Title: Scripting and monitoring meet each other: Aligning learning analytics and learning design to support teachers in orchestrating CSCL situations

Authors:
María Jesús Rodríguez-Triana, Alejandra Martínez-Monés, Juan I. Asensio-Pérez, Yannis Dimitriadis
Email: (chus@gsic, amartine@infor, juaase@tel, yannis@tel).uva.es
GSIC-EMIC, Universidad de Valladolid, Spain (http://www.gsic.uva.es)

Abstract:
From the conceptualization to the evaluation of Computer-Supported Collaborative Learning (CSCL) scenarios, teachers address multiple tasks, sometimes being overwhelmed on account of the required time and associated burden. To support teachers in this endeavour, we propose to connect the pedagogical decisions made at design time with the analysis of the participants' interactions. Thus, teachers would be provided with relevant and coarse-grained information that could help them manage their CSCL scenarios. This paper synthesizes the main contributions obtained from a 3-year Design-Based Research process, and presents the findings obtained from the evaluation of the current proposal in 2 authentic CSCL scenarios. The participant teachers valued the proposal positively and stated that it was helpful for their orchestration of CSCL scenarios.

1. Introduction

Among the multiple concerns and tasks involved in the orchestration of Computer-Supported Collaborative Learning (CSCL) scenarios (Dillenbourg, 2013), many are oriented to foster effective collaboration. Several strategies may be adopted to support collaboration, assuming either a Learning Design (LD) or a Learning Analytics (LA) perspective (Jermann, Soller, & Lesgold, 2004). In LD approaches, scripting defines, before the interaction begins, the sequence of learning tasks, resources, and scaffolds that the students will need throughout the learning situation. From a LA perspective, monitoring analyses students' interactions during the enactment of the learning scenario, and facilitates the intervention on the situation towards a more productive direction.

Although these strategies help teachers in the orchestration of CSCL scenarios, there are still outstanding problems. Despite scripting the learning scenario beforehand, eventualities may emerge during the enactment and jeopardize the initial plan. 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 (Dyckhoff, Lukarov, Muslim, Chatti, & Schroeder, 2013). Thus, teachers often lack relevant information to eventually intervene and adapt their plans as the learning scenario evolves.

Several researchers point out the potential synergies that may be derived from aligning both strategies in CSCL, eg., improving the monitorable evidence from the learning scenario (Martínez-Monés, Harrer, & Dimitriadis, 2011), and providing teachers with data analyses connected to the pedagogical decisions described at design-time (Lockyer, Heathcote, & Dawson, 2013). In addition to these conceptual works, there are few technological solutions that support the ad-hoc alignment in scripted forums (Magnisalis, Demetriadis, & Pomportsis, 2010) and collaborative canvas (Gijlers, Weinberger, Dijk, Bollen, & Joolingen, 2013). 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 work dealing with the generic needs of blended CSCL scenarios.

In response to these needs, our main research objective is to help teachers monitor whether their design decisions are being accomplished or not in blended CSCL scenarios. Based on the aforementioned approach of alignment between scripting and monitoring, we propose to provide teachers with design and management support capable of linking their pedagogical intentions and awareness needs.

Towards this main objective, we have followed a Design-Based Research (DBR) approach involving 3 iterations, encompassing 7 studies in authentic CSCL scenarios with 5 different teachers. While the first and second iterations were mainly exploratory, the third one focused on the evaluation of the main contributions that emerged during the previous iterations: a monitoring-aware design process and model, and a script-aware monitoring process. The results of the first two iterations have been reported elsewhere (Rodríguez-Triana, Martínez-Monés, Asensio-Pérez, & Dimitriadis, 2013a) (Rodríguez-Triana, Martínez-Monés, Asensio-Pérez, & Dimitriadis, 2013b). In this paper, we focus on the third iteration, presenting the proposals in their final state, and their global evaluation in terms of the benefits for the orchestration of blended CSCL scenarios.

2. Related work

Orchestration is defined by some authors 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 (Prieto, Holenko Dlab, Gutiérrez, Abdulwahed, & Balid, 2011). In order to support teachers in this endeavour, different strategies have emerged in the area of CSCL to support them in certain aspects of the orchestration process.

In CSCL contexts, collaborative activities with different levels of structuring are often used to foster discussion and interaction among students. In this field the debate around whether and to what extent it is useful to structure the activities proposed to students, has been in the limelight during the last years (Pozzi & Persico, 2011). CSCL scripts are scaffolds that structure and constrain the way students are expected to interact when learning collaboratively using (although not necessarily) technology. More concretely, CSCL micro-scripts are a compendium of very specific instructions given to students. On the contrary, macro-scripts describe coarse-grained guidelines to enhance collaboration, based on learning pedagogical methods, that typically include a sequence of activities in which a set of groups, roles and resources are involved (Kollar, Fischer, & Hesse, 2006) (Dillenbourg & Tchounikine, 2007) (Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl, & Fischer, 2009). Designing CSCL macro-scripts (‘scripts’ hereinafter) has been recognized as a key aspect for the orchestration of CSCL scenarios: CSCL practitioners can anticipate during the design process of their scripts contextual issues of their classroom (technological, social, timing,… and also awareness needs) that may require subsequent orchestration interventions (Dillenbourg, 2013).

Orchestration interventions in response to unexpected events heavily depend on the awareness of what is happening. Learning Analytics can thus be considered as an important orchestration aid, especially when using non-trivial technological settings. In the particular case of CSCL, monitoring students' interactions (mediated or not by technology) plays a crucial role, since such interactions are the main drivers of the collaborative learning process. Monitoring entails a systematic collection of data related to specified indicators, that are provided to the teacher (or the main stakeholders) to inform them about the progress of the learning process (Persico, Pozzi, & Sarti, 2009). Existing models of technology-mediated interactions typically include: participating peers, groups, roles, resources and actions (Miao, Hoeksema, Hoppe, & Harrer, 2005) (Harrer, Martínez-Monés, & Dimitracopoulou, 2009). Current data gathering and analysis proposals can be classified in two main coarse-grained sets. Data-driven approaches (Mitra, Pal, & Mitra, 2002) (Dron & Anderson, 2009) (Chatti, Dyckhoff, Schroeder, & Thüs, 2012) generate indicators describing the collaboration process in a bottom-up fashion, based on available data. Conversely, model-driven approaches (Soller, Martínez-Monés, Jermann, & Muehlenbrock, 2005) need pre-specified models of expected collaborative interactions that guide the monitoring data gathering and analysis in a top-down process. Such pre-specified models should be closely linked with the pedagogical intentions of the designed CSCL scenario.

All in all, current work on CSCL orchestration recognizes the need for aligning scripting and monitoring (Lockyer et al., 2013; Martínez-Monés et al., 2011) . However, few proposals make this alignment explicit throughout lifecycle of design, technological deployment, enactment/management, and evaluation/ assessment of CSCL scenarios (Gijlers et al., 2013; Magnisalis et al., 2010). 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". The final goal is providing those educators with valuable awareness information that they can use, for orchestration purposes or reflection material about the effectiveness of the enacted script.

3. Overall context and methodology

The complex, evolving nature of our research goal (aligning scripting and monitoring to support teachers in designing and managing CSCL scenarios) led us to employ a Design-Based Research approach. According to the DBR criteria, our research process comprised several iterations (see Figure 1) 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 (encompassing from *Study1* to *Study5*) was to explore the dependences between scripting and monitoring and collect the requirements for the alignment of these two strategies. The results of the exploratory work led to the definition and refinement of the proposals (presented in their current status in Section 4): a monitoring-aware design process, an accompanying model of CSCL scripts, and a script-aware monitoring process. Then, these proposals were applied in the third iteration (*Study6* and *Study7*) for their evaluation according to three main questions: 1) Does the monitoring-aware design process of CSCL scripts help teacher to align pedagogical and monitoring issues; 2) Does the monitoring-aware model of CSCL scripts allow expressing the scripting and monitoring aspects required to guide the monitoring process?; and 3) Does the script-aware monitoring process provide teachers with relevant information for the management of the CSCL scenario?. The results of this evaluation are described in Section 5.

The focus of CSCL research in the social context, as well as the importance of contextual factors in orchestration, led us to base our work in authentic educational settings. The learning scenarios were chosen by theoretical sampling. For the first two studies, 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. Her dual expertise using scripting and monitoring (separately) was very helpful to identify the connections between these two strategies. Besides, attending to methodological reasons this teacher was also an appropriate candidate, since she 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 short experience in CSCL, one in the second exploratory iteration and another in the evaluation. With the two last mentioned teachers, we could verify whether non-expert teachers found additional difficulties and whether our proposal was suitable for them.

The 7 studies that make up our 3-iteration DBR were connected to 7 courses carried out at the University of Valladolid (Spain) between October 2010 and May 2013, involving 5 subjects, 5 teachers and a total of 365 students from 3 different degrees ("Telecommunication Engineering", "Master's Degree for Pre-service Secondary Education Teachers" and "Degree in –early- Childhood Education"). These scenarios present a common profile: blended CSCL scenarios interleaving face-to-face and computer-supported activities, mixture of individual and collaborative learning activities, developed both inside and outside the classroom, within a time frame between 2 and 4 weeks per scenario, and technologically supported by Distributed Learning Environments (DLEs). DLEs integrate existing learning platforms (eg., 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 environments are becoming increasingly popular in current pedagogical practice, even if they make designing and managing the learning process even more challenging. Further information about the studies from the explorative iterations are available in (Rodríguez-Triana et al., 2011b) (Rodríguez-Triana et al., 2013a), and (Rodríguez-Triana et al., 2013b).

Finally, this research employs mixed methods, as they are adequate for exploring the different perspectives and multiple factors that affect learning situations, and it is typically used in DBR and CSCL. In this research, qualitative and quantitative data was gathered from different sources -teachers, students, computational support and researchers-. We used qualitative sources such as open questionnaires, observations, semi-structured interviews and focus groups, and quantitative sources such as closed questionnaires and scrutinies of user's interactions.

[Figure 1: Overview of the iterations and studies that constitute the DBR process]

4. Proposals

The first two iterations of our DBR process explored how to support teachers in aligning their pedagogical intentions (at design-time) and awareness needs (during the enactment). During that exploratory phase we iteratively proposed two interdependent processes, named “monitoring-aware design process” and “script-aware monitoring process”, as well as a model for enhancing CSCL scripts with design-time decisions on monitoring issues, thus establishing the connections between the two processes. This section presents the final version of these three contributions.

1. Monitoring-aware design process

The monitoring-aware design process (Rodríguez-Triana et al., 2013a) describes the steps that teachers should follow during the design of CSCL scenarios, in order to reflect on their monitoring needs and express their expectations about students’ interactions (see Figure 2). Our proposal builds on the pattern-based design process defined by Villasclaras-Fernández, Hernández-Leo, Asensio-Pérez, & Dimitriadis (2009), who identify four steps that should be addressed in the design of CSCL scripts: the determination of learning objectives and prerequisites, the selection of the pedagogical patterns -if any- that will inform the following steps of the process; the definition of the activity flow; the configuration of each activity and group; and finally, the selection of resources and tools to be used in the scenario.

Our proposal comprises two cycles of the aforementioned pattern-based design process, including some specific tasks devoted to reflect on the monitoring needs and take into account the teacher’s monitoring concerns. In the first one, the monitoring-aware design cycle, practitioners provide details regarding the flow (eg., sequence dependences), activities (eg., timeframe, social level, learning mode, or students’ interaction), groups (eg., size), and resources (eg., expected use) in order to explicitly state the script constraints. For instance, teachers specify when students have to accomplish the activities, whether they have to work face-to-face or at distance, with whom (individually or according to certain group formation policies), which resources support the activity and whether they are mandatory or not. These constraints represent the practitioners’ expectations about the learning process. Besides, it is also relevant to detect the dependences between activities, in order to know how one activity affects another. For example, two activities are interrelated if the outcome of the first one is the input of the second. Apart from providing concrete details about these script elements, certain design decisions are informed by monitoring aspects. This is the case of the selection of the technological support: teachers should choose those tools that better satisfy both pedagogical and monitoring needs, eg., considering the monitoring information provided by each tool (such as user accesses, changes, uploads, etc.). Finally, since maybe not all the data available in the learning scenario are relevant for monitoring, this first cycle also entails that

practitioners specify the information they are interested in, such as which activities or resources should be monitored.

Once the first cycle is completed, it may happen that some monitoring needs cannot be covered by the data available. For example, in a face-to-face activity without computers, the technological support cannot provide information about the students' participation. The second cycle (monitoring enhancement cycle), faces this problem by extending the script with new activities and/or resources that provide additional monitorable data. For example, including new ways of collecting the required data, eg., observations during the face-to-face sessions, or questionnaires asking the students about their work.

[Figure 2: Monitoring-aware design process of CSCL scripts]

2. Monitoring-aware scripting model

This model describes the connections between scripting and monitoring (Rodríguez-Triana et al., 2013a) and supports the data flow between the design and the monitoring process presented in this document. 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, as we will see in the following subsection.

The proposal draws on scripting and interaction analysis models mentioned in Section 2, but also incorporates information about design-time decisions that could eventually affect monitoring, as elicited during the exploratory iterations of the DBR process. We have classified these design-time decisions into 3 dimensions (see Figure 3):

- Pedagogical Pattern and/or general script constraints: dependencies between activities (eg., sequencing or resources reuse), collaboration and group formation policies.
- Activity constraints: deadlines, resources and tools assigned to each activity, participants, groups, social level (individually or in groups), interactivity types (face-to-face, through computers or blended), learning mode (face-to-face, distance or blended) and participation (optional or mandatory).
- Teacher's monitoring decisions: monitoring periods, elements (activities, resources and actions) to be monitored, and expected use of resources (eg., optional or mandatory, individually or by groups).

[Figure 3: Monitoring-aware model of CSCL scripts]

3. Script-aware monitoring process

This so called script-aware monitoring process defines how the design-time pedagogical decisions captured in the script may guide data gathering and analysis to provide teachers with monitoring information connected to their concerns (Rodríguez-Triana et al., 2013b). Our proposal (see Figure 4) extends the collaboration analysis process of Soller et al. (2005), which encompasses four steps: data collection, definition of indicators, comparison between the desired and current state of the learning situation, and finally, based on the comparison results, provision of advice or guidance.

The script-aware monitoring process inherits the four steps defined by Soller et al., focusing the data collection on the elements described in the "monitoring-aware scripting model", and adopting the script as the desired state of the learning situation. Step 1 uses the description of the learning activities of the CSCL script for collecting interaction data: for each activity, the involved participants' interactions are gathered, taking into account the teachers monitoring preferences (resources and types of interaction to

be monitored) and the activity deadlines. In Step 2, the desired model of interaction is built upon certain parameters of the script, as defined in the “monitoring-aware scripting model”: participation (involvement of an individual or group in the activity); collaboration (interactions among groups and/or group members); use of resources (interactions between participants and resources); group formation policies (requirements that groups should meet in terms of criteria such as size or type of participants); and activity flow dependencies (activity parameters that affect other activities, eg., reused resources, groups, or deadlines). In Step 3, actual (Step 1) versus ideal (Step 2) models of interaction are compared. In Step 4 teachers are informed about the alignment (or lack thereof) of the actual/ideal models of interaction. Finally, teachers interpret this output and intervene in the learning situation if needed.

[Figure 4: Script-aware monitoring process]

5. Evaluation

The main contributions presented in Section 4 were evaluated in the third iteration of the DBR process. This section introduces the two studies carried out in this iteration (Study6 and Study7 in Figure 1) and presents the evaluation results.

1. Context and methodology

The evaluative studies involved two teachers and two scenarios with different sets of challenges that made them good candidates for the evaluation of the proposal: *Study6* involved a high number of students and resources; and *Study7* presented a complex design, with many interrelated activities occurring in a short period of time. Figure 1 describes the scenarios in terms of number of students, activities and resources, as well as the tools that made up the DLE.

Study6 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 and 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.

Study7 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, who had participated in the definition of the proposals, 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.

Figure 5 illustrates the workflow followed in both studies. First, we provided teachers with worksheets to scaffold the “monitoring-aware design process” and forms to collect teacher’s decisions. Then, the first author manually transformed the forms filled in by the teacher into an XML representation compliant with the “monitoring-aware model” of CSCL scripts. Second, the teacher used WebCollage, an authoring tool compliant with the “pattern-based design process”, to create a computational representation of the CSCL script. Then, the teacher, by means of GLUE!-PS (Group Learning Unified Environment - Pedagogical Scripting), deployed automatically the design into the DLE. The “script-aware monitoring process” was enforced by the GLIMPSE prototype (Group Learning Interaction Monitor for Pedagogical Scripting Environments). GLIMPSE took the script instantiation file generated by GLUE!-PS and the XML version of the forms to guide the data gathering and analysis. Based on the script description, GLIMPSE obtained the evidence from the DLE via the GLUE!-CAS prototype (Collaboration Analysis Support for GLUE!)

(Rodríguez-Triana, Martínez-Monés, & Asensio-Pérez, 2011a). Finally, GLIMPSE compared the desired and current states of the learning situation and generated the monitoring reports provided to the teacher.

[Figure 5: Overview of the workflow followed in the evaluative studies]

Figure 6 shows the data sources collected in both studies and the relation between these sources and the evaluative questions. The researcher interviewed the teachers at the beginning of the studies to collect the teachers' common CSCL design and management strategies. Then the researcher observed how the teachers carried out the design process and gathered teachers' impressions regarding the monitoring-aware design process and model through interviews. During the enactment, the teachers were asked to daily annotate all the eventualities that emerged during the learning scenarios, expressing their expectations about the monitoring reports before checking them, and notifying any errors detected. At the same time, the researcher observed the DLE to verify that the data gathered from the technological infrastructure were coherent. Once the learning activity finished, the researcher interviewed teachers again, to collect their opinions on the script-aware monitoring process, and to evaluate the proposals as a whole.

[Figure 6: Connections between evaluative studies, evaluative questions and data sources]

2. Results

Below we discuss the evidence gathered from the studies, following the evaluative questions presented in Figure 5.

a. EQ1: Does the monitoring-aware design process of CSCL scripts help teachers to align pedagogical and monitoring issues?

To answer this question, we needed to assess whether the proposed process was understandable and affordable for the teachers (in terms of the effort). We also needed to know whether the process allowed teachers to express their pedagogical intentions, and whether they perceived that the resulting design was enriched by the process.

Both teachers agreed that the process was coherent and easily understandable, and they perceived the monitoring aspects as an integral part of the design process. Additionally, some suggestions emerged during the interviews to improve the flexibility of the process.

Regarding the costs and benefits of the design process, Study6 required a total of 94 minutes and Study7 108 minutes. Despite the time involved, the teachers did not identify a significant increment in the required effort, since they usually devote a comparable amount of time to design their scenarios.

The teachers confirmed that they could describe the scenarios as they had initially envisioned using the provided forms and tools. Nevertheless, the "monitoring-aware design process" encouraged them to modify the scripts to better satisfy both pedagogical and monitoring needs. According to the teachers' comments, the monitoring-aware design process helped them not only to improve the learning designs, but also to be aware of potential eventualities and how the emergence of problems could affect the different activities ("it helps you start thinking about what consequences such event may have") and contributed to think *a priori* about possible solutions. This knowledge guided them to configure the monitoring process according to their needs, 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"). .

b. EQ2: Does the monitoring-aware model of CSCL scripts allow expressing the scripting and monitoring aspects required to guide the monitoring process?

To address this question, it was necessary to evaluate the model in two directions: first, validating whether the model was understandable for teachers and satisfied teachers' needs to express the design decisions; and second, verifying whether the model provided the details required by the monitoring process to guide the analysis in terms of the scripts.

On the one hand, the teachers confirmed that the model was expressive enough to represent the teachers' pedagogical issues. However, the teachers pointed out that some terms were difficult to interpret or were ambiguous and required clarification (eg., monitoring dates, participation, or social level). 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.

c. EQ3: Does the script-aware monitoring process provide teachers with relevant information for the management of the CSCL scenario?

To answer these questions, we firstly verified whether the information provided by the monitoring process was unknown, comprehensive and relevant for the teacher. Then, we evaluated whether the information reduced the effort invested in the management of the CSCL scenario.

Teachers were sometimes already aware of a part of the monitoring reports' information (eg., when the activities happened in the classroom or the students had contacted them to notify any problem). However, both agreed that including this information in the reports was crucial to keep the scenario in their minds ("with so many students I could not have remembered who had attended to the face-to-face sessions").

According to the teachers, the information presented in the reports was useful to identify unexpected events, follow the learning activities, and better understand the student progress. The teachers agreed that the monitoring reports reduced the time and effort devoted to managing the CSCL scenario, and emphasized three main reasons: (1) gathering and integrating the data from the different sources eliminated the need of going through all the documents involved in the scenarios; (2) using the script constraints to guide and present the data analysis facilitated the interpretation of the monitoring reports; (3) the potential problems detected helped the teachers to use more efficiently the time available for managing the learning scenario.

Despite the aforementioned benefits, there were some drawbacks such as unexpected events that went unnoticed (two cases in Study6) and false positives (one case in Study7). Although the false positives did not represent a problem for the teacher, the eventualities that were not detected could have jeopardized the learning situation. One potential solution is to triangulate the information retrieved from the technology with the students' and teachers' feedback; another is to include new indicators that filter or measure the quality of the students' interactions.

In addition, from the technological point of view, the script-aware monitoring process was implemented automatically by GLIMPSE. This fact shows that it is feasible to guide computationally the monitoring process by means of the parameters collected from the script.

d. Overall remarks

Looking at the proposal as a whole, the teachers highlighted that the alignment of pedagogical and monitoring issues had improved both the design and the management of the learning scenario. They emphasized that the aforementioned proposals could contribute to facilitate the adoption of CSCL in authentic practice, especially if the scenario presents a moderate degree of complexity.

6. Conclusions

Teachers orchestrating CSCL situations can benefit from the alignment between scripting and monitoring, two well-known approaches to LD and LA, respectively. This paper has introduced our proposal of two

interdependent processes -the “monitoring-aware design process” and the “script-aware monitoring process”- connected by means of model of CSCL scripts (the “monitoring-aware scripting model”), which exploits the synergies between LD and LA in CSCL settings. This paper also presents the evaluation of these contributions in two studies, which constitute the last cycle of a DBR process. The studies were carried out in learning scenarios with either a large number of students, or a complex collaborative activity flow.

The results obtained from our evaluations show that the monitoring-aware design process and its underlying monitoring-aware scripting model were capable of supporting teachers in defining scripts enriched with monitoring information, which could be used by the script-aware monitoring process to provide feedback to the teachers. This feedback was meaningful and useful for the teachers to manage the learning activities while they were taking place. Teachers also used this feedback to reflect post-hoc about the development of the courses, using this information to refine their future learning designs. In conclusion, both the monitoring-aware design process and the design-aware monitoring process successfully used monitoring information to support teachers in the design of CSCL situations.

The evaluation processes also helped identify minor issues which have been incorporated in the proposals, or that must be taken into account for future work. One major research line enabled by this work is the inclusion of new forms of feedback, based on higher-level learning analytics, enabling teachers to reflect on the learning outcomes of the students. This line of work will also be promoted by the automation of the design process in an existing authoring tool, which may enable teachers to perform the whole cycle without any aid from researchers.

Summing up, the alignment between scripting and monitoring throughout these studies contributed to support the teachers in several orchestration aspects of CSCL scenarios. Without a notable additional effort in the design process, teachers enriched the scripts to better satisfy both their pedagogical and monitoring needs. Besides, reflecting on monitoring at design-time helped teachers foresee potential problems and anticipate possible solutions. Being aware of the deviations between the script and the evidence gathered, allowed the identification of emerging problems on-time that otherwise could have gone unnoticed. Thus, this information helped teachers in the regulation of the learning scenario and increased the teacher awareness about the learning process. In addition, teachers emphasized that, thanks to the prior thinking about the monitoring, they obtained more evidence about the students' work, than they would have had otherwise.

7. Acknowledgments

This research has been partially funded by the European Union (projects 526965-LLP-2012-1-GR-COMENIUS-CMP and 531262-LLP-1-2012-1-ES-KA3-KA3MP), the Spanish Ministry of Economy and Competitivity (project TIN2011-28308-C03-02) and the Autonomous Government of Castilla y León (projects VA293A11-2 and VA301B11-2). The authors would also like to thank the teachers involved in the scenarios for their support and ideas.

8. References

Chatti, M. A., Dyckhoff, A. L., Schroeder, U., & Thüs, H. (2012). A reference model for Learning Analytics. *International Journal of Technology Enhanced Learning*, *4*(5/6), 318–331.

Dillenbourg, P. (2013), “Design for classroom orchestration”, Computers & Education, Elsevier Ltd, Vol. 69, pp. 485–492.

Dillenbourg, P., & Tchounikine, P. (2007). Flexibility in macro-scripts for CSCL. *Journal of Computer Assisted Learning*, *23*(1), 1–13.

Dron, J., & Anderson, T. (2009). On the design of collective applications. *International Conference of Computational Science and Engineering* (pp. 368 – 374).

Dyckhoff, A. L., Lukarov, V., Muslim, A., Chatti, M. A., & Schroeder, U. (2013). Supporting action research with learning analytics. *International Conference on Learning Analytics and Knowledge* (pp. 220–228). Leuven, Belgium: ACM Press.

Gijlers, H., Weinberger, A., Dijk, A.M. van, Bollen, L. and Joolingen, W. van. (2013), "Collaborative drawing on a shared digital canvas in elementary science education: The effects of script and task awareness support", *International Journal of Computer-Supported Collaborative Learning*, Vol. 8 No. 3, pp. 427–453.

Harrer, A., Martínez-Monés, A., & Dimitracopoulou, A. (2009). Users' data: collaborative and social analysis. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, S. Barnes, & L. Montandon (Eds.), *Technology-Enhanced Learning. Principles and Products* (pp. 175–193). Springer Netherlands.

Jermann, P., Soller, A., & Lesgold, A. (2004). Computer software support for collaborative learning. In J.-W. Strijbos, P. A. Kirschner, & R. L. Martens (Eds.), *What We Know About CSCL in Higher Education* (Vol. 3, pp. 141–166). Amsterdam: Kluwer Academic Publishers.

Kollar, I., Fischer, F., & Hesse, F. W. (2006). Collaboration scripts – A conceptual analysis. *Educational Psychology Review*, *18*(2), 159–185.

Lockyer, L., Heathcote, E., & Dawson, S. (2013). Informing pedagogical action: Aligning Learning Analytics with Learning Design. *American Behavioral Scientist*, *57*(10), 1439–1459.

Magnisalis, I.D., Demetriadis, S.N. and Pomportsis, A.S. (2010), "Implementing adaptive techniques in systems for collaborative learning by extending IMS-LD capabilities", *International Conference on Intelligent Networking and Collaborative Systems*, IEEE, Thessaloniki, Greece, pp. 70–77.

Martínez-Monés, A., Harrer, A. and Dimitriadis, Y. (2011), "An interaction-aware design process for the integration of interaction analysis into mainstream CSCL practices", in Puntambekar, S., Erkens, G. and Hmelo-Silver, C.E. (Eds.), *Analyzing Interactions in CSCL*, Springer US, pp. 269–291.

Miao, Y., Hoeksema, K., Hoppe, H. U., & Harrer, A. (2005). CSCL scripts : Modelling features and potential use. *Computer Supported Collaborative Learning Conference: the next 10 years!* (pp. 423–432). Taipei, Taiwan: International Society of the Learning Sciences.

Mitra, S., Pal, S. K., & Mitra, P. (2002). Data mining in soft computing framework: a survey. *IEEE transactions on neural networks*, *13*(1), 3–14.

Persico, D., Pozzi, F. and Sarti, L. (2009), "Design patterns for monitoring and evaluating CSCL processes", *Computers in Human Behavior*, Vol. 25 No. 5, pp. 1020–1027.

Pozzi, F. & Persico, D. (2011), *Techniques for fostering collaboration in online learning communities: Theoretical and practical perspectives*, IGI Global, Hershey, PA, pp. xvii–xxiv.

Prieto, L.P., Holenko Dlab, M., Gutiérrez, I., Abdulwahed, M. and Balid, W. (2011). Orchestrating technology enhanced learning: a literature review and a conceptual framework. *International Journal of Technology Enhanced Learning*, Vol. 3 No. 6, pp. 583–598.

Rodríguez-Triana, M. J., Martínez-Monés, A., & Asensio-Pérez, J. I. (2011a). Monitoring collaboration in flexible and personal learning environments. *Interaction, Design and Architecture(s) Journal, special issue on: Evaluating Educative Experiences of Flexible and Personal Learning Environments*, 11(12), 51–63.

Rodríguez-Triana, M.J., Martínez-Monés, A., Asensio-Pérez, J.I., Jorrín-Abellán, I.M. and Dimitriadis, Y. (2011b), Monitoring pattern-based CSCL scripts: a case study. European Conference on Technology Enhanced Learning: Towards Ubiquitous Learning, Springer Berlin, Heidelberg, Vol. 6964, pp. 313–326.

Rodríguez-Triana, M. J., Martínez-Monés, A., Asensio-Pérez, J. I., & Dimitriadis, Y. (2013a). A monitoring-aware learning design process : Pilot studies in authentic CSCL scenarios. *Computing & Informatics*, 1–62.(Accepted)

Rodríguez-Triana, M. J., Martínez-Monés, A., Asensio-Pérez, J. I., & Dimitriadis, Y. (2013b). Towards a script-aware monitoring process of computer-supported collaborative learning Scenarios. *International Journal of Technology Enhanced Learning*. Vol. 5 No. 2, pp. 151–167.

Soller, A., Martínez-Monés, A., Jermann, P., & Muehlenbrock, M. (2005). From mirroring to guiding: a review of the state of the art in interaction analysis. *International Journal on Artificial Intelligence in Education*, *15*, 261–290.

Villasclaras-Fernández, E. D., Hernández-Leo, D., Asensio-Pérez, J. I., & Dimitriadis, Y. (2009). Incorporating assessment in a pattern-based design process for CSCL scripts. *Computers in Human Behavior*, *25*(5), 1028–1039.

Weinberger, A., Kollar, I., Dimitriadis, Y., Mäkitalo-Siegl, K., & Fischer, F. (2009). Computer-supported collaboration scripts: Theory and practice of scripting CSCL. Perspectives of educational psychology and computer science. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, S. Barnes, & L. Montandon (Eds.), *Technology-Enhanced Learning. Principles and Products*. Springer Verlag.

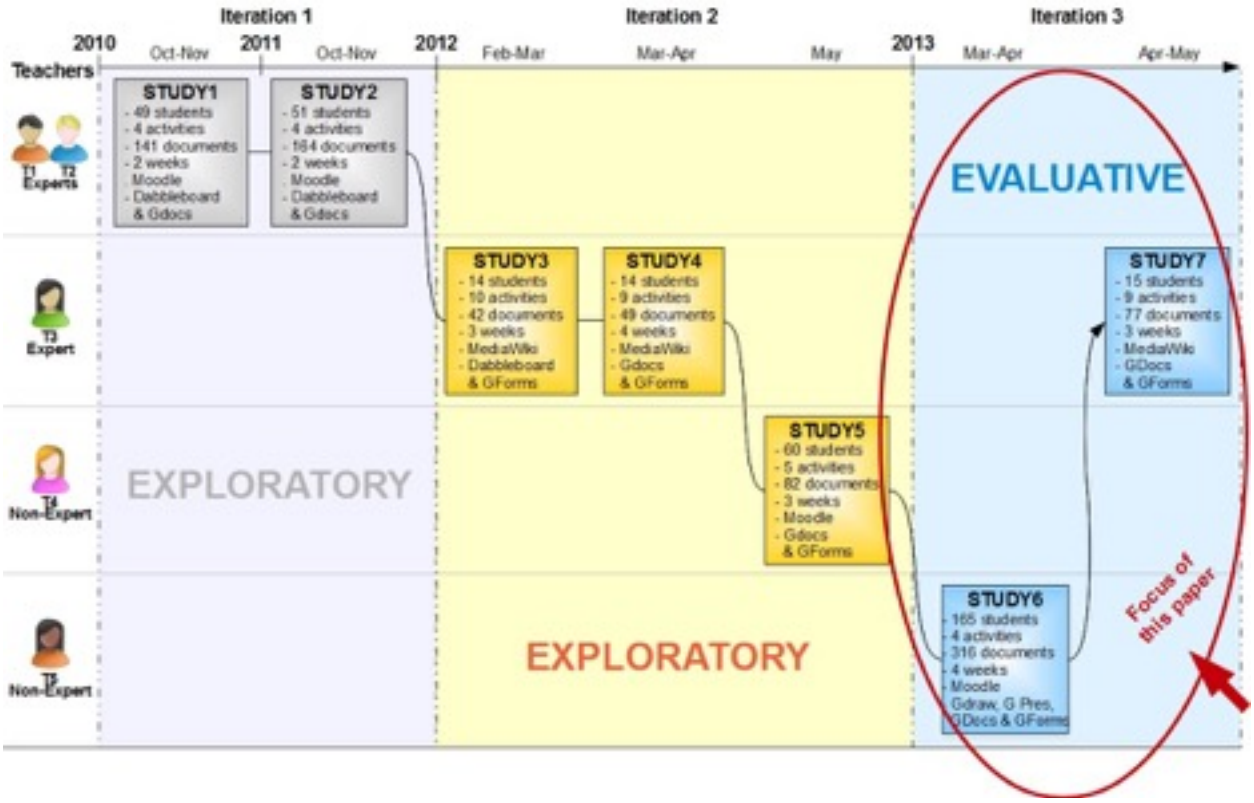

Figure 1: Overview of the iterations and studies that constitute the DBR process. The highlighted studies, pointed out with the red arrow, are the focus of this paper, as described in Section 5

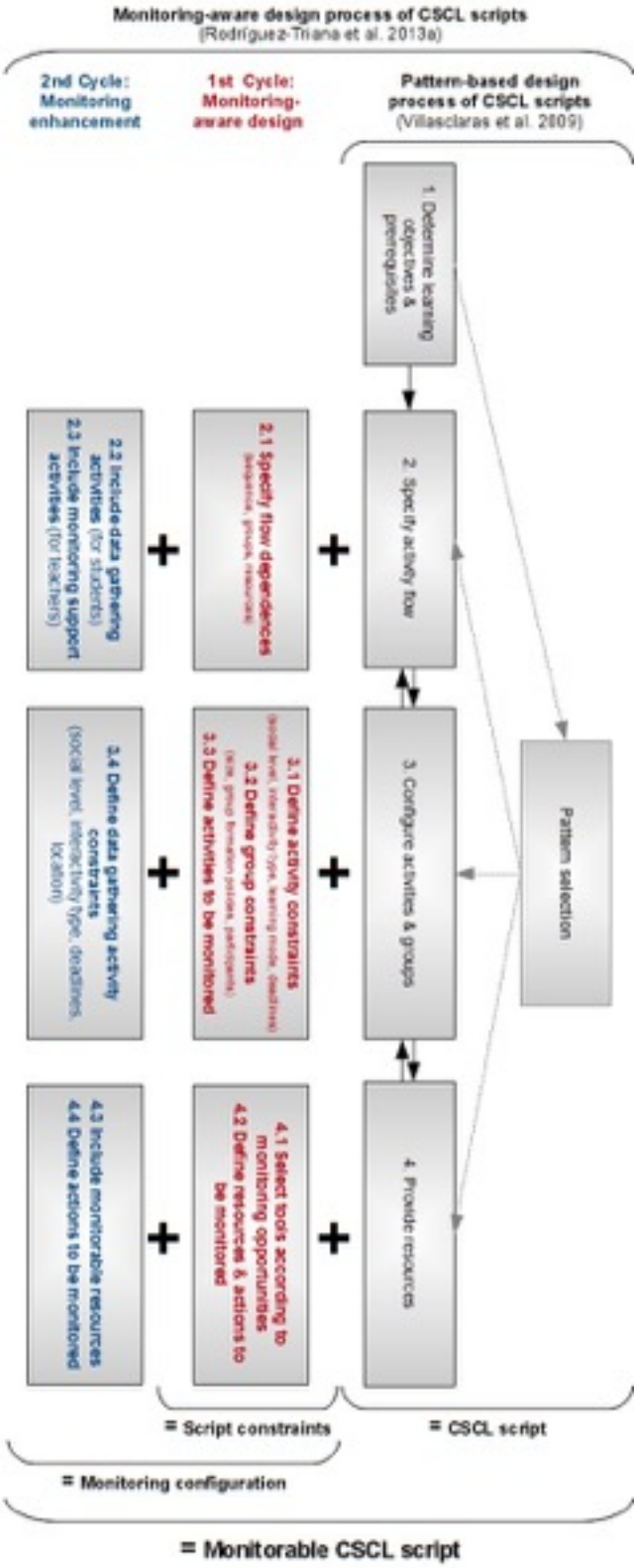

Figure 2: Monitoring-aware design process of CSCL scripts

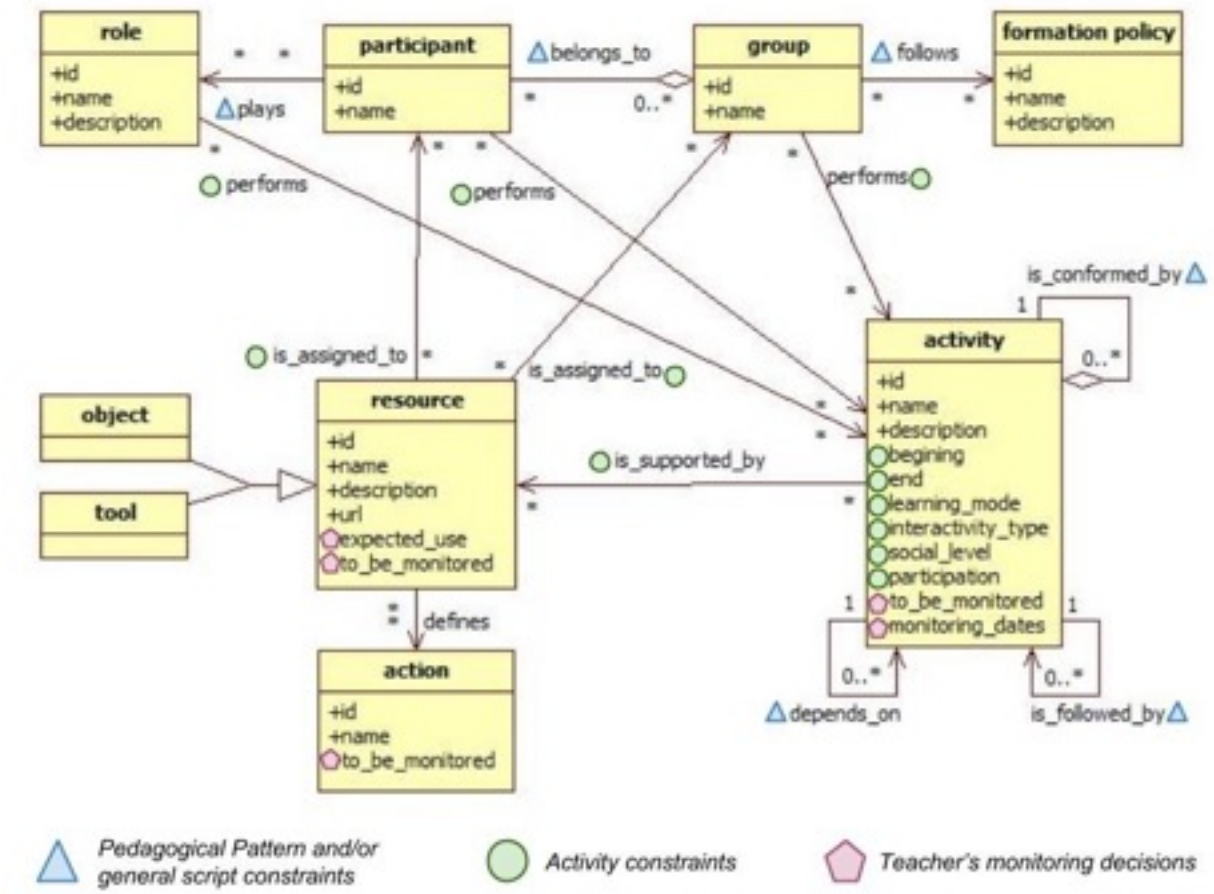

Figure 3: Monitoring-aware model of CSCL scripts

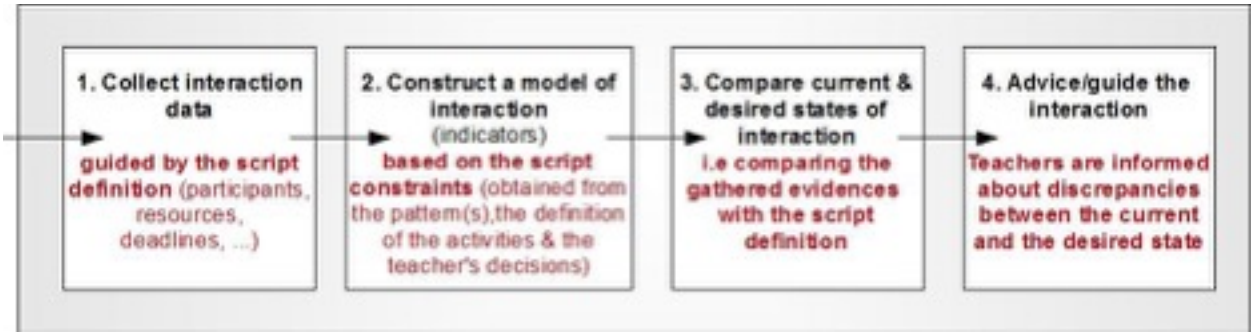

Figure 4: Script-aware monitoring process. The boxes represent the steps defined by Soller et al. (2005) and the descriptions in red explain how design-time script elements affect each step

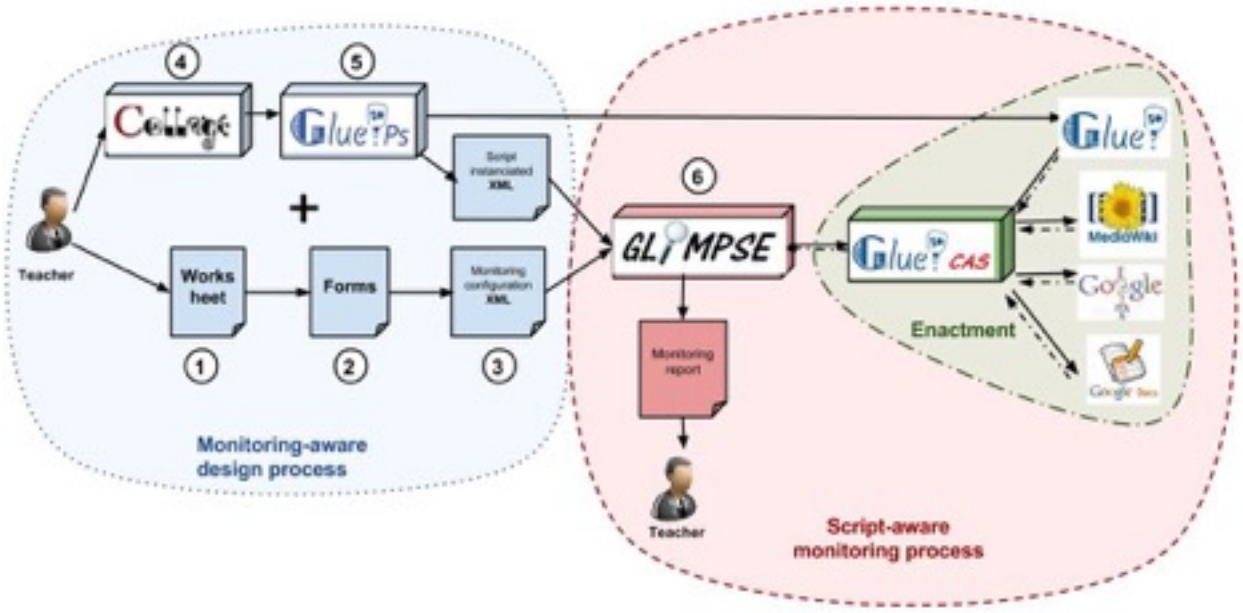

Figure 5: Overview of the workflow followed in the evaluative studies. The technological environment corresponds to Study7

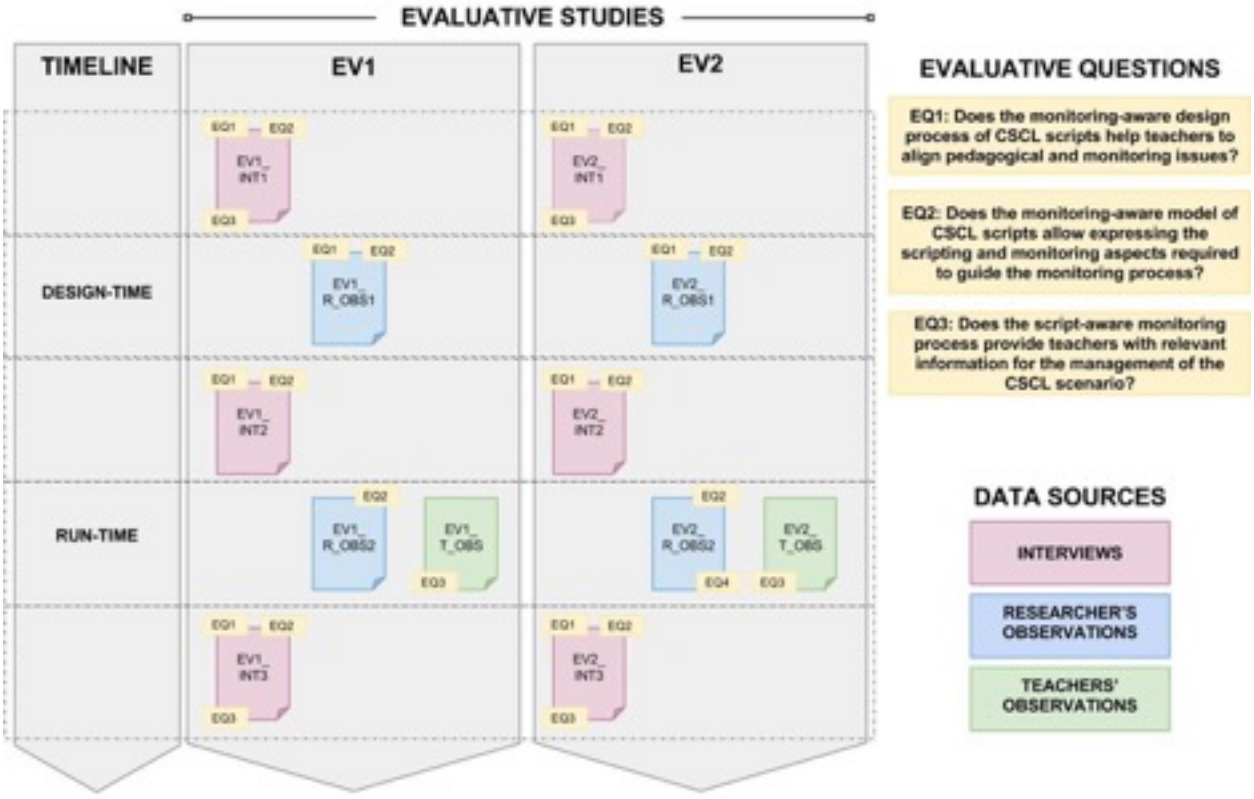

Figure 6: Connections between evaluative studies, evaluative questions and data sources. Illustrative evidence is provided for each data source