert in CSCL scenarios. However, neither during the design or the enactment we identified special difficulties from Carmen (aside from those that arose in previous studies). Indeed, she highlighted the strengths of the proposal and provided us with valuable recommendations for the improvement of the design and the monitoring process.

The teacher highlighted that reflecting on monitoring improved the script, without a notable additional effort. Besides, the design process helped Carmen be aware of potential eventualities and how the apparition of problems could affect the different activities. She emphasized that thanks, to the prior thinking about the monitoring, she obtained much more evidence about the students' work, than she would have had otherwise. Finally, the teacher stated that in the design of future scenarios she would take into account these lessons learnt.

The difficulties found during the design process were aligned with the teacher's concerns during the third and fourth exploratory studies: without help she would not have known what ICT tools could be monitorable, and she would not have realized of which script constraints might be informed about (or not) with the available data sources.

Among the benefits of the monitoring process, the teacher stressed the time saving, the integration and organization of the evidence in a single report, and the usefulness not only for regulation but also for assessment purposes. In order to enhance monitoring and the consequent regulation, the teacher proposed several improvements such as integrating additional teacher comments, providing information about the evidence gathered out of the activity timeframes, and the availability the monitoring information at any moment.

Appendix H

Additional material attached to this thesis dissertation

This appendix describes the additional material attached to this thesis dissertation. In the following URL `http://www.gsic.uva.es/~chus/MJRodriguezTriana_PhD_May2014`, there are four main folders:

- **CV & publications.** This folder includes the author's curriculum vitae and the publications related to this dissertation.
- **Manuscript.** This folder contains the dissertation manuscript, the reports submitted by the experts, and a summary of changes carried out after the experts' review.
- **Prototypes.** The folder contains the source code of the *EdiT2++, GLIMPSE and GLUE!-CAS* prototypes.
- **Studies.** The folder contains data collected in the exploratory and evaluative studies (e.g., transcriptions of the interviews, questionnaires, logs, etc.) as well as anonimized versions of the monitoring reports provided to the teachers.

Summary in Spanish

Resumen en español

Preámbulo

Las siguientes páginas hasta completar el documento contienen el resumen en español de la tesis "Linking scripting and monitoring support in blended CSCL scenarios" (Alineamiento entre el guionado y la monitorización en entornos mixtos de aprendizaje colaborativo soportado por ordenador). Este resumen contiene el índice de la tesis doctoral traducido al español (para facilitar la búsqueda y referencia de las diferentes secciones de la versión original inglesa), así como un resumen de los objetivos, metodología, propuesta y conclusiones extraidas de esta tesis doctoral. Nótese que las referencias bibliográficas que aparecen en estos resúmenes deben buscarse en la lista de referencias de la versión original en inglés (página 161).

En el Capítulo 2 podemos encontrar una revisión de literatura acerca de las diferentes áreas de investigación relacionadas con esta tesis, tales como el Diseño del Aprendizaje (Learning Design) o el Análisis del Aprendizaje (Learning Analytics), especialmente enfocadas en el guionado (scripting) y la monitorización (monitoring). Asimismo, el capítulo los principales contextos pedagógicos y tecnológicos en los que se enmarca la tesis: aprendizaje mixto (blended learning), aprendizaje colaborativo soportado por ordenador (CSCL), así como tendencias actuales en el uso de entornos de aprendizaje distribuidos (DLEs). Finalmente, analizamos los problemas que aparecen al intentar alinear guionado y monitorización en escenarios CSCL mixtos soportados por DLEs.

El Capítulo 3 sintetiza los resultados de las iteraciones exploratorias de la tesis, que sentaron las bases para la formulación de las contribuciones de la misma. Una descripción completa de dichos estudios exploratorios se ha incluido al final de este documento (Apéndices C a G). Creemos que este formato descriptivo fragmentado puede soportar más fácilmente los estilos de lectura de diferentes lectores (p.ej., aquellos que quieran sumergirse profundamente en las evidencias recogidas, así como de los que buscan encontrar rápidamente los resultados principales).

Aunque la formulación de las contribuciones evolucionó a lo largo del período exploratorio, el Capítulo 4 presenta las principales contribuciones de la tesis en su estado final, en aras de la claridad. Estas contribuciones son: un proceso diseño de guiones CSCL que integra aspectos de monitorización, un modelo de guiones CSCL que integra las decisiones pedagógicas y de monitorización hechas durante el proceso de diseño, un proceso de monitorización de escenarios CSCL basado en guiones, y una arquitectura para la recogida e integración de datos en DLEs.

Las contribuciones presentadas en el Capítulo 4 fueron evaluadas en dos estudios llevados a cabo durante escenarios CSCL. El Capítulo 5 describe la metodología de evaluación, los estudios evaluativos, y los resultados de dicha evaluación.

Finalmente, las conclusiones que se extraen de la tesis se detallan en el Capítulo 6, destacando la relevancia de nuestros hallazgos para las comunidades investigadoras de CSCL y del aprendizaje mejorado por tecnología (TEL) en general. También se describen implicaciones para otros contextos educativos y áreas de investigación relacionadas. El capítulo también menciona las principales limitaciones y direcciones de investigación futuras en relación con la tesis.

Los apéndices de la tesis incluyen material suplementario tal como el análisis de las restricciones de los Patrones de Flujo de Aprendizaje Colaborativo, realizado durante la tesis (Apéndice B), la descripción detallada de los estudios exploratorios (Apéndices C a G), y la lista de recursos incluidos como material adicional a este documento (Apéndice H). Al final del documento se incluye también una lista con el significado de todos los acrónimos utilizados en la memoria de la tesis (Apéndice A).

Índice General

Introducción

Con la introducción de las Tecnologías de la Información y de la Comunicación (TICs) en educación, han emergido contextos de aprendizaje. Hoy en día, es cada vez más común encontrar *escenarios de aprendizaje mixtos* [Gra05] que entremezclan actividades presenciales y a distancia, desarrolladas de forma individual o en grupo, y situadas en múltiples contextos físicos (en el aula, en casa, en los museos, etc.)[Sha12]. Además, la combinación de plataformas de aprendizaje (e.g., entornos de aprendizaje virtuales como Moodle o Sakai) con herramientas externas (típicamente herramientas Web 2.0 como wikis, blogs o editores on-line), conocidas como entornos de aprendizaje distribuidos (del inglés 'Distributed Learning Environments', DLEs) [Mac10], está en boga en la práctica docente actual. Sin embargo, la introducción de las TIC en el contexto educativo no sólo trae consigo un amplio abanico de oportunidades, también impone múltiples retos para su integración en escenarios reales. Tales oportunidades y retos son el objeto de estudio de la comunidad investigadora en tecnologías para el apoyo al aprendizaje (en inglés Technology-Enhanced Learning, TEL).

La gestión de contextos educativos soportados por tecnología, denominada por algunos autores *orquestación* [Dil11b], representa un reto para la comunidad TEL [Sut12]. Aunque la carga de trabajo de la orquestación puede distribuirse entre los participantes del escenario de aprendizaje, a menudo esta recae mayoritariamente sobre los docentes. Ello deben llevar a cabo numerosas tareas para orquestar sus aulas, como organizar las actividades, intervenir siempre que sea necesario para adaptarlas a los problemas emergentes, re-estructurar los grupos de alumnos, etc. Al tanto de la complejidad y del tiempo que suelen demandar tales tareas, áreas de investigación como 'Learning Design' y 'Learning Analytics' (diseño y análisis del aprendizaje) than tratado de dar soporte a profesores y alumnos. Por ejemplo, algunas soluciones de diseño están dirigidas a guiar a los docentes en la definición del plan de aprendizaje, y múltiples trabajos en el área del análisis del aprendizaje tratan de proporcionar realimentación que pueda ser útil en aspectos de la orquestación como la percepción de lo que está ocurriendo en el aula, la evaluación o incluso el propio diseño [Sie12a].

Aunque la orquestación es crucial en cualquier escenario TEL, es especialmente crítica en casos tales como los contextos de aprendizaje colaborativo soportados por ordenador (Computer-Supported Collaborative Learning, CSCL) [Sta06], donde una de las mayores dificultades yace en orquestar en la situación de aprendizaje para promover la aparición de formas de colaboración efectiva [Fis06] [Dil13]. En el área del CSCL, se han formulado estrategias de diseño y análisis específicas para apoyar la colaboración [Jer04], como son en guionado y la monitorización. El guionado tiene como propósito definir, a priori, la secuencia de tareas, recursos y otros elementos de apoyo que ayudarán a los alumnos a interactuar y colaborar a lo largo de la situación de aprendizaje [Dil02a]. Desde el lado del análisis del aprendizaje, la monitorización también persigue promover la colaboración efectiva mediante el análisis de las interacciones de los participantes en tiempo de ejecución, para facilitar la intervención y llevar la situación de aprendizaje hacia una dirección más productiva [Sol05]. Estas dos estrategias, lejos de ser incompatibles, se complementan la una a la otra: a pesar de definir un guión de ante mano, puden surgir eventualidades que pongan el riesgo el plan original, para aliviar este problema, la monitorización puede ser de ayuda, detectando desviaciones durante el desarrollo de la situación de aprendizaje [Dil11a].

Investigaciones pasadas han señalado que pueden aparecer sinergias cuando se alinea el diseño del aprendizaje con el análisis del aprendizaje. Como afirman algunos autores, este tándem ofrece la oportunidad de entender mejor el comportamiento del alumnado y proporcionar recomendaciones pedagógicas cuando aparecen desviaciones sobre el plan original [Loc11] [Loo11]. Más concretamente, en el área del CSCL, Lockyer y otros proponen un marco conceptual para considerar los comportamientos esperados del alumnado y sus interacciones, en el proceso de análisis del aprendizaje de escenarios CSCL [Loc13]. Con este marco, sus autores abordan uno de los principales desafíos que el análisis del aprendizaje comporta: interpretar los datos resultantes a la luz de las intenciones pedagógicas originales y el contexto local, para evaluar el éxito (o fracaso) de una actividad de aprendizaje en particular [Sut12]. Goodyear y Dimitriadis señalan que los diseñadores de un escenario de aprendizaje no sólo deberían concentrarse en lo que los estudiantes deben hacer: también deberían mirar más allá y tener en cuenta otros aspectos como la orquestación (proporcionar soporte al trabajo del profesor durante el proceso de aprendizaje [Kar10]) o la reflexión (asegurarse de que se recogen durante el aprendizaje datos susceptibles de acciones posteriores [MM11b] y para evaluación [VF09b]) [Goo13]. Además, Martínez y otros sugieren que el alineamiento entre necesidades pedagógicas y de información es crucial a la hora de integrar el análisis del aprendizaje en la práctica CSCL habitual [MM11b]. Aparte de estos trabajos conceptuales, también existen (escasas) soluciones tecnológicas que implementan dicho alineamiento, para tareas que implican dibujo colaborativo [Gij13] y foros de discusión guiados [Mag10].

A pesar de los beneficios del alineamiento concebidos por las propuestas teóricas mencionadas, y los resultados positivos de las soluciones tecnológicas concretas, hasta donde nosotros sabemos no existe ningún trabajo que intente aplicar dicho alineamiento de manera más genérica a escenarios CSCL mixtos. Además, ninguna de las soluciones tecnológicas existentes aborda el caso de los DLEs (que nosotros sepamos). Dichos DLEs están creciendo en popularidad en la práctica docente, y sin embargo, hacen que el diseño y gestión del escenario sea un desafío importante. Así, esta tesis pretende avanzar en nuestro conocimiento sobre este tipo de alineamiento entre guionado y monitorización, para dar soporte a los docentes en la orquestación de escenarios CSCL auténticos, soportados por DLEs.

Para introducir al lector en el trabajo realizado durante la tesis, la siguiente sección detalla el objetivo de investigación principal y los objetivos parciales que han sido definidos hacia el mismo. Luego, la Sección H describe la metodología utilizada a lo largo del proceso de investigación y, finalmente, la Sección H resume las principales conclusiones de este trabajo de investigación.

Objetivos y contribuciones

Dado el contexto de investigación previamente expuesto, el principal objetivo de esta tesis es *dotar a los docentes con herramientas de diseño y gestión que permitan el alineamiento de los intereses pedagógicos con las necesidades de monitorización en escenarios mixtos CSCL desarrollados en DLEs*. Desde el punto de vista pedagógico, esta tesis se centra en aprendizaje CSCL mixto, puesto que la orquestación de este tipo de escenarios es especialmente compleja y requiere mucha atención de los docentes [Dil07b][Dia10]. Por otra parte, los DLEs constituyen nuestro principal contexto tecnológico, por dos motivos: en primer lugar, los DLEs están cada vez más extendidos en los contextos de aprendizaje pero plantean especiales dificultades en su diseño y gestión; y, en segundo lugar, la recogida e integración de datos heterogéneos en contextos descentralizados, como es el caso de los DLEs, sigue representando un reto en sí mismo [Scl08][Fer12]. Dicha combinación de entornos mixtos CSCL y DLEs, no ha sido cubierta por las propuestas existentes de alineamiento entre el guionado y la monitorización, como así se ha expuesto anteriormente.

Para alcanzar nuestro objetivo principal, esta tesis aborda cuatro objetivos parciales como se detalla a continuación y como se muestra en la Figura 1.1:

1. **Dar soporte al profesorado para identificar e integrar los aspectos relativos a la monitorización en el proceso de diseño de escenarios CSCL.** Como Martínez et al. apuntan en [MM11b], normalmente, las preocupaciones relativas al monitorización no se tienen en cuenta durante el diseño del escenario de aprendizaje. Apoyar a los docentes para reflexionar en sus necesidades de monitorización es crucial, ya que las decisiones tomadas en tiempo de diseño pueden condicionar la calidad de los resultados de la monitorización (e.g., dependiendo del soporte tecnológico que se escoja, los datos que se pueden recoger sobre las acciones de los usuarios varían). Además, guiar al profesor para que exprese sus necesidades de monitorización puede contribuir a proporcionar información más adecuada para la regulación del proceso de aprendizaje (e.g., teniendo en cuenta qué información necesitan conocer [Dyc13] o cuándo necesitan disponer de ella [Vat11]). Por ello, esta tesis presenta un *proceso diseño de guiones CSCL* que integra la monitorización como uno de sus aspectos. En concreto, este proceso de diseño está dirigido a guiones con un alto nivel de abstracción ('macro-scripts'), puesto que el tipo de decisiones que en ellos se reflejan están especialmente relacionadas con la orquestación de las actividades de aprendizaje [Dil07a].

2. **Proporcionar al profesorado información sobre la evaluación de la situación de aprendizaje que esté relacionada con las decisiones tomas sobre el diseño de aprendizaje**. Aún cuando el análisis de las interacciones entre los estudiantes permite ahondar en cómo se desarrolla el proceso de aprendizaje, la información de la que disponen los docentes, a menudo, no les ayuda a intervenir y adaptar sus diseños en tiempo de ejecución [Gwe11]. En unas ocasiones el problema viene dado porque la información no es fácil de interpretar [Sut12], y en otras porque la información ofrecida no da respuesta a las cuestiones que se plantea el docente [Dyc13]. Además, las soluciones existentes proporcionan, frecuentemente, análisis muy detallados sobre la colaboración (e.g., mediante estudios semiautomáticos de datos de audio o vídeo) cuya interpretación no es trivial y por ende, no es directo hacer una toma de decisiones en base a los mismos [Dri05] [Kah11]. En relación a este problema, varios investigadores en TEL ponen de manifiesto la necesidad de los docentes por disponer de información que les sea significativa, presentada de forma eficiente y útil para su uso, conectada co sus intenciones pedagógicas, y que les permita monitorizar a su alumnado durante el proceso de aprendizaje [Sut12]. Como sugieren Soller et al., la contextualización del análisis de las acciones de los alumnos con las decisiones pedagógicas, puede ofrecer una perspectiva de la situación de aprendizaje más cercana al punto de vista del docente, proporcionándole con información útil para la regulación de la situación de aprendizaje [Sol05]. A fin de dar realimentación al docente que le ayude a regular, esta tesis propone notificarle sobre el cumplimiento de sus decisiones de diseño (i.e., como si éste fuera el estado deseado de la situación de aprendizaje). Además, para hacer más fácil

el uso de esta información durante el desarrollo de las situaciones de aprendizaje, esta tesis plantea la hipótesis de que un análisis de alto nivel puede simplificar la interpretación. La definición del 'estado deseado' de la situación de aprendizaje nos lleva a la formulación de un *modelo de guiones CSCL* que integra y relaciona las decisiones pedagógicas y de monitorización hechas durante el proceso de diseño propuesto anteriormente. Posteriormente, los pasos necesarios para recoger e interpretar los datos disponibles en el escenario de aprendizaje (i.e., es 'estado actual' de la situación de aprendizaje) así como la comparación entre los estados 'deseado' y 'actual', se recogen en el que hemos denominado *proceso de monitorización de escenarios CSCL basado en guiones*.

3. **Sentar las bases para la automatización de la recogida e integracición de datos de monitorización en contextos CSCL soportados por DLEs**. Aunque los contextos tecnológicos utilizados actualmente para propósitos educativos brindan la posibilidad de almacenar grandes cantidades de datos [Sie11], hay varios problemas que obstaculizan la recogida y la integración de los mismos [MM11b]. Por ejemplo, algunas herramientas no registran acciones de los usuarios; no hay formatos estandarizados para el almacenamiento y modelado de la información, de modo que cada herramienta sigue su propia aproximación; y frecuentemente, las aplicaciones no proporcionar datos de uso directo (e.g., grabaciones de vídeo o registros de eventos de muy bajo nivel). Estos obstáculos son aún mayores cuando el contexto tecnológico es heterogéneo y descentralizado, como es el caso de los DLEs, o cuando los datos son generados no sólo de forma automática por el soporte tecnológico sino también ad-hoc por los propios participantes. Por ello, el uso de arquitecturas que integran los datos provenientes de diferentes fuentes de datos juegan un papel clave. Dada la complejidad de la recogida e integración de los datos [Fer12], y el tiempo requerido para realizar tales tareas de forma manual, es clara la necesidad existente de dar soporte a su automatización. Este situación es evidente en el caso de los docentes, los cuales han de ser capaces de disponer de la información durante el desarrollo de las actividades de aprendizaje con tiempo suficiente como para poder reaccionar ante posibles eventualidades [Gwe11]. Para atajar este problema, en esta tesis se propone una *arquitectura para la recogida e integración de datos en DLEs*.

Debe tenerse en cuenta que dada la naturaleza de la aproximación metodológica adoptada en esta tesis, investigación basada en el diseño, tanto el objetivo principal como los objetivos parciales han emergido y evolucionado a lo largo del proceso de investigación, como aparece descrito en el Capítulo 3. Sin embargo, para facilitar la compresión de los mismos, han sido presentados en su estado final. Los objetivos parciales tratan tres problemas pendientes que emergen tanto de la literatura como de nuestras propias observaciones en escenarios de aprendizaje CSCL auténticos (ver Capítulos 2 y 3). Aun cuando las propuestas aquí formuladas pueden ser aplicadas por separado (e.g., el proceso de diseño no depende la arquitectura), están íntimamente relacionadas y se han informado entre sí durante el proceso de investigación.

Metodología de investigación

El trabajo presentado en esta memoria de tesis se enmarca dentro del paradigma multidisciplinar del CSCL [Kos96] [Sta06]. En nuestro caso, se esperaba que los factores que influyen en las preguntas de investigación evolucionaran durante la misma, a medida que los investigadores aumentaran su entendimiento a través de las distintas fases del estudio [Bro92]. La naturaleza de este contexto de investigación y de los objetivos perseguidos nos hizo descartar una aproximación metodológica post-positivista, en la que las variables son conocidas de antemano y pueden ser controladas. Como sugieren varios investigadores, la naturaleza multidisciplinar del CSCL require un entendimiento mutuo entre las partes interesadas (profesores, alumnos, investigadores, etc.), así como su participación activa durante todo el ciclo de desarrollo de las soluciones CSCL [H02̈] [Sta06]. Dado que los docentes eran nuestros principales usuarios objetivo, decidimos involucrarlos desde el principio en la formulación de nuestras propuestas [Ken98] [Mul93]. Estas características contextuales nos llevaron a elegir la *Investigación Basada en Diseño* (Design-Based Research, o DBR) [Bar04] como principal marco metodológico de la investigación descrita en esta memoria.

La Investigación Basada en Diseño es una aproximación sistemática pero flexible, dirigida a mejorar la práctica educativa a través del análisis, diseño, desarrollo e implementación iterativas, basada en la colaboración entre investigadores y docentes en entornos reales, hacia principios de diseño y teorías sensibles al contexto [Bar04]. La investigación presentada aquí cumple con los principales criterios del DBR [And12]:

1. Implica múltiples iteraciones
2. Se sitúa en un contexto educativo auténtico
3. Se enfoca en el diseño y evaluación de intervenciones significativas
4. Utiliza métodos mixtos
5. Implica una asociación colaborativa entre investigadores y docentes
6. Tiene como objetivo la evolución de principios de diseño
7. Tiene un impacto directo en la práctica educativa

Más concretamente, estos criterios se aplican a la presente tesis de la siguiente manera:

1. **Proceso de investigación iterativo.** Siguiendo la aproximación DBR, hemos definido una serie de preguntas de investigación (enumeradas en la Tabla H.1) relacionadas con los objetivos de la tesis, presentados en la Sección 1.2. Estas preguntas de investigación se dividieron en preguntas exploratorias y evaluativas [And07]. Tres iteraciones –dos exploratorias y una evaluativa– se llevaron a cabo para responder dichas preguntas (véase Figura H.1), siguiendo las afirmaciones de [And12] (que indica que la mayoría de trabajos DBR siguen tres o más iteraciones), dentro de los límites de tiempo razonables para la realización de la tesis.

   El principal propósito de la primera y segunda iteraciones ha sido recoger información sobre las preguntas exploratorias (abordadas en el Capítulo 3). Basándonos en los resultados obtenidos, hemos propuesto un modelo para representar las relaciones entre el guionado y la monitorización, hemos formulado procesos de diseño y monitorización de guiones

Cuadro H.1: Preguntas de investigación abordadas por la tesis. Las etiquetas *RQ_DES*, *RQ_MON*, y *RQ_DAT* denotan preguntas de investigación relacionadas con el diseño, monitorización y recogida e integración de datos en escenarios CSCL, respectivamente.

Pregunta de Investigación Principal
¿Proporciona el alineamiento de guionado y monitorización información relevante a los docentes sobre el proceso de aprendizaje en escenarios CSCL soportados por DLEs?
Preguntas de Investigación Secudarias
RQ_DES: ¿Cómo podemos dar soporte a los docentes para que tengan en cuenta los intereses de la monitorización durante el proceso de diseño de escenarios CSCL? *RQ_MON*: ¿Qué información de guionado es necesaria para guiar a los profesores y a la tecnología en el proceso de monitorización de escenarios CSCL? *RQ_DAT*: ¿Cómo podemos facilitar la recogida, interpretación e integración de los datos acerca de las interacciones de los usuarios en escenarios CSCL mixtos soportados por DLEs?

CSCL, para ayudar a los docentes en la integración de los aspectos pedagógicos y de monitorización, y hemos propuesto una arquitectura que facilita la recolección e integración de las interacciones de usuarios en DLEs (o sea, las cuatro contribuciones presentadas en la Sección 1.2).

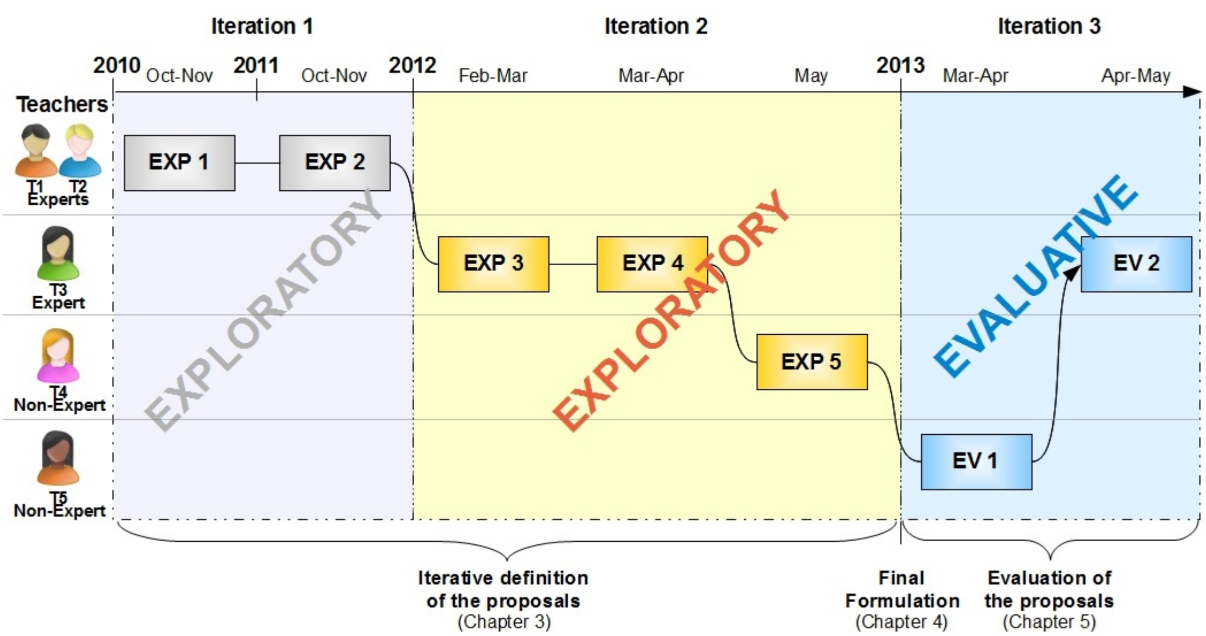


Figura H.1: Visión general de las iteraciones y estudios llevados a cabo durante el proceso DBR. Las etiquetas EXPn representan estudios exploratorios, y EVm señala los estudios evaluativos.

2. **Investigación situada en contextos educativos reales.** La importancia otorgada al contexto social en la investigación CSCL, así como la importancia de los factores contextuales en la orquestación, nos han llevado a evaluar nuestras contribuciones en entornos educativos auténticos. Esta aproximación encaja con el DBR, ya que situar la investigación

en un entorno educativo real valida y asegura que la propuesta aplicada puede ser utilizada para evaluar, informar y mejorar la práctica en (al menos) dichos contextos [And12]. En la presente tesis, siete estudios en escenarios CSCL naturalistas [Bar04], elegidos mediante muestreo teórico [Gub81], componen las tres iteraciones de nuestro DBR. Estos estudios forman parte de siete cursos reales llevados a cabo en la Universidad de Valladolid (España), entre Octubre de 2010 y Mayo de 2013, involucrando a cinco profesores y un total de 365 estudiantes de tres titulaciones diferentes ("Ingeniero en Telecomunicaciones", "Máster en Educación Secundaria" y "Grado en Educación Infantil"). Estos cursos presentan un perfil común: todos ellos incluyeron escenarios CSCL que combinaban actividades presenciales y a distancia; combinaban actividades individuales y colaborativas (cara a cara y mediadas por ordenador), soportadas por DLEs; además, todos los escenarios tenían una duración de entre dos y cuatro semanas por escenario; y todos ellos involucraban alumnos de educación superior.

3. **Foco en el diseño y evaluación de una intervención significativa.** Según Brown, una intervención efectiva debería ser transferible de una clase experimental a una clase media con estudiantes y docentes medios [Bro92]. Este punto de vista está alineado con la perspectiva de Dillenbourg, que enfatiza el hecho de que los métodos pedagógicos deben ser adaptables a las diferencias entre docentes (tanto aquellos excepcionales como los más convencionales) [Dil10]. De esta manera, nuestra selección de profesores participantes no se hizo al azar (la Figura 1.2 ofrece una visión general de los docentes asociados a cada estudio). Hemos tratado de seguir las recomendaciones proporcionadas por Muller y otros, que proponen que el número apropiado de personas a involucrar en un diseño participativo es de entre dos y cuatro [Mul93]. Para los dos primeros estudios de la tesis, involucramos a dos profesores que integran normalmente CSCL en sus cursos. Su experiencia con escenarios CSCL nos dio la oportunidad de aprender de su práctica, y de identificar los problemas que lo profesores expertos afrontan cuando orquestan un escenario CSCL. El tercer docente se involucró no sólo en los estudios exploratorios, también en la evaluación. Su experiencia previa la hacían especialmente adecuada para los propósitos del estudio: a) la docente había impartido clase durante varios años en escenarios soportados por TIC, normalmente incluyendo escenarios CSCL; b) se había involucrado en otros escenarios CSCL en los que el análisis de interacciones se utilizó para entender mejor el proceso de aprendizaje. Esta experiencia dual (pero disociada) en la utilización del guionado y la monitorización podía ser muy útil en la identificación de las conexiones entre estas dos estrategias. También existían otros motivos metodológicos (alineados con el DBR) para esta elección: esta docente estaba interesada en mejorar su práctica, y estaba dispuesta a colaborar con nosotros de manera continuada durante dos años. Así pues, su participación nos dio la oportunidad de refinar iterativamente la propuesta con una persona que conocía a fondo el contexto. También se ha involucrado en esta investigación a docentes con relativamente poca experiencia en CSCL, una de ellas en la segunda iteración exploratoria, y otra en la evaluación. Gracias a estas dos docentes, hemos podido verificar si los docentes no expertos encontraban dificultades adicionales, o si por el contrario la propuesta era adecuada también para ellas.

4. **Utilización de métodos mixtos.** Los métodos mixtos [Gre01] [Cre03] típicamente involucran una variedad de técnicas cuantitativas y cualitativas. Esta aproximación se considera generalmente adecuada para explorar los diferentes factores y perspectivas existentes en

una situación de aprendizaje, y se usa con frecuencia en DBR [And12] [Des02] y CSCL [Jeo10]. Asimismo, muchos investigadores abogan por una selección oportunista de las técnicas de recogida y de análisis de datos que mejor se adecuan a los objetivos de evaluación [Max03] [Joh04]. En esta investigación se han recogido datos cualitativos y cuantitativos de diferentes fuentes –profesores, estudiantes, herramientas TIC e investigadores–, para así obtener información sobre el perfil y experiencia de los participantes, el uso de las contribuciones propuestas, y las reflexiones sobre dicho uso. Las fuentes cualitativas utilizadas incluyen cuestionarios abiertos, observaciones, entrevistas semi-estructuradas y grupos de discusión; las fuentes cuantitativas incluyen cuestionarios cerrados y la recogida automatizada de interacciones de los usuarios.

5. **Asociación colaborativa entre docentes e investigadores.** La colaboración en un estudio DBR permite resolver dos problemas principales: la normal falta de tiempo de los docentes para llevar a cabo una investigación rigurosa, y la falta de conocimiento de los investigadores sobre un contexto educativo concreto [And12]. Durante nuestro proceso DBR, los profesores participantes han colaborado estrechamente con el investigador: los docentes contribuían con su conocimiento sobre el entorno local y con su experiencia pedagógica, mientras que el investigador intervenía proporcionando consejo sobre las decisiones de diseño, informes de monitorización durante el aprendizaje, y desarrollando soluciones tecnológicas que dieran soporte a las propuestas que iban emergiendo.

6. **Evolución de principios de diseño.**

7. **Impacto directo en la práctica educativa.** El tándem docente-investigador favorece la consecución de dos objetivos del DBR: a) tener un impacto real en la práctica, superando los problemas actuales del escenario de aprendizaje concreto y mejorando la práctica docente; y b) basándose en las lecciones aprendidas, hacer evolucionar los principios teóricos que subyacen al trabajo de investigación. En esta tesis, esperamos tener un impacto en la práctica al ayudar a los docentes involucrados a prever la información de monitorización que van a necesitar, a diseñar sus escenarios de aprendizaje teniendo en cuenta estas necesidades, y a entender qué esta pasando durante el proceso de aprendizaje, de manera que puedan gestionar el escenario hacia una dirección más productiva. Además, esperamos contribuír a las líneas y áreas de investigación que convergen en esta disertación, a través de las cuatro contribuciones propuestas.

Aunque los estudios naturalistas tienen la desventaja de no estar diseñados para proporcionar hallazgos generalizables, hemos descrito de manera extensa los diferentes contextos educativos para incrementar la *transferabilidad* [Gub81] de los artefactos que la tesis propone, a otros contextos educativos similares. Por esta razón, nuestra investigación trata de documentar con cuidad el contexto, propósito y contingencias de cada estudio, para que los lectores puedan juzgar por sí mismos la posibilidad de conseguir resultados similares con el uso de las propuestas en sus propios contextos concretos [Orl91]. Esta preocupación nos ha hecho adoptar el *Modelo CSCL de Evaluación Responsiva Orientada al Evaluando* (CSCL-EREM) propuesto por [JA09], a la hora de presentar los estudios de una manera estructurada. El CSCL-EREM proporciona guías prácticas a la hora de evaluar innovaciones educativas, recursos de aprendizaje, estrategias docentes o soporte tecnológico, tomando en cuenta que los escenarios CSCL pueden verse afectados por múltiples variables emergentes durante el proceso.

Para incrementar la *credibilidad* de nuestros resultados hemos usado técnicas mixtas de recogida de datos, así como una variedad de informantes, para así proporcionar múltiples perspectivas que nos permitan triangular nuestras evidencias [Gub81] y generar unos resultados de evaluación ricos. Además, nos hemos esforzado por acumular evidencias de diferentes contextos educativos y hacerlas trazables [Gub81] (véase el material incluido en el CD adjunto). Finalmente y para minimizar el sesgo causado por la involucración del investigador en los escenarios [Bar04], hemos recurrido a la participación de dos investigadores externos, que contribuyeron con sus puntos de vista a la elaboración de las propuestas.

Conclusiones de la tesis doctoral

Existen tres tendencias cada vez más frecuentes en los escenarios TEL, especialmente en educación formal: la combinación de aprendizaje cara a cara y a distancia (lo que se denomina aprendizaje mixto), la integración de estrategias colaborativas para promover el aprendizaje, y el uso de Entornos de Aprendizaje Distribuidos (DLEs). La unión de estos tres pilares constituye el principal contexto de nuestro estudio: los *escenarios CSCL mixtos soportado por DLEs*. A pesar de la creciente adopción de estos escenarios (debido a las oportunidades de aprendizaje que implican), tales escenarios presentan varios desafíos, tales como su orquestación (que suele ser más compleja y exigente, sobre todo para los docentes).

El uso de estrategias de diseño y análisis del aprendizaje, tales como el *guionado y la monitorización*, ha probado ser útil. Aunque a menudo ambas estrategias a menudo se aplican separadamente, en realidad son complementarias y varios investigadores proponen su *alineamiento*. De hecho, se anticipa que esta aproximación podria mitigar uno de los mayores desafíos actuales del TEL (y del CSCL): *la necesidad de interpretar el análisis de los datos obtenidos del entorno de aprendizaje a la luz de las intenciones pedagógicas y del contexto de una actividad de aprendizaje particular*. Esta tesis ha profundizado en este alineamiento del guionado y la monitorización en escenarios CSCL soportados por DLEs (un contexto todavia no abordado por las soluciones existentes), y pretendía **proponer, desarrollar y evaluar herramientas** (ya sean tecnológicas o conceptuales) **que den soporte a dicho alineamiento**.

La naturaleza compleja, evolutiva de nuestro objetivo de investigación (alinear guionado y monitorización para dar soporte a docentes en diseñar y gestionar escenarios CSCL) nos llevó a emplear una aproximación de Investigación Basada en Diseño. Siguiendo los criterios del DBR, nuestro proceso de investigación se compuso de varias iteraciones en una colaboración entre investigadores y docentes, con el fin de mejorar la práctica educativa en entornos reales, dando lugar a principios de diseño y teorías sensibles al contexto. El principal propósito de la primera y segunda iteraciones (resumidas en el Capítulo 3) fue la exploración de las dependencias entre el guionado y la monitorización, y la recogida de requisitos para el alineamiento de ambas estrategias. El trabajo exploratorio resultó en la definición y refinado de las propuestas (presentadas en su estado actual en el Capítulo 4): *un proceso de diseño sensible a la monitorización, un modelo de guiones CSCL compatible, un proceso de monitorización sensible al guionado, y una arquitectura para la recogida en integración de datos en DLEs*. Después, estas propuestas han sido aplicadas en una tercera iteración para su evaluación, tal y como se describe en el Capítulo 5. El foco de la investigación CSCL en el contexto social, y la importancia de los factores contextuales en la orquestación, nos ha llevado realizar dicha evaluación en entornos educativos auténticos.

Para ello hemos empleado métodos mixtos ya que son adecuados para explorar las diferentes perspectivas y factores que afectan a las situaciones de aprendizaje, y son usados ampliamente en DBR y en el campo del CSCL.

El primer problema que nos encontramos al intentar alinear estas dos estrategias es un problema de diseño: *la falta de reflexión sobre los aspectos de monitorización en el momento del diseño, en ocasiones condiciona los resultados de monitorización.* El segundo problema está más relacionado con la monitorización misma: *las propuestas existentes a menudo siguen una aproximación impulsada por los datos*, que trata de inferir indicadores de los datos disponibles, en vez de usar un modelo predefinido (basado en las preocupaciones del profesor) para guiar el análisis. Finalmente, se detectó un tercer problema en la práctica CSCL soportada por DLEs: *la naturaleza heterogénea y distribuida del entorno de aprendizaje dificulta la recogida e integración de los datos de monitorización.*

Con estos tres problemas en mente, en la tesis propusimos tres objetivos parciales que los abordaban:

Dar soporte a los docentes para identificar e incluir los aspectos de monitorización a lo largo del diseño de escenarios CSCL. Nuestra revisión de literatura reveló que las propuestas de diseño y modelos de guionado existentes no tenían en cuenta los aspectos de monitorización, dificultando el alineamiento de ambas estrategias. Además, nuestro trabajo exploratorio puso de manifiesto múltiples dependencias a tener en cuenta, así como la necesidad de apoyar a los docentes en la reflexión y expresión de las necesidades de monitorización. En respuesta a estos problemas, la tesis propone un *proceso de diseño de guiones CSCL sensible a la monitorización* (Sección 4.3). Este proceso de diseño guía a los docentes a lo largo de la construcción del guión CSCL, para que reflexionen sobre aquellos aspectos que afectan a la monitorización, adaptando el proceso de monitorización a sus necesidades, y recogiendo la información del guión necesaria para la monitorización del escenario de aprendizaje.

Hemos analizado los beneficios pedagógicos y de monitorización, el esfuerzo del profesor, la coherencia y utilidad del proceso de diseño, a lo largo de dos escenarios de aprendizaje auténticos que involucraron a dos docentes con diferentes niveles de experiencia en CSCL. Los resultados de la evaluación muestran que, siguiendo el proceso de diseño, los docentes identificaron mejoras tanto en el guión como en los resultados de monitorización, así como en la percepción que los docentes tenían sobre las eventualidades que podían poner en peligro el escenario de aprendizaje. Además, ambos docentes consideraron que el esfuero dedicado era asequible, y afirmaron que lo adoptarían en su propia práctica, y lo recomendaron a otros docentes haciendo frente a escenarios CSCL con un número significativo de estudiantes, o realizando diseños complejos. La evaluación también reveló que la terminología utilizada debería ser revisada y que el proceso podría ser algo más claro y eficiente para el docente si se desarrollara un formulario interactivo que le guiara a lo largo del diseño. Esta evaluación todavía no ha sido publicada, aunque formas intermedias de las propuestas sí han sido publicadas en [RT12b], [RT13a], y [EM14]. Por lo tanto, aunque el proceso de diseño puede ser refinado en iteraciones futuras (p.ej., proporcionando guías adicionales al docente), *el proceso de diseño sensible a la monitorización ha cumplido su objetivo de dar soporte a los docentes en la identificación e inclusión de aspectos de monitorización a lo largo del diseño de guiones CSCL.*

Asimismo, para recopilar los detalles que deben ser proporcionados durante el proceso de diseño, y para modelar los enlaces entre guionado y monitorización, hemos formulado un *modelo de guiones CSCL sensible a la monitorización* (Sección 4.2). Este modelo también se utilizó durante los estudios evaluativos, para representar los guiones generados usando el proceso de diseño mencionado más arriba. En estos estudios hemos evaluado si el modelo era suficientemente expresivo para la descripción de las decisiones de diseño y de información necesaria durante el proceso de monitorización. Las evidencias recogidas muestran que el modelo satisfizo adecuadamente estos requisitos de expresividad, en ambos escenarios de evaluación. Versiones intermedias de este modelo sensible a la monitorización se han publicado ya en [RT12a] y [RT13a]. Sin embargo, la versión presentada en este documento todavía está pendiente de publicación.

Proporcionar al docente información de monitorización sobre la evolución de la situación CSCL, relacionada con las decisiones de diseño del aprendizaje. Para enlazar la información de monitorización con las decisiones de diseño del docente, hemos revisado propuestas de análisis del aprendizaje existentes, y hemos detectado que la mayoría de ellas siguen una aproximación “bottom-up”, es decir, infieren indicadores basándose en los datos existentes. Esta aproximación no asegura el alineamiento entre los indicadores resultantes y las necesidades perceptivas del docente. Además, durante los estudios exploratorios descubrimos que involucrando al docente en la configuración del proceso de monitorización, era posible adaptarlo mejor a sus necesidades (p.ej., enfocando el análisis en los aspectos relevantes para los docentes, y proporcionando la información en los momentos que el docente consideraba relevantes para la gestión del escenario). Para hacer frente a estos problemas, la tesis propone un *proceso de monitorización sensible al guionado de escenarios CSCL* (Sección 4.4), que tiene por objetivo informar al docente sobre la consecución de sus decisiones de diseño.

La evaluación de este proceso de monitorización reveló que los informes de monitorización proporcionaban al docente más información de la que solían tener los docentes por sí mismos, y en buena parte información desconocida para ellos. En términos generales, la información proporcionada por los informes de monitorización estaba alineada con los hechos reales, dando así una visión realista del proceso de aprendizaje. Sin embargo, también existieron algunos falsos positivos y problemas que pasaron desapercibidos. Aunque los docentes no consideraron críticos estos falsos positivos, los problemas no detectados por el análisis deberían ser minimizados, ya que pueden poner en riesgo el escenario de aprendizaje. El principal factor que impidió la detección de estos problemas es el hecho de que el análisis realizado no tenía en cuenta la evaluación de la calidad de las contribuciones de los alumnos: no distinguía entre el estudiante que cambia algunas palabras en un documento y el que escribía un informe completo (ya que ambos se consideraban simplemente como ediciones). Así pues, se debería filtrar de alguna manera las acciones de los estudiantes para incrementar la exactitud de los resultados de monitorización. Sobre la relevancia de los resultados de monitorización, ambos docentes afirmaron que los informes les permitieron, bien verificar que los estudiantes estaban siguiendo el plan como se esperaba, o bien detectar problemas emergentes. Esta realimentación hacía más fácil la gestión de los escenarios de aprendizaje y, aun en el caso en el que el docente podía ya conocer la información de monitorización, los docentes consideraron que los informas eran útiles para recordar qué había ocurrido a corto/medio plazo, soportando así la evaluación. Según los docentes, la interpretación de los informes de monitorización requería sólo unos momentos y, al integrar las diferentes fuentes de datos, reducía significativamente el tiempo y esfuerzo necesarios, promoviendo un uso más eficiente del tiempo. Finalmente, los docentes también sostenían que usarían el proceso de monitorización en su práctica, y lo recomendarían a otros docentes. Estados intermedios de esta propuesta de proceso de monitorización, así como evidencias de su aplicación en escenarios CSCL auténticos (provenientes de los estudios exploratorios) han sido ya publicados en [RT11c], [RT12b], [RT13a], [RT13b], and [EM14]. Así, podemos concluir que *el proceso de monitorización sensible al guionado puede proporcioanr a los docentes realimentación relevante para mejorar la percepción de la situación de aprendizaje y soportar las tareas de regulación*, cumpliendo así el segundo objetivo parcial de la tesis.

Dar soporte a la automatización de la recogida e integración de datos en escenarios CSCL mixtos soportados por DLEs. Los contextos de aprendizaje mejorados por tecnología (tales como los escenarios CSCL) ofrecen la posibilidad de almacenar datos educativos [Sie11]. Sin embargo, como identificamos en la literatura existente y en los estudios exploratorios, *existen ciertos problemas que dificultan la recogida de datos y su integración* (p.ej., la variedad de datos existentes y la falta de estándares para representar estos datos). Estos problemas *se incrementan en contextos descentralizados y heterogéneos como los DLEs*, o cuando los datos generados no se generan de manera automática, sino que son introducidos ad-hoc por los participantes. Debido a la complejidad de la recogida e integración de datos y el tiempo requerido para realizar estas tareas de manera manual, así como las restricciones temporales de los docentes, marcan la clara necesidad de automatizar estas tareas. Para abordar este desafío, hemos propuesto una *arquitectura para la recogida e integración de datos en DLEs* (ver Sección 4.5), proporcionando una solución conceptual genral para recoger e integrar las accciones de los participantes en escenarios CSCL sobre DLEs. Esta arquitectura facilita la recogida e integración de datos en DLEs construidos a través de GLUE!, usando el prototipo *GLUE!-CAS* (presentado en la Sección 4.6.3), que ha sido utilizado en los escenarios evaluativos.

Las evidencias obtenidas durante la evaluación apuntan que la arquitectura cumplió sus objetivos, tanto en tiempo de diseño como de aprendizaje. En primer lugar, para dar soporte a las decisiones de diseño, el prototipo *GLUE!-CAS* nos permitió informar a los profesores sobre las acciones monitorizables de cada VLE y herramienta que integrable a traves de GLUE!. Luego, durante la puesta en marcha, y gracias a la integración de acciones mediadas por ordenador y la información adicional proporcionada por los alumnos y los docentes, pudimos ofrecer al docente una visión realista del proceso de diseño. En cualquier caso, nuevos tipos de datos podrian ser recogidos mediante los adaptadores de herramienta y entorno de aprendizaje de la arquitectura/prototipo (por ejemplo, desarrollando nuevos métodos que den información más detallada sobre las acciones de los usuarios), y desarrollando herramientas específicas para recoger información de los docentes y los estudiantes. La automatización de la recogida e integración de los datos redujo la carga de trabajo de los docentes (en términos de tiempo y de esfuerzo), comparado con el tiempo que hubieran necesitado para obtener la misma información por sí mismos. La recogida de datos requirió unos dos minutos (dependiente de la conexión a internet), un tiempo que los docentes consideraron aceptable. Sin embargo, sería necesario mejorar la eficiencia de este sistema en caso de que los docentes requirieran la información en tiempo real. Así, el prototipo *GLUE!-CAS ha mostrado el potencial de la arquitectura propuesta para dar soporte a la recogida e integración de datos en escenarios CSCL mixtos soportados por DLEs*, cumpliendo así nuestro tercer objetivo parcial. Como en las contibuciones anteriores, versiones preliminares de la arquitectura han sido presentadas en [RT11a] y [RT11b]. Asimismo, lo diversos estudios donde el prototipo ha sido utilizado (sobre todo, en las iteraciones exploratorias) han sido publicados también, en [RT11c] [RT12a] [RT12b] [RT13a] [RT13b] [RT13a].

El cumplimiento de los tres objetivos parciales de la tesis nos permite afirmar con seguridad que *la presente tesis ha conseguido su objetivo de proporcionar soporte al diseño y puesta en marcha por los docentes, enlazando intenciones pedagógicas y necesidades de monitorización, para la orquestación de escenarios CSCL mixtos soportados por DLEs*. De cualquier manera, también podemos reflexionar sobre las principales lecciones aprendidas a lo largo del proceso de investigación de la tesis:

De nuestra investigación alrededor del proceso de diseño y de las limitaciones encontradas para dar soporte a los docentes en entornos auténticos, hemos visto que el principal problema es el soporte a los docentes en la selección de herramientas de apredizaje. Aunque el profesor puede tener una idea de las herramientas que desea incluir en el entorno de aprendizaje, es poco probable que conozca cuál es la información de monitorización que puede extraerse de dichas herramientas. Durante la tesis hemos desarrollado una solución ad-hoc, para entornos GLUE! (el prototipo *GLUE!-CAS*), en la que se puede obtener la descripción de monitorización de las herramientas. Esta información se proporciona a través de los adaptadores de herramientas, y por tanto son los desarrolladores de dichos adaptadores los responsables de proveer dicha información. Sin embargo, para ayudar a los docentes en esta elección, independientemente de la arquitectura específica, es necesario encontrar soluciones más generales. Una posible opción podría ser el permitir la búsqueda de propiedades de monitorización de las herramientas, o incluso encontrar nuevas herramientas basándonos en las necesidades de monitorización. Por ejemplo, *U-Seek* y *We-Share* son dos aplicaciones que permiten a los docentes recuperar y publicar información sobre herramientas TIC educativas [RC14]. Extendiendo la ontología subyacente a estas aplicaciones con las funcionalidades de monitorización de las distintas herramientas, se podría ofrecer a los docentes una solución sostenible que les ayude a seleccionar la herramienta más adecuada teniendo en cuenta tanto sus preocupaciones pedagógicas como de monitorización.

De nuestra investigación sobre la monitorización de escenarios de aprendizaje auténticos hemos extraído la importancia de dar a los docentes visualizaciones fáciles de interpretar, complementadas con información contextual que simplifique las tareas de regulación (p.ej.,accesos a las distintas instancias de herramienta o a los emails de los alumnos). En cuanto a la naturaleza mixta de los escenarios, nos hemos percatado de la importancia de enriquecer las evidencias obtenidas a través de la tecnología con las vistas complementarias que los docentes y los propios alumnos pueden proporcionar. En esta tesis únicamente hemos arañado la superficie de esta "involucración de los participantes" en el proceso de monitorización. Por tanto, investigación adicional seria necesaria para dar soporte a la recogida de datos (y su subsecuente integración) de los docentes y estudiantes. Por ejemplo, el uso de herramientas que soporten la creación y gestión de rúbricas, tales como *iRubric*[1], podrían representar una primera aproximación a la recolección de este tipo de datos.

Finalmente, de nuestra investigación concerniente a la arquitectura de recogida e integración de datos en DLEs, hemos identificado varios problemas que pueden entorpecer dicha recogida e integración. Uno de los principales problemas en la recogida de los datos es la seguridad: normalmente, es necesario tener permisos especiales para acceder a los datos de monitorización en la herramienta de aprendizaje (algo que a menudo los docentes no poseen). Así, las políticas

[1] iRubric :`http://www.rcampus.com/indexrubric.cfm` (Última visita: 24 Mayo 2014).

de seguridad del DLE deben ser adaptadas para permitir al docente (o al usuario que realiza la monitorización) el acceso a dicha información. Otros problemas en la recogida de datos incluyen la persistencia de los datos (i.e., ¿durante cuánto tiempo van a permitir las herramientas el acceso a los datos de las acciones de los estudiantes?) y el ciclo de vida de las instancias de herramienta (p.ej., una vez un Google Document o un curso de Moodle es borrado, ¿cómo se accede a su información de monitorización?). Nuestra propuesta arquitectónica actual recoge los datos bajo demanda; sin embargo, para evitar una posible pérdida de datos, sería más apropiado adoptar una aproximación mixta en la que los datos son recogidos bajo demanca, pero las herramientas (o los adaptadores de herramienta) publican la información bajo ciertas circunstancias (p.ej., antes del borrado de una instancia). En términos de integración de los datos, un problema (quizás insoluble en el caso de los DLEs) es la identificación unívoca de cada participante a lo largo de las distintas herramientas de aprendizaje: muchas herramientas ni siquiera requieren la creación de una cuenta (por lo que es imposible saber quién ha realizado una cierta acción sobre dicha herramienta); y en aquellas herramientas que sí requieren la creación de una cuenta, no existe la seguridad de que el identificador del usuario se mantenga constante en las distintas herramientas y entornos de aprendizaje. Sería necesario tener en cuenta todos los identificadores de usuario de un estudiante para poder trazar las acciones almacenadas en las distintas herramientas hasta el usuario que las realizó.