Toward the integration of monitoring in the orchestration of across-spaces learning situations

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Abstract: Technologies such as augmented Reality (AR), 3D Virtual Worlds (3DVWs) and mobile phones are extending education to other spaces beyond the classroom or the Virtual Learning Environments (VLEs). However, the richness of across-spaces learning situations that could be conducted in all these spaces is hampered by the difficulties (encompassed under the "orchestration" metaphor) that teachers face to carry them out. Monitoring can help in such orchestration, and it has been highly explored in face-to-face and blended learning. Nevertheless, in ubiquitous environments it is usually limited to activities taking place in a specific type of space (e.g., outdoors). In this paper we propose an orchestration system which supports the monitoring of learning situations that may involve web, AR-enabled physical and 3DVW spaces. The proposal was evaluated in three authentic studies, in which a prototype of the system provided monitoring through a web dashboard, an AR app, and a Virtual Globe.

Keywords: Learning analytics, monitoring, across-spaces, VLE, augmented reality, virtual worlds

Introduction

A multiplicity of technologically enabled learning spaces is emerging due to the technological advances of the last decades. Physical spaces such as classrooms, parks, museums or houses, are enriched with a variety of electronic devices: interactive whiteboards, computers, mobile phones, tablets, tabletops, etc. These devices are actually doors to other virtual learning spaces, like the Web or even 3D virtual worlds (3DVWs), in which learning is mediated by software tools, such as web Virtual Learning Environments (VLEs, e.g., Moodle[1]), 3DVWs platforms (e.g., Second Life[2]) or Virtual Globes (VGs, e.g., Google Earth[3]). There has been substantial research focused on the continuity of the learning experience across-spaces where the students may benefit from the affordances of the different spaces while learning anytime anywhere (Milrad et al., 2013). Technologies such as mobile devices, sensors, and Augmented Reality (AR, i.e., the combination of virtual and physical objects in a physical environment) help connect different spaces, enabling across-spaces learning situations (Wu, Lee, Chang, & Liang, 2013). For instance, a virtual object generated by a group of students in a classroom can be afterwards used in-context in a park with AR. Actually, when learning across-spaces, there is a special emphasis on the physical context where the learning activity takes place, which is a core factor in the typical educational approaches involving different spaces (Milrad, et al., 2013).

Despite the benefits that across-spaces learning situations may provide, teachers still face several difficulties to create and conduct this kind of situations (Delgado Kloos, Hernández-Leo, & Asensio-Pérez, 2012). These difficulties to create and enact learning situations in technologically complex educational settings (not only across-spaces) have been encompassed by the research community under the "orchestration" metaphor (Prieto, Dlab, Gutiérrez, Abdulwahed, & Balid, 2011). Across-spaces learning situations, where the activities frequently involve a number of separate groups interacting simultaneously from distant locations using different technologies, pose special requirements to orchestration. One of these requirements is that teachers lose awareness of what students perform, and need special help to keep track of the development of the activities and the progress (or lack thereof) of the different groups. One of the key functions that can help teachers in the orchestration of these settings is *monitoring*. Monitoring is the collection of data related to specific indicators, which provides different stakeholders of a development intervention with indicators regarding the progress and results of such intervention (Marriott & Goyder, 2009). Monitoring can be understood as a shared task between

[1] https://moodle.org. Last access January, 2016.
[2] http://secondlife.com. Last access January, 2016.
[3] https://www.google.com/earth/. Last access January, 2016.

the system and the user (i.e., the teacher or the student), where the response given by the system can range from showing the state of the interaction without much processing to the user, leaving the responsibility of interpreting the data to the user (mirroring); to more 'intelligent' approaches that analyze the state of the interaction and present direct advice to the user (guiding) (Soller, Martínez, Jermann & Muehlenbrock, 2005).

In across-spaces learning situations, where, as mentioned, typically the physical context is relevant, context-aware data usually needs to be collected using a variety of devices, such as sensors, and be integrated with the already heterogeneous data of traditional distributed educational systems (e.g., VLEs, Web 2.0 tools, social applications, etc.). However, despite the need for monitoring solutions in across-spaces situations to help orchestration (Long & Siemens, 2011), research in this field is still in its infancy. Most of the orchestration approaches considering physical spaces beyond the classroom propose solutions for monitoring the activities only in those physical spaces, typically using mobile devices, without integrating such data with data coming from other learning activities, spaces or devices (e.g., accesses to a web 2.0 tool such as Google Drive). These monitoring proposals are usually classified into ubiquitous or pervasive learning analytics (ULA or PLA) and mobile learning analytics (MLA) (Aljohani & Davis, 2012; Shoukry, Göbel, & Steinmetz, 2014) depending on whether the monitoring collects context-aware data (e.g., Facer et al., 2004; Santos, Hernández-Leo, & Blat, 2014) or not (Seol, Sharp, & Kim, 2011). Alternative approaches are weSPOT (Miteva, Nikolova, & Stefanova, 2015), which integrates the data of activities carried out in different spaces but lacks of context-aware information, or the system proposed by Tabuenca, Kalz, & Specht (2014), that provides contextual information but does not integrate data coming from other activities or spaces.

Therefore, to the best of our knowledge, there is a scarcity of orchestration proposals enabling the monitoring of across-spaces learning situations in which activities can take place in different physical and virtual spaces. In this paper we describe our research in this issue. Section 2 describes Glueps-maass, our proposal for the orchestration of across-spaces learning situations including activities in physical, web and 3DVW spaces and making use of a variety of existing technologies. Section 3 summarizes the main happenings and results of the evaluation carried out, which comprised three studies in authentic settings. Finally, in Section 4, we present the main conclusions obtained in the research.

Glueps-maass

During the latest years, we have been exploring in parallel the orchestration of across-spaces learning situations (Muñoz-Cristóbal, 2015), and the design-aware monitoring of blended learning situations (Rodríguez-Triana, 2014). For the former issue, we proposed GLUEPS-AR, a system to support teachers in multiple aspects of orchestration of learning situations that may involve activities in web (using VLEs), physical (using AR apps) and 3DVW (using VGs) spaces. GLUEPS-AR is able to offer user-awareness in the enactment platforms (by showing avatars in the enactment platforms), and it provides a user interface in which teachers can access the design, and the different artifacts created by the students. However, GLUEPS-AR does not provide with a dashboard with aggregated information. Consequently, GLUEPS-AR showed to be complex for teachers since they could not access a single source of information to understand what happened during the enactment of the learning situation. Additionally, in the other research line regarding the monitoring of blended learning, we proposed two systems, GLUE!-CAS and GLIMPSE, aimed at supporting monitoring by gathering, integrating and analyzing data based on the information provided by the learning design. GLUE!-CAS and GLIMPSE are able to collect data from heterogeneous sources (web-based blended learning environments and participants feedback), and to provide teachers with monitoring reports structured according to the learning designs initially defined. However, this approach is focused on blended learning, without taking into consideration learning situations happening in other non-web spaces, like the physical or 3DVWs.

Interestingly, the two approaches complement very well, since each one could cover the main orchestration limitations of the other. Furthermore, both approaches share a same technological architectural philosophy, since they both are based on the well-known *adapter pattern* of software engineering in order to facilitate the integration of multiple technologies. Therefore, we can easily abstract both approaches and combine them, following the conceptual model proposed by Martinez-Maldonado et al. (2013), in a new system integrating their orchestration features. The resulting system is Glueps-maass (Group Learning Unified Environment with Pedagogical Scripting, Monitoring, Analysis and Across-Spaces Support), whose architecture is described in Figure 1 (left). Glueps-maass provides support to the multiple aspects of orchestration, enabling teachers to deploy their learning designs, which may have been created with multiple authoring tools, into enactment settings that can be composed by multiple web VLEs, AR apps and VGs. Teachers can also manage and adapt the across-spaces learning situations at runtime through a user interface. Different virtual artifacts (e.g., Web 2.0 tools such as Google Docs) can be accessed from any of the spaces, due to the possibility of integrating in Glueps-maass multiple artifact-providers or Distributed-Learning-Environment adapters (e.g., GLUE! or IMS-LTI[4], see Alario-Hoyos & Wilson, 2010). In addition, the system is able to collect and integrate data from the multiple sources available in the learning scenario. Such data can be subsequently visualized at runtime and/or after the enactment both in a dashboard or using the enactment technologies (e.g., representing the location of the students in VLEs, AR apps and/or VGs by means of an avatar). Following the design-aware monitoring process inherited from GLIMPSE, the monitoring reports inform about the progress of the learning activities with respect to the teachers' pedagogical intentions represented by the learning design. These reports can be personalized according to the teachers' interests and taking into account contextual variables relevant in these contexts (e.g., a teacher can decide that s/he wants to monitor the number of times a group visits a position in a specific phase of the designed activity, while another can decide s/he wants to monitor the number of files uploaded by the participants in a particular location at another phase, etc.).

Aiming to evaluate the monitoring support of Glueps-maass, we developed a prototype (see Figure 1, right) integrating GLUEPS-AR, GLIMPSE and GLUE!-CAS. The prototype has been evaluated in different authentic across-spaces learning situations, which are described in the next section.

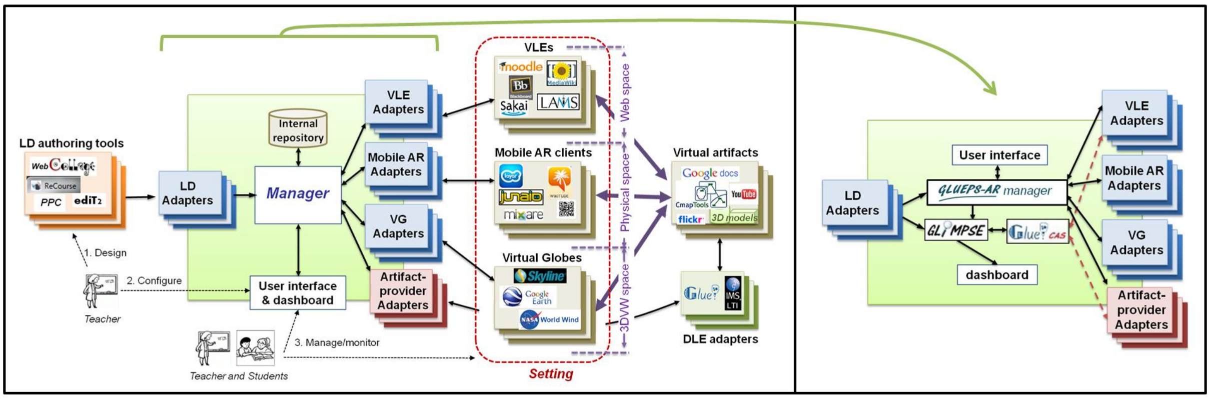

Figure 1. Glueps-maass architecture (left) and implemented prototype (right)

Intervention

We followed the Systems Development Research Methodology (Nunamaker, Chen, & Purdin, 1990) with an underlying interpretive perspective (Orlikowski & Baroudi, 1991) for the overall research process, as well as the Evaluand-oriented Responsive Evaluation Model (EREM; Jorrín-Abellán & Stake, 2009) as a framework for the evaluation. The research question we posed was *how can technology help integrate monitoring in the orchestration of across-spaces learning situations?* This research question was refined by means of a data-reduction process (Miles & Huberman, 1994) that led us to focus on a reduced set of topics, two of which are relevant for this paper: i) the support of the system to monitor across-spaces learning situations and ii) the affordability of the proposed solutions for the participant teachers.

To address the research question we proposed the architecture and developed a prototype of the Glueps-maass system, which was used in three studies involving authentic educational settings (see Muñoz-Cristóbal, 2015, for more information about the studies). We used multiple data gathering techniques, such as interviews, web-based questionnaires, participant observations and collection of teachers and students' generated artifacts (e.g., teachers' emails, learning materials and outcomes). The next paragraphs describe the three studies, which took place in 2013 in Spain.

Study1: Orientate!

Orientate! is an across-spaces learning situation carried out by a pre-service teacher in his practicum. It was conducted with a class with 18 students of around 12 years old, in a course on Physical Education belonging to the official curriculum of a primary school. The situation was composed of 5 sessions taking place in different physical and web spaces: the classroom, the school's playground, a nearby park, and a wiki-based VLE. Many technologies were used, such as an interactive whiteboard, netbooks, tablets, Web 2.0 tools and the Junaio[5] mobile AR app. The objective of the learning situation was to help develop orienteering skills in the children. During the activities, the pre-service teacher and the students created different virtual artifacts, which were

[4] https://www.imsglobal.org/activity/learning-tools-interoperability. Last access January, 2016
[5] https://my.metaio.com/dev/junaio/. Last access January, 2016

afterwards accessed from a different space from where they were created. For instance, they created geolocated quizzes using Google Docs[6] in the VLE while staying in the classroom, which later on were accessed at specific locations in the park using the Junaio AR app.

In this study, Glueps-maass supported the pre-service teacher in different orchestration aspects (such as in deploying the learning situation in the enactment setting, in managing the learning activities, or in adapting them when facing emerging events). Regarding monitoring, by means of the adapters, Glueps-maass collected data from the different technologies used in the different spaces (Junaio, Web 2.0 tools, wiki-based VLE), which were processed by the Glueps-maass manager and stored in the internal repository. Both the Glueps-maass user interface and the wiki-based VLE served as a control panel for the teacher, since he could view and access what the students did. In addition, after the end of the activities, the pre-service teacher reviewed the actions conducted by the students using a report produced by the Glimpse dashboard (see Figure 2, left). The report provided information about how the learning design unfolded, such as the number of accesses of the different groups of students to the different learning artifacts in each activity. The report did not provide context-aware information, since the prototype did not triangulate the information coming from the different sources. Thus, the pre-service teacher needed to access the Glueps-maass user interface, or the wiki, and consult the artifacts created by the students if he wanted, for instance, to be aware of the location where an artifact had been generated. Other context-aware interaction data was stored in the internal repository, but not provided to the pre-service teacher. The pre-service teacher valued as useful the wiki-based VLE to be aware and control the students' actions in run-time during activities in the classroom, and the design-structured dashboard to understand what had happened and help him assess the work of students after the end of the activities. However, the teacher missed to be able to access the dashboard information at run-time during the enactment so that he could be aware of what students were actually doing. Other limitations highlighted by the pre-service teacher were the absence of location information in the dashboard, and the lack of runtime awareness in physical spaces outside the classroom (e.g., the park), where the students spread out over a huge area. He also indicated that a map, where the learning artifacts and the students' actions could be tracked, would have been very useful. However, when asked about his opinion regarding the implementation of a dashboard in a tablet for accessing at runtime to the information he demanded, he considered that it would be complicated to be able to use it in activities such as the ones conducted outdoor.

Study2: Game of Blazons

Game of blazons is an across-spaces learning situation involving physical and web spaces, which was carried out by two teachers and 47 undergraduate students of a course on Physical Education in the Natural Environment, for pre-service teachers. The learning situation took place in a medieval village, together with other related learning situations conducted during a weekend in the village and its surroundings. The situation was aimed at helping students acquire different skills and knowledge of the subject (orienteering, hiking, history, culture and environment, etc.), as well as to be able to prepare and carry out physical education activities with children in a natural environment. The students, in groups, had to find (using orienteering skills) several stone blazons (coat of arms) chiseled in houses of the village. Close to each blazon, they had to use an AR app (Junaio or a QR code reader) in a mobile device to access Web 2.0 tools containing learning resources and instructions of different activities to be performed (quizzes, challenges, geocaching activities, etc.). Before and after the session in the village, other blended activities were conducted in the classroom and online, with the help of the Moodle VLE. As in Study 1, Glueps-maass supported teachers in different aspects of orchestration, and regarding monitoring, context-aware data was collected by the different adapters, processed by the manager, and stored in the internal repository. In addition to user-interaction data, in this case we also collected periodically information about the user, containing its location in physical spaces. Also, we extended the prototype, and user information was sent from the manager to the AR adapters, in order to use the mobile AR apps to trace the participants, providing runtime user awareness using AR. During Game of Blazons, the students used Junaio to access AR learning resources, while the teachers could see the location of the different groups of students by means of avatars in Junaio (see Figure 2, centre). Due to the characteristics of the learning situation, in which the teachers were overwhelmed, and also since the AR monitoring feature had been developed shortly before, the teachers did not monitored the position of the students continuously. Nevertheless, the main teacher used such feature in different occasions during the learning situation. In the final interview, he identified the AR user-awareness feature as one of the most interesting findings of the learning situation. He considered that it could be very relevant, for security reasons, in many learning activities performed with children. He also described other possible uses in different learning situations, such as for promoting

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[6] https://www.google.com/docs/about/. Last access January, 2016

collaboration in physical spaces (an expert student could help a learning partner). The main limitation emphasized by both teachers was the lack of a tracking feature in which they could observe (both in runtime and after the enactment) in a map the whole paths followed by the students (not just their runtime positions), with different information, such as learning artifacts involved, times devoted, being able to comment in runtime, etc. Finally, the possibility to access to the information anytime anywhere was identified by the students as one positive asset of the system, which helped them acquire and reinforce the learning contents in a motivating way.

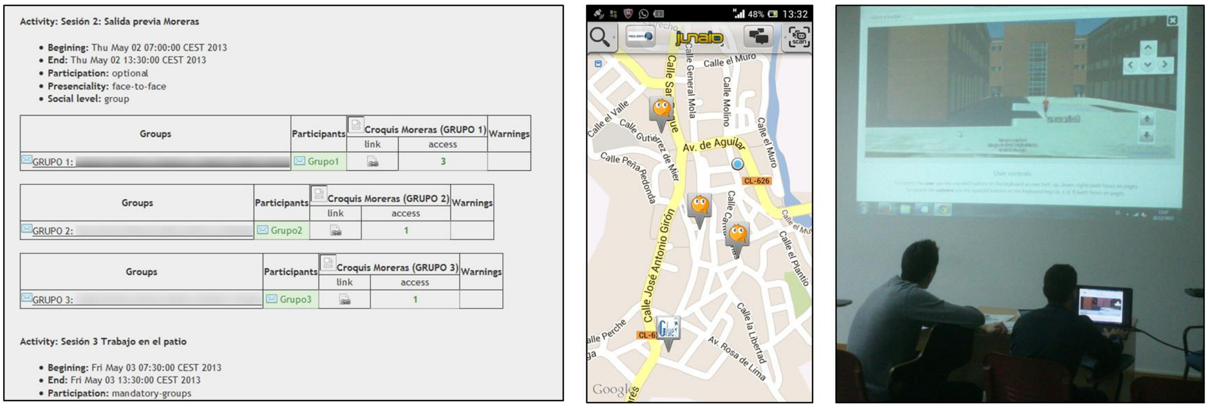

Figure 2. Partial view of Glimpse dashboard's web report during Study 1 (left); students' avatars showed in the Junaio's map view during Study 2 (center) and in the 3D view of the Google Earth VG during Study 3 (right)

Study3: 3D mirrored campus

This study relied on an across-spaces learning activity involving web, physical and 3DVW spaces, in the frame of a review session of the different topics addressed in the same course on Physical Education in the Natural Environment for pre-service teachers. The same two teachers of the Study 2 participated, together with 48 students of the same class. The students performed the activity taking turns, in groups of 6 students (while a group was conducting the activity, the rest of the students were carrying out other different activities). The activity was complemented with pre- and post-tasks using Moodle, created by students and teachers. The objective of the activity was to assess and reinforce the spatial and orienteering abilities acquired during the course, showing them also some more complex technological setups. The 6 students had to split into two groups. One of the groups had to walk outdoors around the campus following whatever route they wanted, carrying a tablet with the Junaio AR app active. The other group, in a classroom, could follow the path of their learning partners, represented as an avatar in the 3D view of the Google Earth VG (see Figure 2, right). The students in the classroom had to draw in an orienteering paper map the path that the other group was following. When the group with the tablet returned to the classroom, they also had to draw their followed route in a paper map, and compare it with the map drawn by their colleagues. Afterwards, they changed roles and repeated the activity.

The main differences of this case with the other two described above are the inclusion of a new kind of space (a 3DVW), and the fact that the awareness of the users' actions was provided to the students, in order to promote self-regulated and collaborative learning. As in the previous study, user's context and interaction data was sent from the different spaces by the adapters to the manager, processed by the manager and stored in the internal repository. Also, user information was sent back from the manager to the adapters, in order to represent the location of the users by means of avatars. This way, the outdoor location in the physical space of a group of students using Junaio was represented indoors in runtime by means of an avatar in the Google Earth 3D view of the campus. The main problem faced in this study was technological. It was the first usage of the VG user-awareness feature in a real setting, and the prototype did not support more than one user represented simultaneously in the VG (initially the teachers had conceived 3 members of the 6-students group carrying individual tablets). Later on, we solved these problems and we tested the prototype simulating more than 100 concurrent users. The teachers valued positively the use of Google Earth in the activity, asserting that it supported technologically a typical activity to develop orienteering skills that they had performed usually without technology (e.g., using post-its). Also, they thought that the activity had an important pedagogical sense and the aims were achieved. Furthermore, they perceived that it would be very useful for them to be aware of the students' actions during the enactment of activities in physical spaces, although they considered the available time as the main problem to be able to use it. Finally, they confirmed the necessity of tracking functionalities (during and after the enactment) to register in a map the routes, actions, and times performed by the students. It is also worth mentioning that among other pedagogical benefits, students stated that this situation had helped them get in touch with new technological resources to develop spatial perception, and to collaborate with partners tracing paths.

Discussion, conclusions and future work

We have proposed a new system, Glueps-maass integrating two existing orchestration approaches that emphasized different orchestration aspects: GLUEPS-AR and GLIMPSE/GLUE!-CAS. Glueps-maass aims at supporting teachers in the multiple aspects of orchestration of across-spaces learning situations, including the monitoring of the students' actions. The three authentic settings where the system was evaluated - in terms of its monitoring aid for teachers - enabled us to assess some interesting and innovative characteristics of the proposal. In addition to providing monitoring support in across-spaces learning situations involving web, physical and 3DVWs spaces, Glueps-maass also provides *across-spaces monitoring* support, enabling monitoring in web, physical and 3DVW spaces, using, respectively, a web dashboard, an AR app and a VG. This not only increases the monitoring possibilities of the system, but it can also enrich its educational usage, enabling teachers to adapt the monitoring approach to their pedagogical ideas, or even to use monitoring as a didactic resource in their learning situations, as in Study 3. The use by the students of the Glueps-maass monitoring features is another interesting finding of the evaluation, since it assessed how Glueps-maass provides monitoring support to both teachers (in Studies 1 and 2) and learners (in Study 3). It is also relevant to underline the three Glueps-maass different monitoring options: The user interface, where a teacher can access (in runtime and after the enactment) to all the artifacts generated by the students; the dashboard, where relevant information is aggregated and organized according to the learning design; and the very same enactment technologies supporting the learning situation, which provide runtime user-awareness by means of avatars. The different Glueps-maass monitoring options showed they offer enough flexibility to be able to adapt to the needs of very different learning situations.

Besides the positive findings, the reported studies have been useful to identify challenges that need further exploration. These challenges address both run-time and post-hoc support. Regarding synchronous support, an important line of research is related to the design of tools that provide teachers with monitoring capabilities they are able to handle at runtime, since they are usually overwhelmed during the enactment, when the available time is limited and the monitoring tools could distract instead of help them. Another demand identified in the cases was the need of a tracking facility able to integrate the positioning information with other meaningful products of the learning situation that could help teachers and students to review and reflect on it.

The studies had some limitations that define our immediate future work. We plan to further explore the combination of the different monitoring features of the system, since each monitoring option was used in a different learning situation. In addition, some of the interaction-data gathered from the enactment technologies is not currently included in the visualizations. We need additional research in order to improve the monitoring features with this information, such as creating the tracking maps demanded by the involved teachers. In fact, the current version of Glueps-maass takes a humble approach to analysis, leaving to the teacher the responsibility for the interpretation of the data. We plan to enrich the existing system with more advanced analytical features and test whether more intelligent ways of support are effective to help teachers orchestrate across-spaces learning situations. Finally, further research would be necessary to explore the scalability of the approach so that it could eventually be used in massive educational environments.

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