GLUE! - GLUE!-PS: An approach to deploy non-trivial collaborative learning situations that require the integration of external tools in VLEs

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Abstract

The deployment of non-trivial collaborative learning situations in VLEs is a burdensome and error-prone process for teachers, especially as the number of participants, groups, tools and activities grows. Besides, this deployment frequently suffers from the limited set of VLE built-in tools teachers can select to support learning activities. GLUE! and GLUE!-PS are two alternative routes for the deployment of collaborative learning situations that respectively tackle the integration of multiple external tools in multiple VLEs, and the deployment of abstract learning designs generated within multiple authoring tools in multiple VLEs. This paper discusses how the GLUE! - GLUE!-PS partnership represents a deployment route that overcomes both the two aforementioned limitations, when deploying in VLEs non-trivial collaborative learning situations that require the integration of external tools. An authentic, though somewhat complex collaborative situation deployed in Moodle illustrates the benefits of the GLUE! - GLUE!-PS approach. Higher education teachers that deployed this situation in Moodle as part of a professional development workshop highlighted that this approach allows an efficient deployment, and emphasized the benefit of reusing learning designs in other courses and VLEs.

Keywords

Deployment, collaboration, integration, learning design, GLUE!, GLUE!-PS, Moodle, VLEs.

Introduction

Virtual Learning Environments (VLEs), also referred to as Learning Management Systems (LMSs), have been mainstream for a while now, especially for distance and blended learning, both in academia and industry (Dillenbourg et al., 2002). Moodle is currently the most popular VLE with more than 65,000 registered sites worldwide as of this writing[1]; other widely adopted VLEs are Sakai or Blackboard.

Teachers play a central role in VLEs, providing learners with adequate resources aimed at meeting the learning objectives and developing intended knowledge and skills (Matsubara et al., 1997). To do so, teachers typically define a structure of activities supported by certain resources (e.g. a website, a static PDF file) and VLE built-in tools (e.g. a quiz about the content of the PDF file). Some of these built-in tools particularly foster the communication and groupwork among learners (e.g. chats, forums). Besides, most VLEs also enable the definition of groups of learners to collaboratively accomplish the learning activities, thus making them suitable for the deployment and enactment of computer-supported collaborative learning (CSCL, see Stahl et al., 2006) situations.

Nevertheless, there are two limitations that significantly hinder the deployment of CSCL situations in VLEs. The first one is the **limited set of built-in tools** included in VLEs to support learning activities (Bower et al., 2011); as an example, Moodle 2.2 only includes 14 tools in its default distribution. Some research efforts are striving to increase the number of tools teachers can choose from by integrating third-party external tools in VLEs using different approaches (Wilson et al., 2008; De-la-Fuente-Valentín et al., 2011). For example, there exist *ad hoc* plugins integrating external tools in Moodle[2]. However, developing these plugins demands a significant effort that can barely be reused for other VLEs or tools. Another example is Apache Wookie (Wilson

1 http://moodle.org/stats. Last visited: May 2012.
2 http://moodle.org/plugins. Last visited: May 2012.

et al., 2008), which promotes the generic integration of W3C widgets (World Wide Web Consortium, 2011) in VLEs. Nevertheless, only those tools that meet the W3C widgets specification can be integrated through this approach, thus precluding many existing and popular tools from being integrated. IMS LTI (IMS GLC 2011) is a generic integration specification that has been adopted by several major VLEs like Moodle, although not many tool providers currently comply with it[3], mainly due to the high development effort required to make tools meet this specification. A subset of IMS LTI, called Basic LTI, which promotes the loosely-coupled integration of tools with a lower development effort, has gained a certain degree of adoption among VLE providers. However, Basic LTI only defines how external tools should be accessed by students using VLEs, but not how these tools should be managed by teachers in the deployment of collaborative activities. That management normally entails the creation and configuration of different external tool instances (e.g. one shared document) for each group of learners, which is a particularly cumbersome task when deploying activities that involve multiple groups.

The GLUE! (Group Learning Uniform Environment) architecture (Alario-Hoyos et al., submitted; Alario-Hoyos et al., 2010) enables the lightweight integration of external tools in VLEs, supporting both individual and collaborative activities. GLUE! imposes few and widespread restrictions on VLE and tool providers, and facilitates the management (and access) of external tools within the VLE interface. Besides, GLUE! is designed to be extended by third-party developers, who may integrate new tools and VLEs. The current implementation of GLUE! has already been used in authentic educational scenarios to integrate different external tools like Google Presentations or W3C widgets in VLEs and other platforms, such as Moodle or LAMS[4].

The second limitation is the **heavy burden that deploying non-trivial collaborative learning designs in VLEs implies for teachers**, especially those complex designs with a high number of groups, activities and tools. In CSCL, it is common to structure the activities intended for learners at multiple social levels with changing group sizes and composition. The discipline of Learning Design (LD, see Koper et al., 2005) has studied for years how to formalize the structuring of groups and activities in a reusable and pedagogically explicit way, producing authoring tools like CompendiumLD[5] or Collage (see Hernández-Leo et al., 2006) and specifications like IMS-LD (see IMS GLC, 2003) for describing learning designs. The compliance with authoring tools and specifications would allow teachers to express and share their learning designs, and to deploy them semi-automatically in VLEs. However, despite some efforts to make VLEs compliant with IMS-LD (Berggren et al., 2005), currently there is no easy way to deploy teachers' learning designs (collaborative or not) in major VLEs like Moodle, apart from manually creating and configuring all the groups, activities and tools involved, which is a time-consuming and error-prone process. LAMS is an exception to this, providing an integrated environment to design, deploy and enact CSCL situations (Dalziel, 2007), although these designs cannot generally be deployed in other VLEs.

GLUE!-PS (GLUE!-Pedagogical Scripting, see Prieto et al., 2011) is a service architecture that aims at bridging this deployment gap between LD authoring tools (and specifications) and VLEs. By using an underlying common data model with the most common LD and VLE concepts (Prieto et al., 2011), GLUE!-PS allows to translate, for instance, a complex collaborative learning design expressed in IMS-LD, to Moodle concepts like topics, activities, groups and groupings[6]. These translated designs can then be deployed automatically in the VLE, e.g. as part of a Moodle course. When used together with the aforementioned GLUE! architecture, these designs cannot only include built-in tools, but also external tools, all configured and ready to be enacted in the classroom. This automation of the deployment process from multiple authoring tools to multiple VLEs aims at facilitating the adoption of this approach, since it is not tied to particular tools, and may favour an efficient (and time-saving) deployment of non-trivial CSCL situations.

This paper shows how non-trivial CSCL situations that require the integration of external tools can leverage the advantages of the GLUE! - GLUE!-PS partnership. An authentic CSCL situation that is intended to be deployed in Moodle serves as an illustrative example. University-level teachers from multiple disciplines deployed this situation using GLUE! and GLUE!-PS in a professional development workshop, with encouraging results.

The next section discusses the deployment of CSCL situations, first using only GLUE!, then using GLUE!-PS alone, and finally using the GLUE! - GLUE!-PS partnership (the main novel contribution of this paper). Then, first evidences of the usefulness of this combined approach are presented, including the illustrative collaborative

3 http://imsglobal.org/cc/statuschart.cfm. Last visited: May 2012.
4 http://lamsinternational.com. Last visited: May 2012.
5 http://compendiumld.open.ac.uk. Last visited: May 2012.
6 http://docs.moodle.org/22/en/Groupings. Last visited: May 2012.

learning situation and evidences collected from teachers that actually deployed this situation. The paper concludes with remarks of the relevance of this approach and future research directions along this line of work.

Deployment of CSCL situations using GLUE! and GLUE!-PS

GLUE! and GLUE!-PS are two alternative routes that allow the deployment of CSCL situations in VLEs, with different design goals. While GLUE! aims at increasing the set of tools teachers may select when deploying these situations, GLUE!-PS aims at facilitating the management of structures of groups, activities, resources and tools to be deployed in VLE courses or lessons. Thus, GLUE! and GLUE!-PS can be combined to facilitate the deployment in VLEs of non-trivial CSCL situations that require the integration of external tools.

Deployment using GLUE!

Figure 1 (circle labeled ‘A’) shows the GLUE! architecture and the elements involved in the GLUE!-mediated deployment of CSCL situations that require the integration of external tools in VLEs. GLUE! is a three-tier, loosely-coupled architecture composed by an intermediate layer (*GLUElet Manager*), and two sets of adapters (Gamma et al., 1995) for VLEs and tools (*GLUE! VLE adapters* and *tool adapters*). These adapters wrap existing VLEs and tools and make them interoperable with the integration contracts defined by the GLUElet Manager (Alario-Hoyos et al., submitted). These contracts aim at overcoming the limitations of previous tool integration approaches (Alario-Hoyos et al., 2010) by imposing few and widespread restrictions to VLEs and tools, and reducing the development effort, due to the definition of popular loosely-coupled technologies (e.g. these contract interfaces follow a RESTful approach, see Richardson, 2007). Besides, this architecture fosters the many-to-many integration of VLEs and tools, insofar as the development of a new VLE adapter automatically enables the integration of the available external tools in the corresponding VLE, and vice versa.

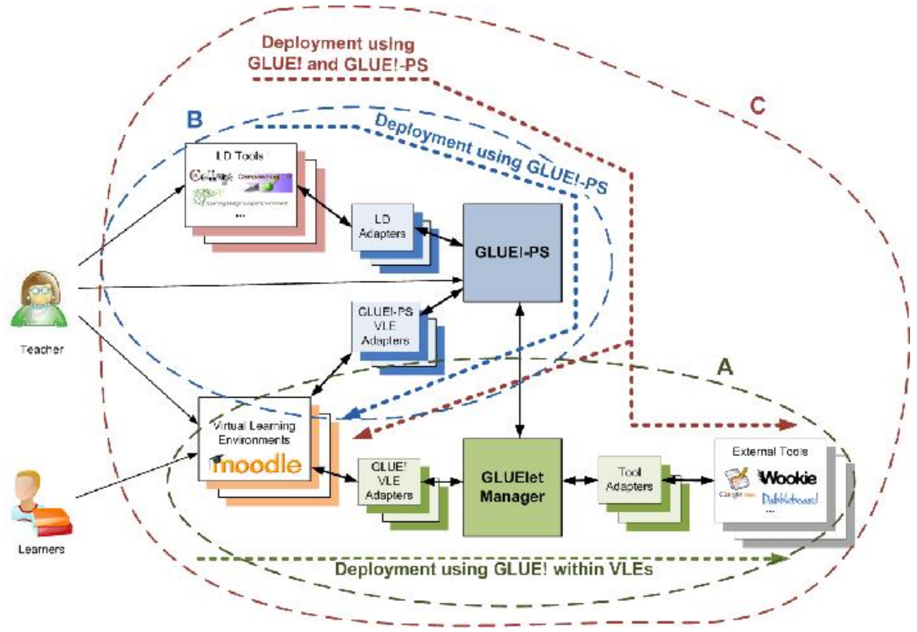

Figure 1: Deployment in VLEs using: A) GLUE!; B) GLUE!-PS; C) GLUE! and GLUE!-PS.

The elements of GLUE! are designed to provide the functionality to manage the life cycle of external tools (Gómez-Sánchez et al., 2009), which includes the *creation*, *configuration*, *retrieval*, *deletion* and *update* of external tool instances. This life cycle can be combined with the native features of VLEs, so that teachers can request the creation and management of instances in a way that every VLE group automatically receives its own shared instance in each activity. The support of these operations enables teachers to seamlessly design and deploy CSCL situations that require the integration of external tools within the VLE graphical interface.

The GLUElet Manager, three GLUE! VLE adapters and nine tool adapters have been already implemented as of this writing (see http://gsic.uva.es/glue for further details). Thus, in its current state, GLUE! enables the deployment of CSCL situations that require the integration of external tools such as Doodle, Google Spreadsheets or Kaltura in VLEs and learning platforms like Moodle, LAMS or MediaWiki.

Deployment using GLUE!-PS

Figure 1 (circle labeled 'B') depicts the GLUE!-PS-mediated route to deploy non-trivial CSCL situations in VLEs. GLUE!-PS (Prieto et al., 2011) is the main element of another three-tier service-oriented architecture that enables the automatic deployment of learning designs generated with multiple authoring tools and LD languages in multiple VLEs. This three-tier architecture is formed by *GLUE!-PS* as a central component, and two sets of adapters: *LD adapters* (which translate from authoring tools or LD languages to a common data model used as a sort of *lingua franca*) and *GLUE!-PS VLE adapters* (which deploy the translated learning designs into VLEs). Thus, the same learning design may be deployed, thanks to GLUE!-PS, in different courses and lessons in the same VLE, and even in different VLEs, what makes GLUE!-PS an advisable alternative for those teachers interested in sharing abstract learning designs, no matter the VLE they normally use.

Through the GLUE!-PS graphical interface, learning designs coming from authoring tools and LD languages may be particularized, modified or extended to include concrete information about groups, activities and resources. In this regard, GLUE!-PS can overcome some limitations of authoring tools and LD languages. For instance, the designs generated with authoring tools that do not consider the concept of groups (e.g. the Pedagogical Pattern Collector[7]) can be extended using GLUE!-PS in order to include a certain group structure. Before deploying a learning design in a particular VLE, GLUE!-PS can import (through the corresponding GLUE!-PS VLE adapter) the list of participants registered in a certain course or lesson, as well as the list of built-in tools provided by such VLE, allowing teachers to populate the groups and select the specific tools supporting each learning activity.

As of this writing, the GLUE!-PS prototype includes two LD adapters (one of them for the most widely used LD specification, IMS-LD) and two GLUE!-PS VLE adapters. This limited implementation already enables at least 4 different deployment routes, from WebCollage[8] (or other IMS-LD Level A compliant authoring tool) and the Pedagogical Pattern Collector, into Moodle and MediaWiki.

Deployment using GLUE! and GLUE!-PS

Figure 1 (circle labeled 'C') shows a third possibility: the approach that combines both GLUE! and GLUE!-PS to deploy non-trivial CSCL situations that also require the integration of external tools. Here, when teachers set the tools intended to support the learning activities within the GLUE!-PS interface, they may select any VLE built-in tool, but also any external tool integrated through the GLUE! architecture. The deployment of learning designs in VLEs is then done in a similar way as if using GLUE!-PS alone, although in this case VLE users that enact the learning activities can access both the built-in and the external tools selected by the teacher.

The interoperability between GLUE! and GLUE!-PS is achieved because the latter meets the contract defined by the GLUElet Manager for VLE adapters, being GLUE!-PS also able to request the creation, configuration and management of external tool instances. Thus, the GLUE! - GLUE!-PS partnership allows the deployment *in multiple VLEs* of learning designs created *with multiple authoring tools* and *LD languages*, and that include *multiple external tools*.

Validation of the deployment of a CSCL situation in Moodle using GLUE! and GLUE!-PS

A non-trivial CSCL situation, intended to be deployed in Moodle, illustrates the two limitations mentioned throughout this paper (i.e. the need for integrating external tools, and the cumbersome deployment process for teachers). Real higher education teachers have designed, particularized and deployed this situation in Moodle as part of a professional development workshop.

An authentic CSCL situation

The teacher of Research Methodology, a master-level degree course on research about Information and Communication Technologies (ICTs) at the University of Valladolid (Spain), wants to conduct a CSCL situation to get students to improve their skills to search for reliable information in a critical manner, produce well-structured written reports and work in teams. In order to achieve these learning objectives, the students participating in this course must discuss with their partners the typical structure of a research paper on ICT, and also agree on the ten main references on this research field.

7 http://tinyurl.com/ppcollector3. Last visited: May 2012.
8 http://gsic.uva.es/webcollage. Last visited: May 2012.

This situation has a blended learning format, with three face-to-face hours (in two different sessions) and another four hours of on-line work (equally distributed before and after the first face-to-face session). During the situation, students should enact four collaborative activities (two face-to-face and two on-line). These activities are arranged following a collaborative learning flow pattern (CLFP, see Hernández-Leo et al., 2006), called *Pyramid*. The Pyramid pattern fosters reaching a consensus solution to one complex, open-ended problem (i.e. to agree on the typical structure of a research paper and the top ten references), with students working in groups of increasing size. In this CSCL situation the four activities are organized in a three-level Pyramid, as depicted in Figure 2. This figure also represents the resources and tools supporting the activities (i.e. a paper provided by the teacher, a collaborative text editor and a collaborative drawing tool), and the group structure exemplified for a 12-student class. Interestingly, in three of these activities some of the outcomes from previous activities need to be reused (e.g. in the last level, drawings from the second activity are used as material for the debate).

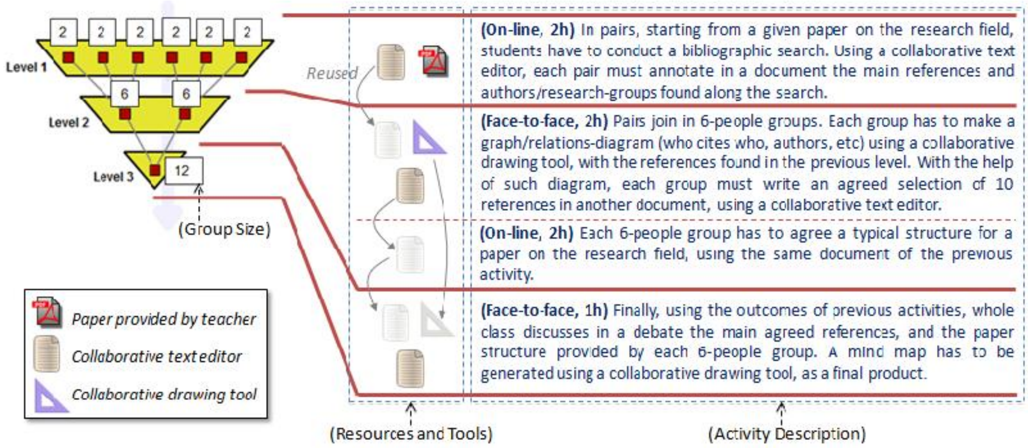

Figure 2: Structure of the collaborative learning situation.

This CSCL situation is to be deployed in a VLE to facilitate the structuring of activities and the sharing of resources and tools in a blended learning context. In this case, Moodle is chosen, since this is the University of Valladolid’s institutional platform, and students are already registered in the corresponding course. Moodle provides some built-in tools that may be of help to support collaborative activities (i.e. the paper provided by the teacher can be added as a Moodle resource). However, Moodle does not include drawing tools, and the built-in collaborative text editors (Moodle’s wiki and online text) offer a very limited functionality. Also, the teacher might prefer a popular tool, rather than Moodle built-in tools to reduce the cognitive barrier (for students and for himself). Thus, the deployment of this situation in Moodle suffers from the *restricted set of built-in tools*, and so, some way of integrating external tools is needed. The teacher might accomplish this integration manually (i.e. creating instances of each external tool using its own interface, copying and pasting the instance locations to Moodle activities, and assigning these activities to the corresponding groups/groupings), but that is a very time-consuming and error-prone process, especially when a large number of groups and tools are involved.

For illustrative purposes 12 students are included in the Pyramid (see Figure 2), with six pairs forming the first level, two 6-people groups in the second level and one whole-class group in the third. Nevertheless, there is no restriction on the actual number of students that may enact this CSCL situation. This kind of group arrangement requires a non-trivial structure of Moodle groups (for the first level) and Moodle groupings (for the second and third levels). Moodle enables the creation of a particular shared instance of its built-in tools for each group in one single Moodle activity. However, a different Moodle activity must be created to obtain equivalent results in the case of groupings. Therefore, the deployment of this situation in Moodle also suffers from the *heavy burden demanded to the teacher*. Remarkably, this burden increases as the number of participants does. Therefore, it would be desirable to have some way of facilitating this deployment.

Deployment using GLUE! and GLUE!-PS in Moodle

The GLUE! - GLUE!-PS partnership can be employed to deploy this CSCL situation in Moodle, overcoming the two limitations detected above. The teacher can choose either integrated external tools through GLUE! or Moodle built-in tools (as usual). Both built-in and external tools can be selected within the VLE interface or within the GLUE!-PS interface. Once the design is deployed, teachers might also add new tools through the

VLE interface. Among all the available external tools, the collaborative text editor *Google Documents*, and the collaborative drawing tool *Dabbleboard* fit the teacher's needs for this situation.

Besides, the use of GLUE! offers several interesting features for the deployment of this situation. GLUE! enables the individual configuration of each external tool instance. Thus, teachers may, for example, upload templates to Google Documents when selecting this tool, in order to e.g. establish the format in which the references should be noted. GLUE! also allows the update of users sharing instances in a way that teachers may modify the group members once the designed is deployed to adapt it, for instance, to some students' absences.

Thanks to GLUE!-PS, this non-trivial CSCL situation can be formalized using an authoring tool, being afterwards particularized and deployed in Moodle. For example, WebCollage is an authoring tool that supports the definition of learning designs using best practices in the form of CLFPs (such as the *Pyramid* considered here). This authoring tool enables the definition of the group structure, the set of activities, and the learning objectives. Once the activities, groups and objectives are defined in WebCollage, they can be particularized for the concrete Moodle users enrolled in the course in which the design is to be deployed.

GLUE!-PS can retrieve the users of this Moodle course, as well as the list of Moodle built-in tools and the external tools integrated through GLUE!. Using the GLUE!-PS interface or even the WebCollage interface (since GLUE!-PS acts as a service offering this data for other tools to take) the teacher can populate the groups, as defined in Figure 2, adding also Google Documents and Dabbleboard to the learning activities. Significantly, GLUE!-PS also supports the reuse of previously used external tool instances in subsequent activities, allowing e.g. the documents and drawings generated in 6-people groups to be employed in the last debate activity.

Once the groups are populated, and the (built-in and external) tools are selected, the learning design can be deployed in Moodle. In its current prototype (available for Moodle 1.9), the deployment is done by generating a Moodle course backup with all the information, mapping the GLUE!-PS data model concepts to Moodle data model concepts (e.g., GLUE!-PS *activities* are mapped to Moodle *topics*); this backup is imported and deployed within a Moodle course using the Moodle restauration process for a course. The fact that GLUE!-PS allows for the manipulation and particularization of abstract learning designs facilitates these designs to be easily reused in different academic years and courses. Even more, teachers may share these designs with other practitioners, to be easily deployed and enacted in their own Moodle courses, and even in other VLEs.

Validation through a teacher professional development workshop

In order to provide a first validation of this approach, especially regarding teachers' perceptions on the usefulness of the GLUE! - GLUE!-PS partnership, this CSCL situation was put in practice in a professional development workshop with higher education teachers at the University of Valladolid. Although the complete evaluation of this workshop is still in progress, a preliminary analysis of the available data is presented here. This workshop is developed as part of a workshop series organized at the University of Valladolid during 2011-2012. Interestingly, a study was realized in two other workshops to analyze the information lost from design to enactment when using different tools (Muñoz-Cristóbal et al., 2012). In this study, results showed evidences that even though some information was lost, teachers would use the deployed courses.

This particular workshop aimed at improving teachers' skills in designing and enacting collaborative activities using new technologies, and followed a blended format with 12 hours of face-to-face and on-line work. 24 teachers with multidisciplinary backgrounds (mathematics, medicine and education, among others) participated in this workshop, in which they had to design and deploy this CSCL situation in Moodle, using GLUE!, GLUE!-PS and WebCollage. Teachers were provided with a description of this CSCL situation and a worksheet to guide them throughout the whole process. GLUE! was (transparently) used due to the need of integrating external tools (Dabbleboard and Google Documents). It is noteworthy that none of the participants had used GLUE!, GLUE!-PS or WebCollage before, although most of them had previous experience with Moodle.

The face-to-face sessions were audio- and video-recorded, and observed by at least two researchers. The face-to-face sessions also included a debate among the participants in order to discuss the usefulness and practical uses of the workshop and the technological support (which was also audio-recorded). Moreover, an optional on-line questionnaire with quantitative and qualitative questions was answered by most of the teachers.

Main findings from teachers participating in this workshop are arranged in Table 1, indicating the data sources wherein there are evidences to support them. The first relevant finding is that all the participants were able to successfully design and deploy this CSCL situation into Moodle (*F1*), only requiring specific help in particular actions of the WebCollage and GLUE!-PS graphical interfaces. Concerning the integration of tools, 81% (17/21) of the teachers completely or quite agreed that the tools they added to support the learning activities (i.e. Google Documents and Dabbleboard) allowed to put in operation their design ideas (*F2*). In addition, 86% (18/21) of them were in complete or quite agreement that having all the tools and resources learners need to use in a centralized platform would facilitate the enactment of the learning activities (*F3*).

Table 1: Main findings and data sources from teachers participating in the workshop.

Tag	Finding	Data sources
F1	Teachers with different backgrounds can design and deploy this CSCL situation into Moodle using GLUE!, GLUE!-PS and WebCollage.	Questionnaire, Observations
F2	The external tools integrated through GLUE! allow to put into operation the design ideas in this CSCL situation.	Questionnaire
F3	The centralization in a VLE of all the tools and resources needed in this CSCL situation facilitates the enactment of the learning activities.	Questionnaire
F4	Designing and deploying this CSCL situation with GLUE!, GLUE!-PS and WebCollage is efficient in time.	Questionnaire, Debate recording
F5	The learning design in this CSCL situation can be reused in different Moodle courses.	Debate recording
F6	The learning design in this CSCL situation can be deployed in various learning environments.	Debate recording

The process of designing with an authoring tool like WebCollage, particularizing and extending these designs with GLUE!-PS (and GLUE!), and subsequently deploying them in Moodle was considered efficient by the teachers (*F4*), as it can be inferred from the 81% (17/21) of them in complete or quite agreement with this statement. Teachers' comments in the debate also remarked this fact, e.g. *"I will use this in my practices because the tools* [the authoring tool, GLUE!-PS and GLUE!] *save time"*. Some teachers also noted the potential of reusing learning designs thanks to GLUE!-PS (*F5*), e.g. *"GLUE!-PS offers flexibility to reuse learning designs"*; *"the design can be easily tailored"*. Finally, after the deployment in Moodle, teachers were told to deploy the same learning design in MediaWiki, something that sparked their interest and also received positive feedback (*F6*), e.g.: *"It is an advantage to deploy it not only in Moodle, but also in* [Media]*wiki"*.

All in all, findings *F2* and *F3* highlight the need of an integration approach like GLUE! to centralize all the tools students must use in a single environment, and the suitability of the external tools integrated through GLUE! to support this type of CSCL situations. Findings *F5* and *F6* underline the importance for teachers of reusing learning designs in different courses, and the potential to deploy these designs in different VLEs, something that is facilitated through the use of GLUE!-PS. Significantly, *F4* makes a point on the importance of time-effectiveness for teachers, emphasizing the efficiency of using the GLUE! - GLUE!-PS partnership for the deployment of this non-trivial CSCL situation. Finally, *F1* suggests that the technological support was not an impediment for the teachers to accomplish the deployment of this CSCL situation in Moodle.

Conclusions and future work

The GLUE! - GLUE!-PS partnership facilitates the deployment of non-trivial CSCL situations that require the integration of external tools, such as the one presented here. This partnership is designed to *reduce the heavy preparation and configuration burden* on teachers, especially regarding the creation and management of complex group and activity structures that are a hallmark of many CSCL situations. The preliminary experimental evidences hint that teachers perceive the potential usefulness of this partnership.

Apart from the workload reduction, there are other collateral benefits of this partnership that should be highlighted. First, it allows teachers to *widen the array of tools* they can choose from to enact their learning activities, enabling them to select external tools that they (or their students) might already be familiar with (e.g. Google Documents). Second, and more important, this partnership enables an *easier sharing and reuse of learning designs*, even among practitioners that use different VLEs (i.e. it is not restricted to Moodle users). Again, our first experiences with teachers from multiple disciplines hint that teachers appreciate the value of these advantages. Besides, the open, extensible nature of GLUE! and GLUE!-PS enables third parties to extend or change the way each tool or VLE is supported (e.g. to take advantage of latest developments in a tool/VLE).

Yet, however useful this kind of technological support might be, this approach is still under research. More thorough experimental validation is needed in the immediate future. The support for new external tools, LD authoring tools and VLEs (by developing new adapters of different kinds) is currently ongoing. Even more, the extension of this approach to include augmented-reality and geolocated collaborative activities (e.g. using mobile devices), is another promising research path being explored in our immediate future work.

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