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MONITORING-AWARE LEARNING DESIGN PROCESS: PILOT STUDIES IN AUTHENTIC CSCL SCENARIOS

María Jesús Rodríguez-Triana, Alejandra Martínez-Monés
Juan I. Asensio-Pérez, Yannis Dimitriadis

GSIC-EMIC, Universidad de Valladolid, Spain
e-mail: {chus@gsic, amartine@infor, juaase@tel, yannis@tel}.uva.es

Abstract. ICT tools offer the possibility to store, analyse and visualise large amounts of educational data. However, in order to make sense of these analyses, teachers need meaningful information connected to their pedagogical intentions. We envision an enriched learning-design process, which supports the integration of the issues related to monitoring in the script. This paper presents a study where the first author and a teacher iteratively co-designed two authentic learning scenarios with the aim of defining and evaluating a monitoring-aware design model and process. These two proposals, the model and the process, were positively evaluated by the participant teacher, and are the basis for the future implementation of an authoring tool that will support the proposed monitoring-aware design process.

Keywords: Computer-supported collaborative learning (CSCL), learning design, scripting, monitoring, design-based research

Mathematics Subject Classification 2010: 97-U50

1 INTRODUCTION

With the introduction of ICTs (Information and Communication Technologies) in education, it is increasingly common to encounter learning scenarios that combine activities developed at different social levels (in individual, group and whole-class tasks) and in different locations (face-to-face or distance) [1]. These trends make the management of technology-enhanced classrooms highly demanding [2]. Teachers must carry out numerous tasks to orchestrate their classroom, such as structuring the activities, intervening at any time to adapt these activities, re-structuring groups, etc. A clear example of this complexity is that of a teacher trying to orchestrate a Computer-Supported Collaborative Learning (CSCL) scenario [3].

One of the major difficulties of CSCL relies on orchestrating the different activities so as to produce effective collaboration [4]. Collaboration can be influenced in advance, by structuring the collaborative process in order to favour the emergence of productive interactions, or retroactively, by regulating interactions [4]. Considerable efforts have been done in both directions. For instance, scripting and monitoring are two long-discussed techniques in the research community, aimed at fostering effective collaboration [5]. On the one hand, CSCL scripting structures the learning scenario and provides students with a set of instructions that guide potentially fruitful collaboration; on the other hand, monitoring the collaboration facilitates the intervention of the teacher in order to redirect the group work in a more productive course.

Previous research has pointed out that synergies may appear when monitoring and learning design are aligned [6, 7, 8]. Monitoring the learning scenario and comparing its actual state with the teacher's plans (e.g. pedagogical decisions made at design time) may provide useful information to regulate collaboration [9]. Conversely, the information from the designed script could be used to guide the data gathering and analysis, taking into account elements such as the deadlines, the group structuring and the tools involved in each activity. There are approaches that support this idea of aligning learning design and assessment techniques. For example, Gluga et al. [10] present a conceptual model for connecting the curriculum design with the evidence that needs to be gathered for the assessment of competences. The NEXT-TELL project[1] has developed an Evidence-Centered Activity and Assessment Design methodology (ECAAD) [11] that comprises the design of technology-enhanced learning activity sequences, and the design of formative assessment based on e-portfolios that can be integrated into the learning activity sequences. Villasclaras et al. [12] proposed a design process for the integration of assessment within CSCL scripts.

Despite the benefits that the combination of scripting and monitoring could offer, it has not been widely adopted in mainstream CSCL practices. As Martínez et al. explain in [6], several problems hinder the application of monitoring in real CSCL scenarios. For instance, the lack of attention to the monitoring issues when designing learning scenarios often causes that the resulting technological set-up does not provide monitoring facilities. Additionally, the heterogeneous and distributed nature of the current technological environments increases the data gathering, interpretation, and integration complexity. In these technological environments, it is necessary to process and take into account the information of distinct data sources in order to obtain a general and realistic view of the learning scenario [13].

The long-term objective of our research is to provide teachers with feedback that links the analysis of participants' interactions with the learning design decisions.

[1] http://www.next-tell.eu/ (last visit, September 2013)

In this paper, we address an intermediate objective towards this long-term goal: *supporting teachers to reflect and include monitoring issues throughout the design process of CSCL scenarios*. We aim at identifying elements of such a monitoring-aware design process, that can eventually be incorporated to an authoring tool.

Due to the mutual dependencies between design and monitoring in our proposal, we set up *two pilot studies* (reported in this paper), with the intention of identifying the required conditions to carry out the aforementioned monitoring-aware learning design process. One teacher and the first author of this paper worked together during the whole learning scenario (from its initial design to its enactment in a real course), taking respectively the roles of "learning design expert" and "monitoring expert". The first study helped identify the elements required for the coordination of pedagogical and monitoring issues, leading to the definition of a monitoring-aware scripting model; and also guided the formulation of a monitoring-aware design process of CSCL scripts. The second study allowed to refine and evaluate the proposal.

The rest of this paper is structured as follows: Section 2 introduces the overall research proposal; Section 3 describes the research method followed; Sections 4 and 5 are devoted to explain the exploratory and evaluative studies that helped us formulate and test our proposals for a monitoring-aware design process and model; finally, conclusions and future work are summarised in Section 6.

2 GENERAL APPROACH: GUIDING THE COLLABORATION MANAGEMENT BY MEANS OF CSCL SCRIPTS

The previous section introduces the relevance of providing teachers with appropriate awareness information in CSCL scenarios. In this section we present our approach to approximate this awareness to the teachers' pedagogical intentions.

The considerable amount of ICT tools used in many CSCL settings, and the variety of locations where the learning process takes place, often hinder teachers from witnessing the students' work [14]. As the Society for Learning Analytics Research (SoLAR) mentions[2], the technological context registers great amounts of data about the participants' actions that may be analysed to better understand and optimise the learning process. However, educators are often overwhelmed by the information received [15] and lack the specific details they need to identify critical points in the learning situation [16]. In short, teachers need to make sense of the amount of data provided by ICT tools in order to facilitate learning [17, 18].

Very little research exists to indicate which monitoring variables may be pedagogically meaningful [19]. Snibbe points out that in advance defining the goals of the analysis may be used to determine which data to capture and to simplify the feedback provided to educators [15]. In this direction, several authors have argued that *the pedagogical decisions made at design time may be helpful in order to guide the monitoring of CSCL scenarios* [7, 6]. Such an approach would allow to gather

[2] `http://www.solaresearch.org/mission/` (last visit, September 2013)

evidence that informs about whether the current state of the learning situation satisfies the teacher's goals [20].

In CSCL, many of these pedagogical decisions have to do with learner scaffolding. The effectiveness of collaborative learning depends on multiple factors, including the way interactions among learners are promoted, structured, and regulated [4]. Such learner scaffolding may be achieved through CSCL scripts, that can take the form of computationally interpretable specifications of a desired collaboration process [21]. CSCL scripting can be considered a specific form of learning design [22], focused on collaborative learning pedagogical principles and techniques.

2.1 Life-Cycle of CSCL Scripts

Since 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 scripting and monitoring. Though there is no clear consensus on the composition and nomenclature of this life-cycle, 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 [23, 24, 25, 26], edition [27], or specification [21].
2. The script adaptation to the setting (specifying participants, groups, tools and resources and their usage by each group/participant), known as script instantiation [23, 27, 26], formalisation [21], or operationalisation [24].
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 [27, 26], enactment [24, 25], execution [23], or deployment [21].
4. And, eventually, the revision and refinement of those activities, that is the script evaluation [24, 25].

In this paper, we refer to the aforementioned script phases as design, instantiation, management, and evaluation (see Figure 1). 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. In order to ascertain how the design and management phases can be structured, the next subsections reviews previous works that constitute the starting point of our proposal.

2.2 Design of CSCL Scripts

Several authors have worked on modelling CSCL scripts, identifying the different elements that should be included in a script definition and providing frameworks for that purpose [28, 27, 21]. However, the design of potentially effective CSCL scripts

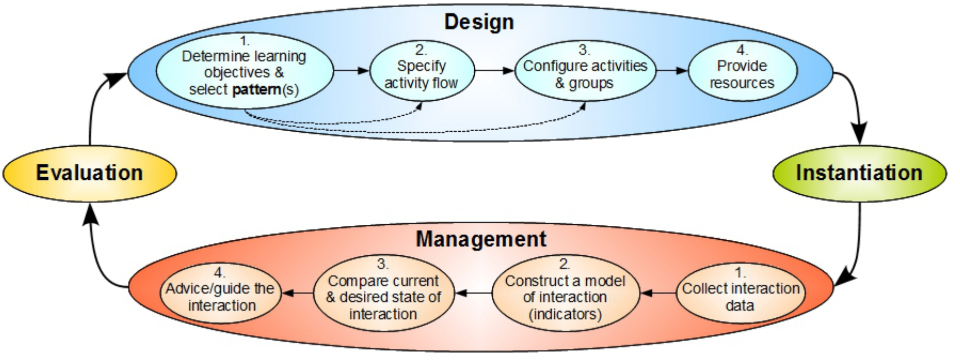

Figure 1. Relation among the CSCL scripts life-cycle, the design process [12] (depicted in the design phase) and the collaboration analysis process [9] (represented in the management phase)

is still a difficult task, especially for non-expert designers. For that purpose, the use of patterns that reflect good practices in structuring collaborative learning has proved to be helpful [29, 30].

Villasclaras et al. [12] 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 [23].

As Figure 1 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 affects not only the activity flow but also the configuration of the activities.

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 has already been used with success for embedding assessment in the design of CSCL scripts [12]. Therefore, we propose that this process may be used as a framework for integrating monitoring issues in the script.

2.3 Management of CSCL Scripts

Although the CSCL script is designed to favour productive interactions, unexpected events during its enactment may jeopardise the initial plan. Thus, monitoring participants' interactions during the management phase may contribute to detect emergent problems and regulate the learning situation.

There are several proposals in the literature devoted to conceptualise monitoring data analysis processes. Many of them define a data-driven approach, obtaining indicators based on data available and trying to extract meaning from them [31, 32, 33]. Others follow a model-driven approach, in which the data collected is compared with a pre-specified model that guides the analysis [9]. Since we aim to use the script to guide the analysis, representing the ideal model of interaction, we will base our proposal in the second approach, concretely in the collaboration analysis model proposed by Soller et al. [9].

According to Soller et al. [9], the *computer-supported collaboration analysis process* presents five steps: first, to collect and aggregate interaction data; second, to construct a model of interaction, to select and to compute higher-level variables and/or termed indicators to represent the current state of interaction; third, to compare current state of interaction to the desired state; fourth, to offer advice and guidance; and finally, to evaluate the interaction for assessment and diagnosis. This last step corresponds to the evaluation phase of the script life-cycle (see Section 2.1), and therefore, Figure 1 only represents the first four steps by Soller et al., within the management phase.

As mentioned above, we propose to guide the collaboration management phase by the pedagogical decisions made during the design phase. Teacher's decisions represented by the script, and expressed in a computer-interpretable Educational Modelling Language such as IMS Learning Design [34], will help us to automatically construct the desired state of interaction and guide the collection of evidences. Once we compare the current and desired states, teachers will be informed on the results of the analysis. This information in turn may influence the teacher in the decision making process about regulatory actions.

2.4 Purpose of This Paper and Research Questions

To implement this proposal, it is necessary to identify how scripting and monitoring influence each other. On the one hand, we must identify what script information is necessary to guide the data gathering and to represent the ideal interaction state. On the other hand, it is known that teachers frequently do not pay attention to the monitoring issues when designing learning scenarios, and ignore the impact their decisions have on monitoring [6]. Thus, in this paper, we address the following research questions:

1. What script information is necessary to guide the process of collaboration analysis?

2. How can teachers be supported to integrate monitoring issues into the pattern-based design process of CSCL scripts?

These questions have led us to define a learning design process of CSCL scripts that takes monitoring into account, and a model that represents the connections between scripting and monitoring. In this paper, we will explain what information is needed from the script to guide the monitoring and what is our proposal to gather this information by means of a monitoring-aware learning design process. These outcomes will be used to facilitate the integration of monitoring issues in learning design authoring tools, and to automatise the guidance of collaboration analysis process by means of the script description.

3 METHODOLOGY OF THE STUDY

The work presented in this paper is located under the multidisciplinary CSCL paradigm [35, 3]. The complexity of the 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. 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 [36]. Additionally, since teachers are our target users, we decided to involve them from the very beginning in the formulation of our proposals [37]. Thus, we chose *Design-Based Research* (DBR) [38] as a methodological framework for the definition of the process and model presented in this paper. Design-Based Research is a systematic but flexible research approach aimed to improve 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.

The selection of the teacher involved in these scenarios was not done at random. On the one hand, there were reasons related to her background that made her suitable for the purposes of the study: this teacher had taught for several years in scenarios supported by ICT tools, usually including CSCL scenarios during her courses; she had also been involved in CSCL scenarios where interaction analysis was used to better understand the learning process. Thus, her profile could be very helpful to identify the connections between scripting and monitoring. On the other hand, there were also methodological reasons aligned with the DBR principles. This teacher was interested in improving her practice, and she was willing to collaborate with us on a continuous basis. Therefore, her participation gave us the chance of iteratively refining the proposal with an individual who knew the context in depth. This helped us to address the need of performing multiple iterations in a learning context, a major challenge in the application of DBR approaches [39]. Finally, in order to minimise the bias caused by the involvement of the researcher in the scenarios, we counted with the participation of two external researchers, who contributed with their views to the elaboration of the proposal.

Following the DBR phases, initially we defined a set of research questions (listed in Table 1) that were studied in two naturalistic CSCL scenarios [38]. The main purpose of the first study was to gather information about the exploratory questions [40]. Based on the results obtained, we proposed a model to represent the relations between scripting and monitoring, and formulated a monitoring-aware design process for supporting teachers in the design of pattern-based CSCL scripts. Then, these proposals were applied in the second learning scenario for their evaluation – by means of the evaluative questions [40] – and refinement. The following two sections report these two studies in detail.

Exploratory Questions	*A)*	*What script information is necessary to guide the process of collaboration analysis?* A.1) What script information is necessary to guide the data gathering of participants' interactions? A.2) What script information is necessary to represent the desired state of a CSCL situation?
	B)	*How can teachers be supported to integrate monitoring issues in the pattern-based design process of CSCL scripts?* B.1) What scripting decisions affect monitoring? B.2) What script information, necessary to guide the process of collaboration analysis, is already available? What additional information is necessary? Who can provide it?
Evaluative Questions	*A)*	*Is the proposed monitoring-aware design process affordable for teachers?*
	B)	*Is it possible to guide the first two phases of the collaboration analysis by means of the information obtained from such design process?*

Table 1. Summary of research questions. Exploratory questions are addressed in the 1st study (Section 4) and evaluative questions in the 2nd one (Section 5)

To address these questions, in both aforementioned pilot studies, teacher and researcher co-designed a CSCL script that was enacted in the authentic learning scenario. This approach allowed us to better detect the dependencies between scripting and monitoring, to inform the teacher about the impact that her decisions had on monitoring, to reach an agreement on the most appropriate choices for both sides, and to obtain the missing information required to guide the monitoring process. We will discuss these research questions in the following sections.

4 EXPLORATORY STUDY: IDENTIFYING THE ELEMENTS THAT AFFECT MONITORING

This section reports the pilot study that was set up in order to gain insight into the exploratory questions presented in Table 1. First, we present briefly the context of the study; then, we explain how the monitoring issues were taken into account during the co-design process, as well as how the design supported the management of the learning situation; and finally, the section ends with the discussion of the results obtained from the case study and the formulation of proposals.

4.1 Context of the Study and Research Questions

The case 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 the Master's Degree for Pre-Service Secondary Education Teachers, with 14 students attending the course and an expert teacher in CSCL scenarios. 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 elaborate this poster, students worked in a blended CSCL setting, interleaving face-to-face with distance activities mediated by ICT tools.

The co-design of the learning scenario consisted of 7 face-to-face sessions, that lasted altogether 17 hours, working from the conceptualisation of the learning design to its deployment in the learning environment. Teacher and researcher followed the pattern-based design process outlined in Section 2, 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.

In this study, we address the exploratory questions shown in Table 1. Our first research question aims to clarify which script information could influence the process of collaboration analysis [9]. In this work, we focus on the two first steps of the collaboration management phase, trying to identify which information must be included in the script to guide the data gathering and to represent the desired state of a CSCL situation (questions A.1 and A.2). The second research question aims to find ways to support teachers to include monitoring issues in the pattern-based design of CSCL scripts presented in Section 2. To answer this question, we will address two more specific ones. On the one hand, we will try to identify which teachers' pedagogical decisions affect monitoring (question B.1). On the other hand, once we know what script information may guide the collaboration analysis process (question A), we will try to clarify what information is already available, what must be incorporated, and who can provide it (question B.2).

4.2 Co-Design Process

The co-design process consisted of *two cycles*. First, the teacher designed the learning scenario following the guidelines given by the pattern-based design process. Meanwhile, 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' interaction. In the second cycle, both the teacher and researcher analysed the possibility of including complementary data sources that may inform about the state of the activities. Table 2 summarises the main decisions made in both parts of the co-design process.

4.2.1 First Cycle: The Pattern-Driven Co-Design

The teacher designed the scenario following a pattern-based learning design process (see Section 2). Two tools were used to facilitate the application of this design process: *Web Collage*[3], an authoring tool that produces IMS-LD [34] compliant formalised scripts; and *GLUE!-PS*[4], a tool that allows practitioners to particularise and deploy IMS-LD scripts (among other learning design languages) into mainstream virtual learning environments.

Throughout this cycle, the researcher informed the teacher 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 [41]. 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 Jigsaw [41] and on the literature review [42, 43], informed the teacher about the constraints [4] that must be satisfied to comply with this pattern. Table 3 shows the pattern constraints that should be monitored in the different phases that constitute the learning flow.

[3] Web Collage: `http://pandora.tel.uva.es/wic` (last access, September 2013)
[4] GLUE!-PS: `http://www.gsic.uva.es/glueps/` (last access, September 2013)

Phase	Activity	Social level	Interactivity type	Physical location	Resources & tools for learners	Teacher's monitoring support activities
Individual	Individual study	Individual	Through computers	OTC	– Documentation on learning methods	
Expert	Individual summaries	Individual	Through computers	OTC	– A wiki page	*– Check monitoring report*
	Expert consensus	Expert groups	Blended	ITC & OTC	– A shared board (Dabbleboard) – A wiki page	*– Control attendance* *– Check monitoring report*
	Workgroup report	***Expert groups***	***Through computers***	***OTC***	***– A questionnaire (Google Forms)***	*– Check monitoring report*
Jigsaw	Selection of methods	Jigsaw groups	Through computers	OTC	– A questionnaire (Google Forms)	*– Check monitoring report*
	Poster development	Jigsaw groups	Blended	OTC	– A wiki page	*– Check monitoring report*
	Peer review	Individual	Through computers	OTC	– Wiki pages	*– Check monitoring report* *– Control participation*
	Posters presentation	Jigsaw groups	Face-to-face	ITC		*– Control attendance* *– Control participation*
	Workgroup report	***Jigsaw groups***	***Through computers***	***OTC***	***– A questionnaire (Google Forms)***	*– Check monitoring report*
	Peer evaluation	Individual	Blended	ITC & OTC	– A questionnaire (Google Forms)	*– Check monitoring report*

Table 2. Overview of the activities included in the script of the first 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. (ITC – Inside the classroom/OTC – Outside the classroom)

2. **Specify activity flow.** Following the pattern guidelines, the teacher 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

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.

Table 3. 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).

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 2 show the structure of phases and activities that conformed the activity flow.

Regarding monitoring, identifying the constraints of the activity flow is useful to detect whether the current state of the learning scenario may jeopardise future activities. For instance, if one group of experts does not submit the analysis of the learning methods assigned to them, the activities of the jigsaw phase may fail, since the contribution of these experts would be missing. This constraint is derived from the use of the pattern (see Jigsaw constraints in Table 3).

3. a Configure activities. The teacher described the tasks to be carried out in each one of the activities. Additionally, the definition was complemented with decisions that affect 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 must be set by the designer (the teacher, in this case), the *interactivity type* (face-to-face, through computers or blended), and the *physical locations* (inside and/or outside the classroom). Some of these details have been included in Table 2.

From the monitoring point of view, the time limits are needed to narrow the period of the analysis. Being aware of which activities have to be carried out individually or in groups – and in which groups – gives information about *which evidences 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 interactivity type and the physical location of the activity provides information about which evidences are 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).

3. b Configure groups. The group formation consisted in distributing students in jigsaw and expert groups. As mentioned in Table 3, 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, the teacher configured 4 expert groups and 3 jigsaw groups. 12 students were assigned to these groups in order to ensure the pattern constraints, and the other two were allocated to existing groups.

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 defined by the CLFP would, for example, help to foresee whether a particular jigsaw group may miss the contribution of one expert.

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 2 specifies the ICT tools used in each activity. On the one hand, the teacher posed the restriction of using MediaWiki[5] to support the collaborative writing and to centralise the access to all the resources and

[5] MediaWiki: `http://www.mediawiki.org` (last access, September 2013)

activities. Both of them agreed using the GLUE! architecture[6], because it allows the integration of external tools into MediaWiki and besides, it facilitates the collection of information from the different technologies used in the learning scenario [44]. Additionally, the teacher proposed to use Text2MindMap[7], a web application for development of conceptual maps, and Google Forms[8] for the on-line questionnaires. However, since Text2MindMap did not offer any information about user actions, it was replaced by Dabbleboard[9]. From such technological context it was possible to detect who and when would access Dabbleboard or Google Forms, as well as the editions and uploads done by the users of MediaWiki. Being aware of the *tools* required for each activity influences the data gathering and contributes to the definition of the desired state.

4.2.2 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. The teacher 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. This first cycle helped to identify parts of the design that were difficult (if not impossible) to monitor with such configuration of the activities. Hence, there was a need of going one step further, looking for new ways on which the design could be modified in order to 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 interactions 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 data, are necessary.

After an analysis of the factors that affect the usefulness of different types of data sources, we observed that the interactivity type and physical location have an influence on which data sources can be used to get information about one activity. For example, activities being performed face-to-face outside the classroom 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 tools (ICT), by the teachers in their observations of the class and by the students themselves. Table 4 summarises the *informants* that were identified (the technological support, the teacher herself and the students) *depending on the physical location and interactivity type* of the specific activity.

According to this, the learning design built in the previous cycle of the process was complemented with new activities that enabled the collection of data from

[6] GLUE! - Group Learning Uniform Environment: `http://www.gsic.uva.es/glue/` (last access, September 2013)

[7] Text2MindMap: `http://www.text2mindmap.com/` (last access, September 2013)

[8] Google Forms: `http://www.google.com/drive/start/apps.html` (last access,

	Face-to-face	**Blended**	**Computer mediated**
ITC	students & teachers	students & teachers & ICT support	students & teachers & ICT support
ITC & OTC	students & teachers	students & teachers & ICT support	students & teachers & ICT support
OTC	students	students & ICT support	students & ICT support

Table 4. Data sources needed for the monitoring of a collaborative activity depending on the interactivity type (face-to-face, computer mediated or blended) and the physical location (ITC – Inside the classroom and/or OTC – Outside the classroom).

an appropriate informant for each case (see text in italics in Table 2). 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 2). 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*.

4.3 Management of the Learning Situation

The script was put into practice in the context previously described. A prototype of a GLUE! module named *GLUE!-CAS* [44] (GLUE! Collaboration Analysis Support) was used to collect the participants' interactions from the technological support, and from the attendance registers filled out by the teacher during the activities. These participants' interactions were analysed taking into account the script definition, and a monitoring report was sent to the teacher at the end of each activity. In most cases, this report helped her to confirm that the students were following properly the script: 85 out of the 99 evaluated elements (84.86 %) were consistent with the script expectations, while the other 14 (16.14 %) were unexpected events that made the teacher take regulatory actions. 98 out of the 99 evaluated elements (98.99 %) had been 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). 80 out of the 99 elements (88.89 %) were considered relevant by the teacher for regulating the scenario, and 54 out of the 99 (54.55 %) were unknown by her, i.e., she would not have been identified them without the feedback provided by the system. 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, in three of the activities: *individual summaries*, *peer review* and *peer evaluation* (see Table 2) there was no evidence that some of the students had performed their tasks. In these situations the teacher started by verifying the work

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[9] Dabbleboard: `http://dabbleboard.wordpress.com/` (service no longer available)

done by the students, and in the cases in which the problem was confirmed, she sent a reminder, extending the deadlines. These problems could not have been detected by the teacher without the monitoring report, or without a review to the spaces where the submissions were to be uploaded, which is a more demanding task. A similar problem arose with the *workgroup report* carried out by expert groups, where no evidence of participation was registered by two of the groups. However, in this case, the cause was a technological problem with the on-line questionnaires supporting the activity, that could be easily fixed on the fly, and the students could submit their answers on time.

Another issue was detected during the *expert consensus* activity. The monitoring report informed the teacher that two of the groups had not submitted their deliverable on time. If this warning were not a false positive, it would have become a critical situation in the enactment of the pattern, as the lack of these deliverables affected the upcoming jigsaw phase. However, reviewing the work done by the students, the teacher realised that the contributions had been submitted at erroneous pages of MediaWiki. In this latter case, as well as in the previous one, although the problem detected was not due to a fault in the students' performance, monitoring helped the teacher detect and solve them.

Overall, monitoring helped the teacher to confirm that the students were performing as expected; and, in those cases where eventualities happened, monitoring was useful to detect the problem and solve it before it became a real breakdown in the activity. All this information was received with almost no effort on her part.

4.4 Findings and Proposal

In this section, we discuss the results according to the exploratory questions defined in Table 1. Based on the findings, we present our proposals for (1) modelling the script elements that could guide the collaboration analysis process, and (2) adapting the pattern-based design process to support teachers in the integration of monitoring issues in the design of CSCL scripts.

4.4.1 Script Information Necessary to Guide the Collaboration Analysis

Throughout this study, we identified a set of dimensions and parameters that influenced the analysis process (see Table 5). Regarding the first step of the collaboration management (see Figure 3), three configuration parameters of the activities guided the *data gathering of participants' interactions* (question A.1): 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 interactions registered in the learning environment were considered for the analysis.

Pattern	**Activity**	**Teacher's Monitoring Decisions**
Activity flow	Deadlines	Monitoring periods
Collaboration	Resources (tools, contents)	Interactions to be monitored
Group formation policies	Participants	
	Groups	
	Social level	
	Interactivity type	
	Location	

Table 5. Dimensions and parameters identified in the first study that affected the process of collaboration analysis

Concerning the second step of the collaboration management, the activity features also influenced **the representation of the desired state of a CSCL situation** (question A.2). 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 pattern 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. The *activity flow* provided sequencing dependences (finish-to-start, start-to-start, finish-to-finish, start-to-finish) between activities or phases that may jeopardise the script purposes, e.g. the "Expert phase" had to finish before the "Jigsaw phase" starts (see Table 2). The *collaboration and group formation policies* had to be satisfied in order to verify the script collaborative purposes. For instance, during the "Jigsaw phase" in each jigsaw group at least one expert of the different areas had to be actively involved (see Table 3).

Additionally, during the co-design process we identified two more parameters. On the one hand, the selection of tools that satisfied the pedagogical and monitoring needs, called for a list of ICT tools describing their monitoring affordances, in particular the *monitorable actions*. On the other hand, when analysing the data sources needed for the monitoring of a collaborative activity (see Table 4), together with the interactivity type and the social level, another parameter emerged: the *location* of the activity (inside and/or outside classroom). Though this parameter was not used in the analysis process, it was necessary for the reflection on the data sources that may inform about the activity progress. Thus, we have included the monitorable actions and the activity location as parameters that affected indirectly the collaboration analysis at design-time.

Since our final purpose is to integrate the monitoring issues in learning design authoring tools, we defined the computational model shown in Figure 2. This *monitoring-aware scripting model* relates the aforementioned dimensions and parameters with the elements identified in two related research areas: the elements that model CSCL scripts (participants, groups, roles, activities and resources [28, 27, 45, 46, 21]) and the elements that model the analysis of computer-mediated interactions (participants, groups, roles, resources, and actions [47, 48]).

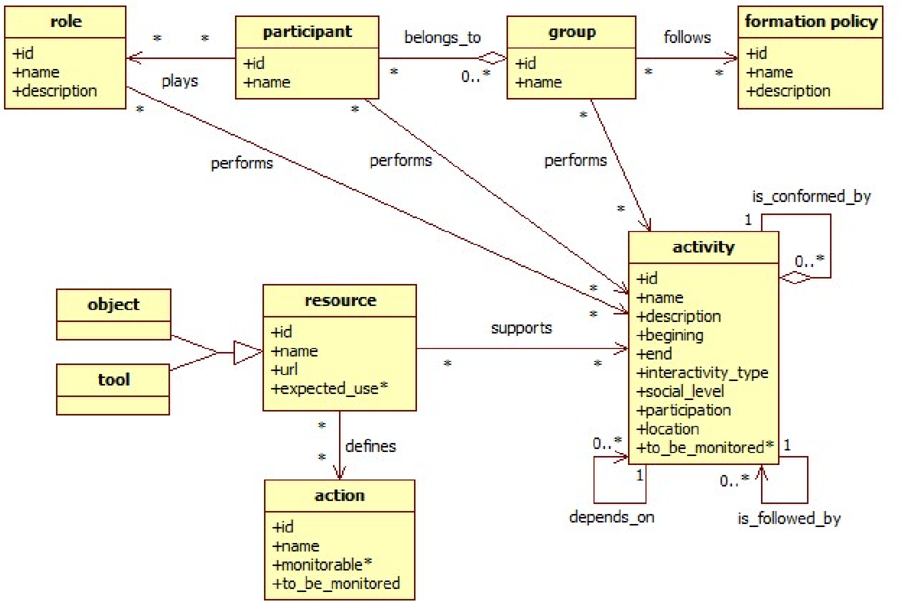

Figure 2. Elements and attributes of the monitoring-aware scripting model. Attributes marked with * were detected in the second study.

4.4.2 Integrating Monitoring Issues in the Pattern-Based Design Process of CSCL Scripts

In order to understand how the teacher was supported to integrate the monitoring issues (question B), we start summarizing the scripting decisions that affected monitoring throughout the co-design process (question B.1). Within the first cycle: when the teacher determined the learning objectives and chose a pattern, the researcher *extracted the pattern constraints* that should be verified during the enactment and that were taken into account for the configuration of the desired state of the CSCL situation; when the teacher specified the activity flow, the researcher *identified the activity flow dependences* that helped defining the desired state and detecting whether the current state of the learning situation might risk future activities; when the teacher configured the activities, the researcher asked her to *provide some additional parameters that affect monitoring* such as the duration, the specification of the social level, the interactivity type, and the physical location; the way the teacher configured the groups was used to *define the desired state of interac-*

tion; and finally, during the provision of resources, teacher and researcher *searched together tools that satisfied the teacher's needs and at the same time allowed us to harvest data about the users' actions*.

During the second cycle, teacher and researcher enriched the design to enhance monitoring, *identifying complementary monitoring data sources* to avoid blind spots, *including additional data gathering activities* for teacher and students to collect evidence about the learning process, and *introducing monitoring support activities* to be performed by the teacher.

Regarding the script information necessary to guide the process of collaboration analysis (question B.2), Table 5 summarises the parameters that were identified during the study. Many of these parameters are also present in the existing proposals related to the definition of CSCL scripts [28, 27, 45, 46, 21]: participants, groups, roles, activities, and resources involved in the learning scenario. Thus, we can assume that not only in the scenario we have presented but also generally, this information is *available in CSCL scripts*. In addition, there are some *details that the teacher will have to specify* about the *activities* (deadlines, social level, interactivity type, and location) and *his/her own monitoring decisions* (monitoring periods and interactions to be monitored). But, in those cases in which the pedagogical design pattern is known, the constraints obtained from the pattern can provide part of these additional parameters, as it happened in this scenario. Finally, *some data must be obtained about the ICT tools*, specifically the *user's actions that are monitorable*. Such information is meaningful for pedagogical reasons (informs the selection of tools) and from technological point of view (helps to automatise the data gathering).

Based on the pattern-based design process (see Figure 1) and the lessons learned from the co-design (Subsection 4.2), we proposed the *monitoring-aware design process* shown in Figure 3. This process emphasises the design decisions that affect monitoring, and points out when the additional parameters necessary to guide the collaboration analysis may be obtained (see the content of boxes marked with stars in Figure 3). As presented during the co-design of the scenario, we suggest that the process should be followed in two iterations, the first to ensure a monitorable script, and the second to better adjust the script configuration to the monitoring purposes:

Monitoring-aware design cycle driven by the pattern(s): This first cycle requires designers to *reflect on the three dimensions* presented in Table 5 (pattern, activity constraints, and teachers' monitoring decisions), *taking into account the monitoring needs* in their decisions. First, once the designer has chosen the pattern(s) that the script will implement, the teacher must have in mind the pattern constraints. Then, regarding the specification of the activity flow, it will be necessary to *identify the flow dependences* (i.e. the sequencing constraints between activities). Then, during the configuration of the activities, their *parameters* will be defined (social level, interactivity type, deadlines, and location), as well as the specific *group formation policies* (for instance, bounding the minimum and maximum sizes). Finally, the selection of resources will take into account their monitoring opportunities, and the teacher will define the *resources and actions* that are *relevant for the monitoring purposes*.

Monitoring enhancement cycle: The second iteration aims to *enrich the design so that monitoring may be enhanced*, extending the activity flow by means of data gathering and/or monitoring support activities. These decisions will be inspired by the data source available to inform the constraints to be monitored (see Table 4). As any other activity, the new activities will be configured, indicating the *resources* and the *actions to be monitored*.

The first cycle will generate a monitorable version of the script the practitioner had in mind, and the second one will extend the script to provide monitoring with additional data sources.

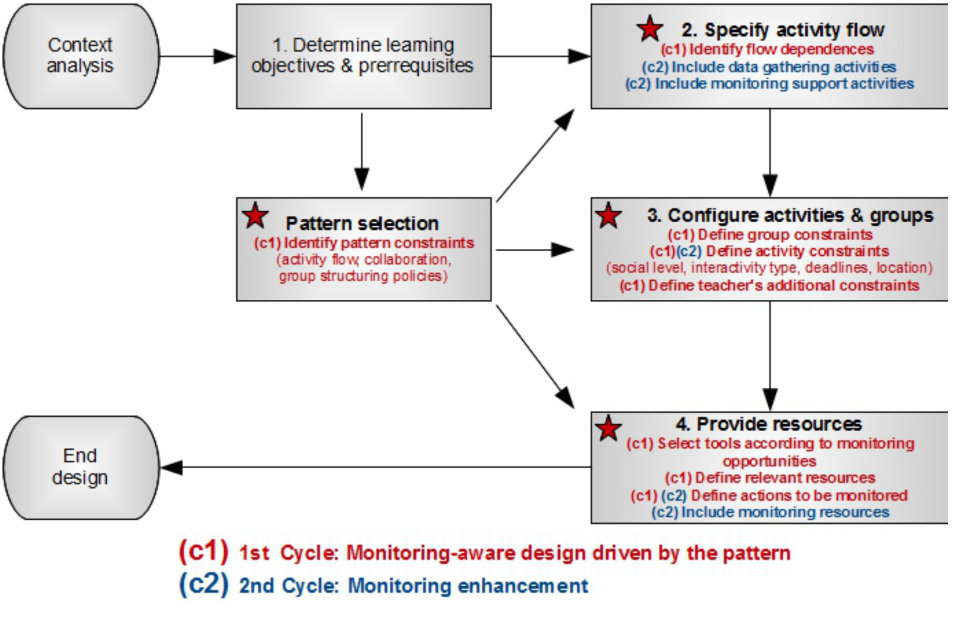

Figure 3. Proposal of monitoring-aware design process. Stars point out steps with monitoring tasks. Red elements, preceded by (c1), refer to the first cycle, and blue elements, preceded by (c2), represent the second cycle

5 EVALUATION AND REFINEMENT STUDY

Following the Design-Based Research approach, the proposals obtained from the exploratory study (presented in the previous section) should be evaluated and refined iteratively. Thus we applied the monitoring-aware learning design process and model in a new authentic scenario. This section presents briefly the context of the study;

explains how the proposal was implemented during the design process, as well as its impact on the management of the learning situation; and finally, it describes the evaluation of the proposal.

5.1 Context of the Study and Research Questions

The second learning scenario lasted from March 26th to April 26th, 2012, and took place within a course dealing with "Research in Education", in the same Master's Degree and with the same participants as in the previous study. 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 [49]. To perform this task, the students worked in groups in a blended CSCL setting, interleaving face-to-face with distance activities mediated by ICT tools.

The design of the learning scenario required 5 face-to-face sessions, that lasted altogether around 8 hours. The tasks developed during these sessions spanned from the conceptualisation of the learning design to its deployment in the technological learning environment. In order to facilitate the design and deployment of the script, the teacher used the tools *Web Collage* and *GLUE!-PS*, as in the previous study.

We are aware that involving the same teacher in this new study may preclude the generalisation of the conclusions eventually drawn from it. However, and in accordance with the principles of Design-Based Research, it is the same teacher who might contribute with a more refined feedback, regarding the proposals derived from the first study. Therefore, it is noteworthy that, in this evaluative study, the teacher will use a set of new design instruments aimed at scaffolding the design activities according to the model and process presented in Subsection 4.4 (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 section was meant, among other goals, to evaluate them, together with the overall process.

In this study, we address the evaluative questions shown in Table 1. On the one hand, we study whether the proposed monitoring-aware design process is affordable for teachers (Question A). And, on the other hand, we verify whether the output of such design process supports the guidance of the first two steps of the collaboration analysis (Question B).

5.2 Monitoring-Aware Design Process

The teacher designed the learning scenario following the guidelines given by the monitoring-aware design process. Table 6 summarises the main decisions made in the two cycles of the design process.

Our final purpose is to implement an authoring tool (or an extension to an existing one) to integrate the monitoring issues into the design process. To this end, an intermediate step was to evaluate the proposed model and process by means of paper prototypes and manual processing, in order to assess their appropriateness and possibly refine them before implementing the envisioned tool.

Phase	Activity	Social level	Interactivity type	Physical location	Resources & tools for learners	Teacher's monitoring support activities
Level 1	Individual research proposal	Individual	Through computers	OTC	– A document (Google Docs)	– ***Check monitoring report***
Level 2	Initial research proposal	Small groups	Blended	ITC & OTC	– A shared document (Google Docs)	– ***Check monitoring report*** – ***Control attendance***
Level 3	Final research proposal	Super groups	Blended	ITC & OTC	– A shared document (Google Docs) – A wiki page	– ***Check monitoring report*** – ***Control attendance***
	Development of the research plan	Super groups	Blended	ITC & OTC	– A shared document (Google Docs) – A wiki page	– ***Check monitoring report*** – ***Control attendance***
	Peer review	Individual	Through computers	OTC	– A shared document (Google Docs) – A wiki page	– ***Check monitoring report***
	Improvement of the proposals	Super groups	Blended	ITC & OTC	– A shared document (Google Docs) – A wiki page	– ***Check monitoring report*** – ***Control attendance***
Level 4	Presentation of proposals & plans	Whole class	Face-to-face	ITC		– ***Control attendance***
	Peer evaluation	Individual	Through computers	OTC	– A questionnaire (Google Forms)	– ***Check monitoring report***
	Workgroup report	***Super groups***	***Through computers***	***OTC***	– ***A questionnaire (Google Forms)***	– ***Check monitoring report***

Table 6. Overview of the activities included in the script of the second 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. (ITC – Inside the classroom/OTC – Outside the classroom)

For this formative evaluation we carried out manually the monitoring-aware design process, supported by *paper-based activity forms*. These activity forms are the concretion of the monitoring-aware scripting model, and represent the elements to take into account to configure the monitoring issues.

In the first cycle of the design process, the teacher used *Web Collage* and *GLUE!-PS*, and also filled out the activity forms with the configuration of each activity. 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, including new data gathering and monitoring support activities. Figure 4 illustrates one activity form.

The following subsections describe the decisions presented in Table 6 and how the teacher used the activity forms.

Activity name:	Activity 3.2 Development of the research plan		**Phase:**	Level 3
Beginning: (YYYY-MM-DD hh:mm:ss)	2012/04/03 11:30:00	**End:** (YYYY-MM-DD hh:mm:ss)	2012/04/04 22:00:00	
Enable monitoring: (yes / no)	yes	**Monitoring dates:** (YYYY-MM-DD hh:mm:ss)	2012/04/04 22:15:00	
Social level: (Individual / by groups / whole class)	By groups	**Interactivity type:** (Face-to-face / computer mediated / blended)	Blended	
Participation: (Optional / mandatory for individuals / mandatory for groups)	Mandatory for individuals	**Physical location:** (Inside / outside / in & out the classroom)	In & out the classroom	
Groups formation:	**Group name:**	Super-group 1	**Participants:**	Mike, Charlie, John, Frank, Robert
	Group name:	Super-group 2	**Participants:**	Esther, Helen, David, Marian, Jeff
	Group name:	Super-group 3	**Participants:**	Eleonor, Louis, Laurance, Serena
ICT Tools & Additional data sources :	**Tool name**	**Expected use** (optional/mandatory, individual/by groups)	**Actions to be monitored**	
	Media Wiki	mandatory, by groups	Editions, uploads	
	Attendance register	optional, individual	Attendance	
Activity constraints: (Derived from the analysis of the activity features)	*1)* Individual participation *(Every participant must be involved in the activity)* *2)* Expected use of resources *(Every group must use its MediaWiki resources)*			
Pattern(s) constraints: (Derived from the analysis of the pattern(s))	3) [Pyramid] Collaboration *(In every Super-group all the conforming 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)*			
Additional constraints: (Specified by the teacher)	--			

Figure 4. Example of activity form filled with the information of the *Activity 3.2 Development of the research plan.* The area surrounded with dash points represents the constraints provided to the teacher, derived from the analysis of the pattern and the activity features. Students' names have been modified to ensure their privacy.

5.2.1 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, playing the role of the envisioned authoring system.

1. **Determine learning objectives and select pattern(s).** The collaboration script implemented a four-level Pyramid, including a Peer-review in one of the

phases [41]. The researcher analysed the definition of these patterns and obtained constraints that must be verified during the enactment [50, 51, 20] (see Tables 7 and 8). These constraints, were visualised throughout the different forms of the activities in the fields *Pattern and Activity constraints* (see Figure 4).

Structuring 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.
$\|groups(level1)\| <= \|groups(leveli-1)\|/2$		**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.

Table 7. List of constraints of the Pyramid CLFP. **X** represents that the restriction must be satisfied in the different levels of the pyramid.

Structuring constraints	**Description**
$\|groups\| >= 2$	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.

Table 8. List of constraints of the Peer Review CLFP

2. **Specify activity flow.** The Pyramid pattern guided the main structure of the activity flow. The activity flow presents 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, 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 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 6 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 sets that every group must review at least one document (see third row in Table 8). 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 4 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 physical locations, as well as the monitoring periods (part of this information appears in Table 6). From this configuration, new constraints could be derived. For example, the description of the *Development of the research plan* was defined to be carried out in groups, combining face-to-face and computer-mediated interactions, both inside and outside the classroom, 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 4).

3. b Configure groups. The Pyramid pattern guided the students grouping. At level-1, students worked individually. At level-2, the teacher created 6 groups of 2 to 3 participants. At level-3, the groups merged to conform 3 super-groups (composed of 2 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 4. 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 groups that conformed the super-groups were involved to enable interchange of ideas (see fourth row in Table 7). This constraint can be observed in the pattern constraint section of Figure 4.

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 5 decided which actions would be monitored for the collaboration analysis. For instance, in the example shown in Figure 4 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 5. Description provided to the teacher of the monitoring capabilities of the tools involved in the learning scenario

5.2.2 Second Cycle: Enriching the Design to Enhance Monitoring

During the second cycle of the monitoring-aware 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 6). This subsection describes how the teacher made such decisions.

Using the relation between data sources, interactivity type and physical location given in Table 4, the teacher analysed whether the current configuration of activities could generate enough evidences to inform the constraints. This analysis moved her to add new data gathering activities – students had to elaborate a workgroup report at the end of the experience, and monitoring support activities – the teacher registered the attendance in those activities that happened partially or completely in the classroom (see text in italics in Table 6).

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. Though MediaWiki provided evidences about computer-supported interactions, there was no data source about face-to-face interactions (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.

5.3 Management of the Learning Situation

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). As it happened in the first study, monitoring reports helped the teacher to confirm that the students were following properly the script: out of 140 evaluated elements, 117 (83.57 %) were consistent with the script expectations, while 23 corresponded to unexpected events, requiring the teacher's intervention. In this second study, all the evaluated elements (100 %) were interpreted correctly by the system. Out of the 140 evaluated elements, 83 were unknown by the teacher (59.28 %) and were considered relevant for regulating the 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 (one student was not involved in the learning situation from the very beginning) or they did not require intervention (activities in which one specific student was not participating). However, in those activities with lack of group participation, the teacher reviewed the wiki pages and realised that the students included their contributions in the wrong place and could fix it on time.

Regarding the patterns constraints, two problems appeared that could affect the accomplishment of the Pyramid pattern. During the first activity, 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 isolate 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).

Figure 6 displays the monitoring report sent to the teacher at the end of the activity *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 4) are included. As it can be seen, in this specific report there was no evidence of participation for four of the students.

Also in this case, providing the teacher with information about the monitoring of the script helped her to follow the students' performance with low effort. On the one hand, when the monitoring reports confirmed that the students were accomplishing properly the activities, the teacher was not obliged to review in detail the students' work to obtain the same information. On the other hand, when the

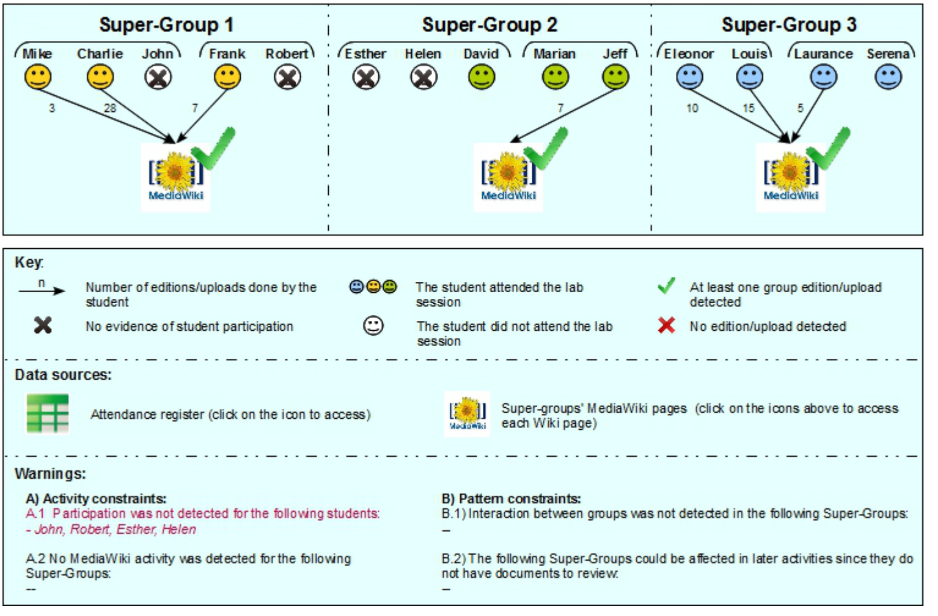

Figure 6. Example of the information sent in the monitoring report of the *Activity 3.2 Development of the research plan*

monitoring report announced potential problems, it facilitated solving the problems before becoming a real breakdown in the course.

Though in both studies part of the information was already known by the teacher (indeed some information was provided by her, such as the attendance register), she considered all the information useful. She argued that despite of having some evidence about how students were participating (mainly in those activities located fully or partially within the classroom), having all the information collected and integrated provided her a clearer view of the learning process. At the end of the activity, the monitoring reports had helped her to reconstruct the students' progress throughout the activity, which she considered also to be helpful for assessment purposes.

5.4 Findings and Discussion

Although the enactment of the proposal in an authentic learning context constitutes and evaluation happening by itself according to Design-Based Research, this section aims at discussing in detail the evidences gathered in the study, following the evaluative questions presented in Table 1.

5.4.1 Is the Proposed Monitoring-Aware Design Process Affordable for Teachers?

The first aim of this pilot study was to assess whether the envisioned learning design process enables the teacher to link the pedagogical and the monitoring decisions, as well as to integrate the monitoring issues at design-time, with a reasonable effort (Question A). The researcher was present during the design sessions, and interviewed the teacher in several occasions during and after the design in order to gather the teacher's point of view about these issues.

The affordability has been explored by measuring the time needed in each monitoring task, and by analysing the teacher's opinions on the process complexity. Though the whole design process took 8 hours, the amount of time devoted to monitoring purposes comprised 30 minutes for filling the forms (in the first cycle) and 20 minutes for enriching the design (in the second cycle). According to the teachers' judgement during the interviews, the teacher valued positively the time required to perform these tasks: *"Though these tasks require an extra effort, the amount of time is not significant. Besides, they help to reflect on other issues that must be considered such as dates, pattern constraints, dependences between activities, or what is expected from each activity." "Knowing when additional data sources may be necessary is very useful and simplifies the process."*

Also, the teacher considered that monitoring and pedagogical decisions were connected: *"This is an aspect very close to the teacher's tasks. When you incorporate it, you realise that it is important to consider monitoring. If you do not pay attention to it, probably, you will not have the information required for monitoring the learning situation. Though I would have noticed some details by myself, I would have ignored others despite being experienced in designing CSCL scenarios."*

Additionally, the teacher detected a positive impact on the students: *"Moreover, the elaboration of workgroup reports has made the students reflect on how they work and collaborate."*

5.4.2 Is It Possible to Guide the First Two Phases of the Collaboration Analysis by Means of the Information Obtained from Such Design Process?

To evaluate this issue (Question B), a prototype was implemented to automate the analysis. This prototype used a computational representation of the activity forms to guide the analysis. First, in combination with the *GLUE!-CAS* module, the tool collected the participants' interactions, filtered according to the deadlines, the participants involved, and the resources and interactions to be monitored in each activity. Then, the tool generated the desired state of the activities based on the collaborative activity flow and the group formation policies set by the pattern; the participants, groups, social level, participation, and interactivity type that describe the activity configuration; and the expected use of the resources. Finally, the tool compared the gathered data with the desired state of the learning situation, and produced a written report. The researcher interpreted the this report with results of the analysis and generated the monitoring reports submitted to the teacher.

Therefore, we can conclude that the information obtained from the monitoring-aware design process facilitated the guidance of the collaboration analysis process. Furthermore, using the parameters detected in Table 9 we automatised both the data gathering and the definition of the desired state of the learning situation.

This study has also helped us to refine the monitoring-aware scripting model depicted in Figure 2. New parameters emerged during the design process that facilitated the collaboration analysis. For instance, offering to the teacher the possibility of specifying which *activities and resources must be monitored*, not only affects the data gathering but also reduces irrelevant information for the 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.

Table 9 offers a detailed analysis of the parameters that were identified and how they impacted on the collaboration analysis. Some parameters were used to guide the data gathering, and others helped to represent the desired state of the learning situation. Additionally, we realised that some parameters 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, physical location, and the monitorable actions were used to detect which activities may need additional data sources in the second cycle.

6 CONCLUSIONS

The work presented in this paper is framed within a research proposal based on the idea that the pedagogical decisions described in a CSCL script should guide monitoring to better satisfy teachers' awareness needs. We carried out *two interventions in a higher education setting*, with the aim of identifying the script elements that may guide the collaboration analysis and finding a way to support teachers in the integration of monitoring issues at design-time.

The first study had an exploratory purpose. The complexity of the design process, and the mutual dependencies between scripting and monitoring, led us to follow a *co-design process* between teacher and researcher. Based on the lessons learnt, we proposed a *monitoring-aware design process* and a *model* to coordinate and align scripting and monitoring. These proposals were evaluated by means of the second study, where we verified that the teacher was able to follow the process with a low effort, and the script information could guide the collaboration analysis.

The monitoring results provided during the enactment were helpful not only for facilitating the regulation tasks but also for saving teachers' time. Presenting feedback based on the teacher's decisions simplified the understanding of the results, and facilitated the decision making for the regulation of the learning situation. Once the teacher knew which constraints were not being satisfied in real-time, it seemed to be easier to address the issues hampering the learning situation. Besides, the

Dimension	**Parameter**	**Script Design**	**Data Gathering**	**Desired State Representation**
Pattern Constraints	Activity flow			1
	Collaboration			1
	Group formation policies			1
Activity Configuration	Deadlines		1	
	Resources (tools, contents)		1	
	Participants		1	1
	Groups			1
	Social level	1		1
	Interactivity type	1		1
	Location	1		
	Participation			**2**
Teacher's Monitoring Decisions	Monitoring periods		1	
	Activities to be monitored		**2**	
	Resources to be monitored		**2**	
	Interactions to be monitored		1	
	Expected use of resources			**2**
ICT Tools	Monitorable actions	**2**	**2**	

Table 9. Dimensions and parameters that influenced the process of collaboration analysis (i.e. the data gathering of participants' interactions and representation of the desired state of a CSCL situation). Parameters marked with 1 were obtained during the first study, and those marked with **2** emerged during the second one.

automation of data gathering and the integration of different data sources in the analysis reduced the time and effort spent by the teacher in monitoring tasks. This is a remarkable benefit in distributed learning environments where several ICT tools are involved.

This proposal aligns learning design and monitoring in a similar way that Gluga et al. [10], the NEXT-TELL project [11], and Villasclaras et al. [12] integrate learning design and assessment. Nevertheless, the focus is different: while [10] and [11] identify evidences of learning that must be gathered, our proposal identifies what evidence is needed to follow the learning *process*; and although the process defined in [12] guides teachers to integrate assessment activities in CSCL scripts, it does not take into account monitoring issues.

The design process and model proposed in this paper are the basis for the integration of monitoring issues into existing (or new) authoring tools. Thus, our first target will be to automatize the proposal. This automatic support will entail, among other things, providing teachers with information about the monitoring capabilities of the ICT tools (what information is offered about the users' interactions and how it can be retrieved), in order to facilitate an appropriate selection that satisfies both the pedagogical and monitoring needs. Taking into account that our proposal is compatible with the one presented by Villasclaras et al. [12], and that they provided the authoring tool that we have employed in our studies, i.e. Web Collage, we envision that in a short/medium term we will be able to implement our ideas in a system based on this tool.

One limitation of the study presented in this paper is that both interventions were applied to a similar context and with the same teacher. Further interventions that will evaluate the refined proposals and the tools that implement them will be applied to new contexts and with different participants, to avoid bias.

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María Jesús Rodríguez-Triana received her Ph.D. in information and communication technologies from the University of Valladolid (Spain) in 2014. Currently she works as a postdoc in the REACT research group at the École Polytechnique Fédérale de Lausanne (Switzerland). Her research is framed within the area of technology-enhanced learning. Her main interests focus on the application of learning design and learning analytics to support orchestration needs.

Alejandra Martínez-Monés received the M.Sc. and Ph.D. degrees in computer science from the University of Valladolid, Spain, in 1997 and 2003, respectively. She is currently Associate Professor of computer science at the University of Valladolid. Her research interests within the field of technology-enhanced learning include computer-supported collaborative learning (CSCL), learning analytics applied to the monitoring, assessment and evaluation of TEL, with a special focus on social network analysis methods and tools, and the application of Augmented Reality technologies for the support learning situations across multiple virtual and physical spaces.

Juan I. Asensio-Pérez received the M.Sc. and Ph.D. degrees in telecommunications engineering from the University of Valladolid, Spain, in 1995 and 2000, respectively. He is currently Associate Professor of telematics engineering at the University of Valladolid. His research interests within the field of technology-enhanced learning include computer-supported collaborative learning (CSCL) scripting, the integration of external tools in virtual learning environments, the technological support for the orchestration of CSCL situations, the semantic annotation of learning tools in the Web of Data, and the application of Augmented Reality technologies for the support of CSCL situations across multiple virtual and physical spaces.

Yannis Dimitriadis studied telecommunications engineering at the National Technical University of Athens (Greece), at the University of Virginia (USA) and the University of Valladolid, where he is currently Full Professor. His research focuses on telematics support to teaching/learning, for both the students and practitioners/teachers. He coordinates the interdisciplinary group GSIC/EMIC since 1994 with the participation of researchers and practitioners from both the field of technology (telematics and informatics) and of education.