From face-to-face to distance LMS-mediated collaborative learning situations with GLUE!

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Abstract

GLUE! is an integration architecture that allows teachers to easily set up an LMS environment with several external tools to carry out complex collaborative learning situations in distance settings. Though its effectiveness in alleviating the burden on teachers of deploying and enacting such situations has been studied elsewhere, there are no studies in the literature analyzing the impact, in terms of learning achievement, of turning traditional face-to-face collaborative learning situations into distance LMS-mediated ones with the support of integration approaches such as the GLUE! architecture. This paper compares the learning achievement in a distance LMS-mediated collaborative learning situation supported by GLUE! and in the equivalent face-to-face in a non-technological setting. The conclusions of this comparison, along with the fact that GLUE! significantly reduces the set up effort, suggest that GLUE! is a good choice for turning traditional face-to-face collaborative learning situations into distance LMS-mediated ones without significant negative effects in the learning achievement.

Keywords

Collaborative learning, distributed architectures, interoperability, Learning Management Systems, external tools

1. Introduction

Collaborative learning is the process where two or more people learn something together, or at least attempt to do [1]. Collaboration is one of the 21st Century Skills [2] and collaborative problem solving is a critical skill in the PISA 2015 frameworks [3]. Thus, learners are expected to develop teamwork and collaboration skills from their early years at school, improving them during Higher Education, vocational training and beyond.

Educators must help learners develop teamwork and collaboration skills, designing collaborative learning situations tailored to particular contexts. However, this is not a simple task since collaborative learning situations should enable both scaffolding productive group interactions and interiorizing knowledge [1]. Collaborative learning flow patterns (CLFPs) [4], such as jigsaw [5] or pyramid [4], are recurrent collaboration structures that formalize the interactions and information exchanged among learners, facilitating non-expert teachers the design, instantiation and enactment of collaborative learning situations based on these patterns [4].

Collaborative learning has traditionally occurred in face-to-face settings, although is also possible in technology-mediated distance scenarios [1]. The rise of Information and Communication Technologies (ICTs) has led to the appearance of numerous software tools and systems that support distance collaborative activities (e.g. chats, forums, synchronous text editors, videoconferencing tools, shared repositories, social networking sites, etc.) [6], and many institutions and educators are incorporating them to the curricula. For example, many distance education institutions, such as The Open University[1] in UK or Universidad International de la Rioja (UNIR)[2] in Spain, use videoconferencing tools, shared repositories and forums in most of their teaching and learning activities. But the use of collaborative tools and systems in traditional face-to-face institutions is also becoming more and more common, as it can be seen in recent scientific works published in the literature [7][8][9]. This trend is aligned with the findings

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[1] http://open.ac.uk

[2] http://unir.net

of the Bologna Process Implementation Report [10], which states that a significant proportion of European Higher Education Area (EHEA) countries are providing more flexible degree programs through distance (and blended) learning. Consequently, educators need to adapt traditional face-to-face collaborative learning situations, employing existing ICT tools and systems, so they can be performed online too.

Within ICT systems, Learning Management Systems (LMSs), such as Moodle[3], LAMS[4] or Blackboard[5], stand out due to their rapid adoption by most educational institutions [11]. LMSs support the management of students, facilitate access to resources, and enable support to some distance collaborative activities through built-in tools, such as forums or chats. However, LMSs do not include most of the tools educators and learners typically employ (see Top 100 Tools for Learning[6]) [12]; even though they would be useful in carrying out frequent collaborative activities such as writing, drawing, simulating or organizing knowledge in teams. Therefore, educators face the task of integrating external tools that provide this functionality in LMSs. This can be very demanding, because of the needs of matching group structures in both LMSs and external tools [13]. Because of this burden, collaborative activities are simplified and courses are often reduced to content delivery and discussions in a forum (mode 1 of engagement in e-learning [14]) as it has been discussed in the literature [15]

In this context, the authors proposed the GLUE! (Group Learning Uniform Environment) architecture [13]. GLUE! provides a lightweight many-to-many integration of external tools (e.g., Google Drive) in LMSs. The functionality supported by GLUE! facilitates educators the management of external tools within the LMS, enabling the creation and configuration of external tool instances that are automatically assigned to student groups, as defined in the LMS. Using this approach, the burden of instantiating a collaborative activity that employs external tools is similar to the one with built-in tools.

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[3] https://moodle.org

[4] http://lamsinternational.com

[5] http://blackboard.com

[6] http://c4lpt.co.uk/top100tools

The reduction of educators' workload and students' satisfaction when GLUE! mediates between LMSs and external tools were assessed through several face-to-face and blended collaborative learning situations involving different LMSs, tools and CLFPs [13].

In the literature there are several approaches, besides GLUE!, that tackle the integration of external tools in LMSs. Some of these approaches were designed as tightly-coupled integrations, enabling a richer communication between the LMS and the tool, but hindering, as a consequence, the reuse of development effort when teachers or institutions decide to change the tools or LMSs they are going to use in their classes. This is for instance the case of Moodle plugins[7] (formerly Moodle modules). Alternatively, IMS Learning Tool Interoperability (IMS LTI) [16] and Apache Wookie [17] were designed, like GLUE!, under the principles of loosely-coupled integration, which reduces the functionality that can be offered, but facilitates the integration of multiple external tools in multiple LMSs (many-to-many integration). The main limitation of Apache Wookie is that it can integrate only applications that comply to the W3C Widget specification. IMS LTI, on the other hand, does not allow managing the tool lifecycle (instantiation, configuration, retrieval or deletion) from the LMS. A thorough analysis and discussion that compares IMS LTI, Apache Wookie and GLUE!, including their architectures, functionalities and differences can be found in [18].

Despite the existence of several approaches in the literature that tackle the integration of external tools in LMSs, there are no studies comparing the learning achievement in such technological contexts with the one in more traditional face-to-face settings without technology. This paper explores this gap in the context of collaborative learning, researching whether collaborative techniques, such as CLFPs, can still be effectively applied to distance LMS-mediated learning scenarios in which GLUE! supports the integration of external tools, without significant negative impact in learning achievement. The work presented in this paper is aimed at teachers who need to turn face-to-face collaborative learning situations into remote ones, in order to meet the current demand for online and blended education.

[7] https://moodle.org/plugins

The remainder of this paper proceeds with Section 2 providing an overview of the GLUE! architecture and presenting a brief summary of previous findings. Section 3 describes the collaborative learning situation that will be put into practice in technological and non-technological settings, introducing the evaluation results in Section 4 and the discussion in Section 5. Finally, conclusions and future work are set out in Section 6.

2. Instantiating and enacting collaborative learning situations with GLUE!

The GLUE! architecture facilitates the instantiation of LMS-mediated collaborative learning situations that require the integration of external tools, and also provides support during their enactment. This section briefly overviews the architecture and previous findings; a detailed explanation of both the architecture and previous findings can be found in [13].

2.1 Overview of GLUE!

Figure 1 shows an overview of the GLUE! architecture, which supports the integration of external tools in LMSs. This integration enables the communication between an LMS and several external tools from the LMS graphical user interface. Three independent software components constitute the GLUE! architecture. The central component (GLUE! core) decouples LMSs and external tools, assuming most of the integration functionality. The side components are called adapters: LMS adapters and tool adapters. Each LMS adapter connects an LMS with the GLUE! core. Each tool adapter connects the GLUE! core with one or more external tools. Unlike LMSs, which typically have diverse technologies and interfaces, several tools can share similar technologies and interfaces; that allows the same adapter to be used for connecting the GLUE! core with several external tools at the same time. End-user actions in the LMS are captured by the corresponding LMS adapter and sent to the GLUE! core. The GLUE! core processes and forwards these messages to the corresponding tool adapter, triggering actions in an external tool. Thus, the LMS adapters and the tool adapters wrap LMSs and tools, and the whole GLUE! architecture provides a lightweight integration solution for external tools and LMSs.

The GLUE! architecture provides functionality to create, configure, retrieve, update and delete external tool instances. Educators can make use of the functionality provided by the GLUE! architecture in order to instantiate collaborative learning situations from the LMS interface. An important feature is that external tool instances are automatically assigned to individual learners or to multiple learners, according to the group settings defined in the LMS. This reduces the burden of instantiating non-trivial collaborative learning situations like those based in CLFPs (especially when many students are involved), and promotes collaborative learning during the enactment of these situations. GLUE! is also aware of the instances that are created, allowing educators to reuse them in various learning activities when collaboration demands working on the outcomes of previous activities.

The current implementation of the GLUE! architecture[8] provides the GLUE! core, three examples of LMS adapters for Moodle, LAMS and MediaWiki, and ten examples of tool adapters for Google Drive, Doodle or W3C widgets deployed in Apache Wookie servers [17], among others. It is important to note that every new tool integrated in GLUE! is ready to be used seamlessly from all the available LMSs, and vice versa.

2.2 Previous findings

The GLUE! architecture was successfully employed to instantiate and enact three different LMS-mediated collaborative learning situations based on CLFPs in real settings (see Table 1) [13]. These collaborative learning situations could not have been carried out only with the LMS, due to the lack of appropriate built-in tools that support the functionality required by the educators. Manually integrating the tools would have been feasible but much more demanding, due to the high workload of creating the instances of the selected external tools, and later matching them to the group structures defined in the LMS. Moreover, these situations could not have been carried out under similar conditions with other integration approaches [13], either because they do not support tools with an equivalent functionality, because they are not available from the selected LMS, because they do not enable the automatic creation of instances for predefined groups, or because they do not support the reuse of instances between activities, as required by the pyramid and think-pair-share CLFPs.

[8] http://gsic.uva.es/glue

Evaluation results showed that employing GLUE! for the instantiation of these situations within Moodle or LAMS could largely reduce educators' workload (compared to the workload of manually integrating all the required external tool instances). Also, it was noted from students' satisfaction that GLUE! did not pose any problem in carrying out the activities in collaboration during their enactment. Both findings reflect the capabilities of GLUE! in different contexts, since the three example situations were designed covering various domains, durations and collaborative strategies, and demanded the integration of several tools in different LMSs. However, despite the fact that students could still collaborate with their partners, their learning achievement was not assessed, nor compared with the one in an equivalent face-to-face non-technological setting, this being the main objective of the present paper.

3. A collaborative learning situation

A collaborative learning situation based on CLFPs was designed and put into practice in a distance setting (in which GLUE! mediated between the LMS and the external tools) and in a traditional face-to-face non-technological setting. The outcomes of these experiments provided data about learning achievement in both settings.

3.1 Educational context and activity design

Introduction to Computer Networks (ICN) is a required course in the second year (out of four) of four different degrees in the field of Information and Communication Technologies at the Universidad de Valladolid, Spain. As an introductory course, ICN aims students to understand the main problems that appear in the communication of data between remote entities, structuring them through communication architectures. The course starts with an overview of the OSI (Open Systems Interconnection) reference model and the TCP/IP protocol architecture [19] and then takes the students deeper into the study of communication problems and protocols in the data link layer; the rest of the layers are studied in later courses. In addition to teaching this content, the ICN course also aims at developing students' cross-curricular skills like team work, decision making and time management.

As a particular implementation of the data-link layer, the HDLC (High-Level Data Link Control) protocol [20] is studied in a detailed way. This involves reading a digested specification, solving paper-based scenarios, and simulating some HDLC procedures in the laboratory using the cnet network simulator [21]. A typical exercise in ICN consists of drawing an HDLC diagram with the exchange of data frames between two remote systems from a set of given instructions, and with the support of an empty time flow chart (Figure 2 shows an HDLC diagram). This task has a certain degree of complexity since it requires students to be aware of the rules of the protocol and to apply them systematically (i.e. given an event, such as the arrival of a frame, one has to consider the state the receiver is in, and then apply the rules that cause a change of state and possibly the transmission of new frames). It has been detected through the years that many students reach the end of the course without mastering this protocol, failing the related exercise in the final exam.

The educator teaching ICN designed a collaborative learning situation aimed at reinforcing students' knowledge of the HDLC protocol and also at developing cross-curricular skills related to team work and decision making. This situation was designed following the pyramid CLFP [4], which enables the resolution of complex tasks reaching a gradual consensus. In this case, three levels were defined for the pyramid. In the first level, students had to draw an HDLC frame exchange diagram individually following a given set of instructions. In the second level, students joined in pairs to discuss the outcomes of the individual phase, generating a new agreed solution. Finally, in the third level, they were arranged in groups of four students to agree on a final solution. This process is known to refine errors from previous phases, students building their learning from the discussions with their mates [4]. In this particular situation, the educator expected students that were unaware of certain protocol rules, or that did not understand them or put them in practice, to be instructed by their peers throughout the collaborative stages of the pyramid. As an expected result, all the students would be more prepared to solve similar exercises on their own after participating in the collaborative learning situation.

This collaborative learning situation was put into practice for the first time in the 2012-2013 school year, with 65 students enrolled in the ICN course (70% of them regularly attending to face-to-face lectures). It was defined as optional, placed out of the regular course schedule, and intended to be carried out from home in order to reduce the amount of face-to-face classes (although a strict timing to foster synchronous interactions among students was established). After generating the HDLC assignment, the educator determined that each of the three pyramid phases needed 25 minutes. At the end, the correct solution was provided so that students could compare and discuss it in the four-member groups for another 10 minutes.

3.2 Instantiation of the situation in the LMS

This situation was instantiated in Moodle, which is the institutional LMS at the University of Valladolid. To support this situation, the educator stipulated a drawing tool and a synchronous communication tool so that students could draw and discuss the generated diagrams in groups. The educator also wanted to upload templates with empty time flow charts when creating the drawing tool instances to facilitate students the resolution of the activities. Following these guidelines, the educator selected Google Drawings to support the generation of the HDLC diagrams, and the W3C Natter Chat widget [17], for synchronous communication and discussion in groups. As mentioned in section 2.1, the current implementation of GLUE! includes an LMS adapter for Moodle, a tool adapter for Google Drive (Google Drawings is one of the tools included in the Google Drive office suite) and a tool adapter for W3C widgets deployed in Apache Wookie servers (the W3C Natter Chat is one of these W3C widgets). Therefore, through an installation of the current implementation of GLUE!, Google Drawings and the W3C Natter Chat were available as tools in the Moodle graphical interface for teachers.

During the creation of the Google Drawings instances the educator was able to upload, within the Moodle interface but thanks to the GLUE! mediation, templates with empty time flow charts and a few examples of transmitted frames to be copied and pasted in the diagram (see Figure 2). The GLUE! architecture enabled the recreation of the group structure defined in the pyramid: external tool instances of Google Drawings and the W3C Natter Chat widget were automatically assigned to Moodle groups in the first level, and to Moodle groupings in levels 2 and 3. Interestingly, the educator set the outcomes of the first and second levels as the input for the second and third levels (in that order). This was possible since the integration of external tools in Moodle with the GLUE! architecture features the reuse of instances.

In summary, it was possible to instantiate the collaborative learning situation in Moodle by means of the GLUE! architecture, integrating Google Drawings and the W3C Natter Chat widget. Figure 2 shows an example of the integration of a Google Drawings instance in Moodle supported by the GLUE! architecture.

3.3 Methodology of the experiment

An experiment was designed aimed at comparing the learning achievement of this collaborative learning situation in the LMS-centered, GLUE!-enriched, technological setting, and in an equivalent face-to-face non-technological setting. The class was divided into two groups of the same size, one carrying out the situation within Moodle enriched by GLUE! with Google Drawings and the W3C Natter Chat widget, and the other performing the same situation through traditional pen and paper and face-to-face discussions, also following the group structures defined by the three-level pyramid. The first group acted as the experimental group and the second as the control group.

In order to produce an equivalent instantiation for the control group, the educator printed empty time flow charts so that the students could draw the exchange of HDLC frames on them, and save some time. These printed templates were handed out to the students in classroom, before the learning activities started.

Students' learning in experimental and control groups was compared employing a pre-test and a post-test. The HDLC diagrams generated in the individual phase of the pyramid were taken as the pre-test. Immediately after completing the pyramid, the students carried out a different HDLC exercise of a similar level of difficulty that acted as the post-test. It is important to note that the educator had to make copies of the (physical or digital) drawings outcome of the first level of the pyramid, so that he could grade them to measure individual performance, but at the same time let students use their copies to share (and possibly improve) in the collaborative phases. If similar scores were obtained in the control and experimental groups, then it would be assumed that the whole technological support (which in this case included GLUE!, Moodle, Google Drawings and the W3C Natter Chat widget) did not pose a problem concerning learning achievement in this collaborative learning situation.

The experiment was performed by 48 volunteer ICN students equally distributed in two consecutive time slots, the first being the control group (20 men and 4 women) and the second the experimental group (22 men and 2 women). Students in the experimental group were also gathered physically in a classroom in order to ensure that the experiment could be monitored by the researchers. The experiment was not scheduled simultaneously in two adjoining rooms due to the lack of space availability and because it was impossible to find a single slot in which a significant number of students could participate (they had to attend other courses). It should be noticed that students' choice was based solely on the time slot, since they were not informed in advance which group would discuss face-to-face and which through technology-mediation. Since no videoconference tool was integrated in the experimental setting, students attending to this group were asked not to speak directly to each other, and interact only through the technological support provided by the teacher and centralized in Moodle. Figure 3 shows a picture of two students belonging to the experimental group collaborating during the third level of the pyramid.

3.4 Enactment of the situation

The enactment of the situation went smoothly in the control group. Nonetheless, the educator detected that some students had problems with Google Drawings in the experimental group. Most of the students had never used this tool before and they found troubles moving and copying items from the template at the beginning. Indeed, in the individual phase, three students preferred to make the HDLC diagram with paper and pen first, copying later the outcomes to the drawing tool. The educator reacted by increasing the time for the individual phase of the pyramid in the experimental group by 20 minutes, so that a similar number of students could end this task in both groups, in an attempt to find a fair compromise solution to this unexpected technology overhead. Nonetheless, in the remaining phases it was noted that the students in the experimental group were able to easily adapt and refine the drawings created in previous phases, while some of those in the control group decided to make new diagrams from scratch.

4. Evaluation results

The purpose of this evaluation was to compare learning achievement in the LMS-centered, GLUE!-enriched technological setting, and in the face-to-face non-technological setting. As a prior step, results from the control and experimental group were individually analyzed to check that there was indeed an improvement in students' learning due to the realization of this collaborative learning situation. Two data sources were employed in the evaluation, the pre- and post-test scores in both the control and experimental groups, and the answers to a questionnaire with Likert scales and open text questions filled out by the students in both groups at the end of the experiment.

4.1 Pre- and post-test scores

The pre- and post-tests scores from the control and experimental groups were analyzed to look for significant differences and so, to obtain evidences of an improvement in students' learning during the experiment. At this point, one of the students in the experimental group was excluded from the analysis because of evidence that he had obtained the answers to the pre-test from their colleagues in the control group (who carried out the learning activities in the first time slot). Thus, the analysis continued with only 23 students in the experimental group.

Table 2 presents the mean scores and the standard deviation for the control group in the pre- and post-tests. An average improvement of 1.85 points out of 10 (27% with respect to the pre-test) was noticed, with 22 students improving their performance, and just one student getting lower marks.

Before deciding on the statistical test to be used in the analysis, the normality of the samples was checked by means of a Shapiro-Wilk test and a Q-Q plot. Both tests revealed that the post-test scores did not follow a normal distribution, mainly due to most scores gathered in higher values (83% of students reached at least 8 points in the post-test). Therefore, parametric tests such as the paired samples t-test could not be employed, and a non-parametric Wilcoxon signed-rank test for paired samples was used instead [22]. Wilcoxon signed-rank test assumptions were checked, samples being paired from the same population, each pair independent from the others. The null hypothesis was "the distribution of both the pre- and post-test scores is the same", while the alternative hypothesis was "the distribution in the post-test was to the right from the distribution of the pre-test" (one-tailed test). The p-value obtained was $p <$

0.0001, and so, the null hypothesis must be clearly rejected ($\alpha = 0.95$), accepting the alternative hypothesis. Also, the effect size in this improvement was calculated employing Cliff's δ for non-parametric tests [23], obtaining a medium effect size (Cliff's $\delta = 0.53$). This value suggests that this collaborative learning situation designed following the pyramid pattern had a moderate impact in students' scores.

Results from the Wilcoxon signed-rank test combined with the effect size allow concluding that the use of the pyramid CLFP in this face-to-face scenario with paper and pen caused a moderate and significant improvement of students' scores, thus promoting students' learning, in the control group. Interestingly, this improvement was reached within only one hour of collaborative work (25 minutes working in pairs, 25 in groups of four, and 10 discussing the solution provided by the teacher).

With respect to the experimental group, Table 3 shows the mean scores and the standard deviation in the pre- and post-tests. A lower average improvement was obtained, as compared to the control group, with 1.19 points out of 10 (17% of improvement with respect to the pre-test in the experimental group); 17 students got higher marks and 3 obtained worse results. The higher mean marks in the pre-test might have been influenced by the extra time added by the ICN educator to compensate for the technology overhead.

Again, the normality of the samples was checked through a Shapiro-Wilk test and a Q-Q plot, revealing that the post-test scores did not follow a normal distribution (with 71% of the students getting 8 points or higher), as in the control group. Thus, a non-parametric one-tailed Wilcoxon signed-rank test was also realized to analyze the scores with the same null and alternative hypotheses that in the control group. The p-value obtained was $p = 0.002$, which indicates that the null hypothesis must be rejected ($\alpha = 0.95$), accepting the alternative one: the scores distribution in the post-test was on the right from the scores distribution in the pre-test. The effect size measurement in this improvement also represents a medium size effect (Cliff's $\delta = 0.48$).

This analysis provides evidence that the realization of this collaborative learning situation in a remote setting in which GLUE! mediates between Moodle and the external tools entailed a significant improvement in students' marks, and also promoted students' learning. Again, this improvement was reached within only one hour of collaborative work, as previously detailed. It is important to note here the effect of the external tools selected, since most of the students did not have previous experience with them.

It can be seen that there is a significant improvement between the pre- and post-test scores in the control group and in the experimental group. However, it is still necessary to compare both groups to assess whether the technological support in the experimental group could have posed a problem for students' learning. This comparison is carried out looking at the improvement in students' marks between the pre-test and the post-test (see Table 4). If one considered only the mean differences, one might assume that the remote settings led to worse results (1.19 of improvement in the experimental group versus 1.85 in the control group). Nevertheless, to draw that conclusion it would be necessary to demonstrate that there was a significant difference between the control and experimental groups regarding the improvement between post- and pre-test scores.

Because the students' scores do not follow a normal distribution, then a non-parametric Mann-Whitney U test was employed for this analysis. The requirements of this test are: samples to be independent (as it happens because they come from different groups), and to have the same distribution. For the latter requirement a Kolmogorov-Smirnov test was carried out showing that the hypothesis "the difference between post- and pre-test scores in both groups is equally distributed" cannot be rejected with a very high p-value ($p = 0.673$). For the Mann-Whitney U test the null hypothesis was "the difference between post- and pre-test scores in both groups is equal to zero", with the opposite for the alternative hypothesis. A two-tailed Mann-Whitney U test brought a high p-value ($p = 0.431$), which indicates that the null hypothesis cannot be rejected ($\alpha = 0.95$).

This analysis shows that it cannot be concluded that the technological environment had a negative effect in the learning achievement of the experimental group. Nonetheless, what can be concluded is that the enactment of this collaborative learning situation based on the pyramid CLFP improved students' outcomes (and indirectly students' learning) in both the group working with pen and paper and the group in which GLUE! integrated in Moodle the instances of the supporting external tools. This is an important finding that offers teachers the opportunity to instantiate and enact collaborative learning situations based on CLFPs in LMS-mediated settings, obtaining a positive effect in the learning achievement.

4.2 Results from the questionnaire

Participants in the control group answered an anonymous questionnaire with 6-point Likert scales (three of the options framed as positive statements and three as negative ones) and open text questions about the situation and the collaboration with their partners. The same questionnaire was handed out to students in the experimental group adding some extra questions on the technology used.

All the students positively assessed the usefulness of the learning situation in the context of the ICN course, which suggests a high level of engagement and a willingness to take the experiment seriously. Answers also indicated that the tight schedule was not a limitation, with 88% of the participants in the control group and 92% in the experimental group giving a positive rating to the available time. This supports the decision of adding extra time in the individual phase of the experimental group due to the technology overhead.

Regarding the collaboration, all the students in the control group and 92% of those in the experimental group expressed positive opinions about the benefits of team work in facilitating the accomplishment of the proposed activities. This supports the design made by the educator and provides evidence of the usefulness of the pyramid CLFP in this kind of situations. Interestingly, all the students in the control group were positive regarding the ease of working in collaboration in the face-to-face activity, and also about being able to see the individual contributions their group partners set with paper and pen. Despite the lack of face-to-face communication, still 88% of the students in the experimental group expressed positive opinions on these issues. These opinions are aligned with the idea of GLUE! being able to support the enactment of non-trivial collaborative learning situations involving tools like Google Drawings or the W3C Natter Chat widget in learning platforms like Moodle.

One expected, yet very significant finding was that most of the participants in the experimental group (84%) had positive feelings about the possibility of repeating the same collaborative learning situation at home. In contrast, hardly anyone in the control group (4%) was positive towards the repetition of the same collaborative activities from their homes. These results reinforce GLUE! as an alternative for the enactment of distance (or blended) non-trivial LMS-mediated collaborative learning situations like the one presented here.

The overall technological support set by the educator during the enactment received positive critiques from 75% of the students in the experimental group. It is noteworthy, 96% of these students supported the idea that having all the tools integrated in one single environment, such as Moodle, facilitated the realization of the proposed activities in collaboration (with 79% of the answers in agreement or complete agreement on this statement). These answers reinforce the need for infrastructures such as GLUE! that centralize collaborative activities and tools in a single environment for the convenience of students and educators.

Even though most of the students had never used the external tools (Google Drawings and the W3C Natter chat widget), they were not perceived as a limitation in carrying out this situation, since their usefulness and ease of use were positively reviewed in most comments. However, open text questions served to detect that some students would have wanted more time to become familiar with the drawing tool, and that this chat may hinder the communication in large groups due to the lack of colors to distinguish the ideas contributed by each partner.

All in all, this questionnaire served to check that students in both groups were highly motivated to carry out the proposed activities in collaboration. Also, the experimental group gave a fairly high rating to the mediation provided by the technological support during the collaborative activities. No significant problems were detected related to the technological support, and learners clearly perceived that it would have been equally valuable if they had worked from their homes. Finally, the need for solutions like the GLUE! architecture to integrate external tools as part of learning activities in non-trivial LMS-mediated collaborative learning situations was highlighted.

5. Discussion

Evaluation results from pre- and post-test scores combined with students' answers to the questionnaire suggest that the technological support employed in the enactment of this collaborative learning situation was not a hindrance for the improvement of students' learning, and so, neither was GLUE! itself. These results were obtained for a particular collaborative situation, but it may be considered a representative one, since it is designed following a widely employed CLFP that requires a non-trivial group structure with changing teams of different sizes, reusing the outcomes of former learning activities as inputs for new ones. Also, the situation can be considered relevant because it had to be instantiated in Moodle, which is the institutional LMS; and students were highly motivated to take it seriously, as reflected in their answers to the questionnaire.

The collaborative learning situation was enacted for a limited number of learners, due to the restriction on the number of students enrolled in the course, and the need to divide the class into two groups: control and experimental. However, an increase in the number of enrolled students would not affect the group with technological support: thanks to GLUE, the instantiation of the experiment would still be feasible with a similar effort. A larger group in the enactment of the situation without the technological support would be more difficult to manage because of the need for adequate physical spaces suitable to the number of participants, and the management effort required to keep students within the flow of planned activities.

The enactment of the situation in the experimental group was set in a controlled environment with all the students in the same room, so that researchers could monitor them for evaluation purposes. Nevertheless, the evaluation results suggest that the same situation could be replicated in real distance settings, with students in the experimental group working outside the classroom. In that case, some differences might occur since students would have a greater degree of freedom. For instance, in the controlled experiment, students were only allowed to use the external tools selected by the teacher. Outside the classroom students could decide to use other tools (e.g., instead of the suggested chat they might use their favorite social network or a videoconference tool to talk to each other). Here it is worth noting that GLUE! supports choice from a wider range of tools, automates the assignment of external tool instances to those group mates that must work together, and enables outcomes from previous activities to be set as inputs in later activities; all this in a seamless way for the convenience of students. The effort required of students to create and share the instances with the right peers if using other tools of their choice would by no means be negligible. Though this effort may not be significant for a chat tool, this may not be the case for other, more complex, collaboration tools, like the drawing tool.

Another issue that may appear in real settings is the need to rearrange groups during the enactment of the collaborative learning situation due, for example, to student dropouts and latecomers. In an LMS-mediated situation the rearrangement includes creating and removing groups in the LMS (creating and removing also tool instances associated to learning activities), and/or moving students from one group to another (modifying access policies to tool instances). That process requires an additional workload for the educator, and is limited by the flexibility of the technology mediating between the LMS and the external tools. When using GLUE!, rearranging groups during the enactment is not problem, since GLUE! supports the automatic and transparent update of external tool instances if educators modify the groups defined in Moodle (as it happens by default with Moodle's built-in tools).

All in all, GLUE! enables traditional face-to-face collaborative learning situations to be turned into distance situations, without the learning design being constrained by the tools available in the LMS. This can be useful in a degree program (as it was the case here) and in postgraduate programs, especially if considering the current trend towards the promotion of distance learning [10], but also in vocational training and life-long learning.

6. Conclusions and future work

The adaption of traditional face-to-face collaborative learning situations so that they can be performed in distance settings is a need in new educational institutions, including those belonging to the EHEA countries, and a challenge for educators, particularly when dealing with many learners and non-trivial group and activity structures, such as those defined in CLFPs. LMSs are the preferred systems to manage contents, activities and learners in formal distance or blended learning as part of undergraduate, postgraduate and professional training programs, but they do not include enough software tools to instantiate and enact a wide range of collaborative activities.

This paper has shown how GLUE! is positioned as a solution to integrate external tools in non-trivial LMS-mediated collaborative learning situations without having significant negative effects in the learning achievement. In the example situation presented here, which was carried out in a controlled environment, GLUE! was able to support the instantiation and enactment of a three-level pyramid, improving students' scores, and leading to results that may be compared to those in face-to-face settings. Thanks to GLUE!, educators can instantiate and enact their traditional learning designs based on collaborative activities into distance settings and may expect a similar effect in the learning achievement, as compared to traditional face-to-face collaborative learning situations.

Future work aims at evaluating the enactment of other collaborative learning situations in real remote settings where students are not constrained by the instantiation established by the educator [24]. Another research line will address the instantiation and enactment of collaborative learning situations that require the integration of external tools in Massive Open Online Courses (MOOCs) [25].

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Table 1: Three collaborative learning situations based on CLFPs instantiated and enacted with GLUE!. Situation 1 was enacted twice in November 2010 and November 2011. Situation 2 was enacted once in May 2011. Situation three was enacted once in February 2012.

Figure 1: Overview of the GLUE! architecture with the LMS adapters, GLUE! core and tool adapters.

Figure 2: Example of an HDLC diagram generated with Google Drawings and integrated in Moodle through the GLUE! architecture. This is the real solution proposed by one of the teams during the enactment of the collaborative learning situation. The empty time flow chart on the right and the examples of transmission data on the left were provided in a template file uploaded to Google Drawings within the Moodle interface before the activity started.

Figure 3: Two students in the experimental group making the HDLC diagram in collaboration with their partners. The student in the foreground is editing the HDLC diagram in Google Drawings. The student in the background is talking to his group mates using the W3C Natter Chat widget.

Table 2: Comparison between pre-test and post-test scores in the control group

Table 3: Comparison between pre-test and post-test scores in the experimental group

Table 4: Comparison between the improvement in control and experimental groups