Orchestrating learning across spaces: Integrating heterogeneous technologies of the existing educational practice

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Abstract: Several approaches provide solutions for orchestrating across-spaces learning situations involving heterogeneous technologies. However, the learning situations that such systems support tend to be isolated from other activities and ICT tools of the teachers' existing practice. We present some lessons learned during our research in the field, which can be used as guidelines to design systems for the orchestration of across-spaces settings that integrate multiple technologies already in use by teachers.

Keywords: across-spaces, ubiquitous learning, augmented reality, virtual worlds, VLE

Introduction

Learning is not restricted to the physical space within the walls of a classroom. There are many other physical and virtual spaces which have shown during years affordances for learning. For instance, Virtual Learning Environments (VLEs) make students active participants and enable both distance and face-to-face learning (Keller, 2005); 3D virtual worlds (3DVWs) enable the simulation of experiences not feasible in the real world (Dede, 2009); and outdoor spaces enable contextual and experiential learning (Dyson, Litchfield, Lawrence, Raban, & Leijdekkers, 2009). Some technologies can especially aid in connecting the different spaces, as is the case of web technologies (access to virtual resources located in the Web), mobile devices (portability and several context aware features) and Augmented Reality (link between physical and virtual spaces). The seamless combination of the different learning spaces, also known as Ubiquitous Learning Environment (ULE; Li, Zheng, Ogata, & Yano, 2004), has been marked by the research community as one of the key research challenges to explore (Milrad et al., 2013). ULEs present several difficulties for teachers to orchestrate their learning situations (Dillenbourg, Järvelä, & Fischer, 2009). Thus, multiple authors have proposed solutions aiming to help teachers orchestrate scenarios that involve different physical and virtual spaces (see, e.g., Ibáñez, Maroto, García Rueda, Leony, & Delgado Kloos, 2012; Sharples, 2013). However, the learning situations enabled by such approaches tend to be isolated from other activities of the teachers current practice and from the ICT tools they already use. This separation from the teachers' everyday practice could affect negatively the teachers orchestration load and the "classroom usability" (Prieto, Wen, Caballero, & Dillenbourg, 2014). Therefore, there is a necessity of alternative approaches aiming to help teachers orchestrate their across-spaces learning situations, while supporting the integration of different activities and tools that the teachers can be already using.

During the last four years, we have explored such line of research, proposing different constructs (*POI model* and *learning bucket* notion) and systems (*GLUEPS-AR* and *Bucket-Server*) that enable the integration of different kinds of existing technologies focused on different learning spaces (including those cases in which such spaces are connected to the physical classroom). We have also evaluated such proposals through multiple feature analysis as well as pilot and evaluation studies. In the following section we outline some lessons learned regarding the *integration and communication of heterogeneous learning technologies*.

Lessons learned for integrating heterogeneous existing technologies

The following are some guidelines for designing systems enabling the integration of heterogeneous existing technologies, that we can extract from the lessons learned in our research, aimed to help teachers in the orchestration of across-spaces learning situations.

1. To enrich the artifacts generated by existing tools with additional information regarding the space, thus enabling the access to such artifacts from different spaces using existing technologies

In this regard we proposed two constructs: The *Point of Interest (POI) model* (Muñoz-Cristóbal et al., 2015), and the notion of *learning bucket* (Muñoz-Cristóbal et al., 2013). The POI model aims at overcoming one of the main challenges for integrating multiple technologies focused on different spaces: each technology tends to implement a different data model for representing a virtual object positioned in a space. The POI model encompasses a selection of the basic set of attributes included in the different data models, that we considered enough (aiming at simplicity) to represent a learning artifact positioned in a space. As Figure 1 (top) illustrates, common artifacts, such as those of the Web 2.0, can be converted into *Positionable Learning Artifacts (PLAs)* by means of enriching (tagging) them with the POI model. PLAs can be accessed in different spaces, using multiple existing technologies focused on each space (e.g., VLEs in web spaces, AR apps in physical spaces, Virtual Globes [VGs; Rakshit & Ogneva-Himmelberger, 2008] in 3DVW spaces). Following a similar fashion we proposed the learning bucket notion, which aims to help overcome another common limitation of multiple across-spaces educational systems: typically, they do not provide a teacher-controlled degree of flexibility for enabling students to manage their learning artifacts during the enactment. As Figure 1 (down) illustrates, a learning bucket is a collection of PLAs, which has been enriched with the POI model and with configurable *constraints*. Such constraints are a set of attributes that the teacher can configure at design time to restrict what students are able to do with learning artifacts during the enactment (e.g., restricting the tools to use, the positioning types, etc.). A bucket can be positioned in a space, and be used (together with the PLAs it contains) by multiple technologies focused on different spaces. A bucket could also transform a system not initially conceived for across-spaces (e.g., a VLE) in an across-spaces system, since using a bucket embedded in such system, the teacher and the students could create and position learning artifacts (PLAs) in different spaces. Thus, enriching the artifacts generated by existing tools (or a set of such artifacts) with additional information regarding the space (vs. proposing new tools focused on specific spaces) enables the efficient access to such artifacts from different spaces using existing technologies likely already available in the classroom.

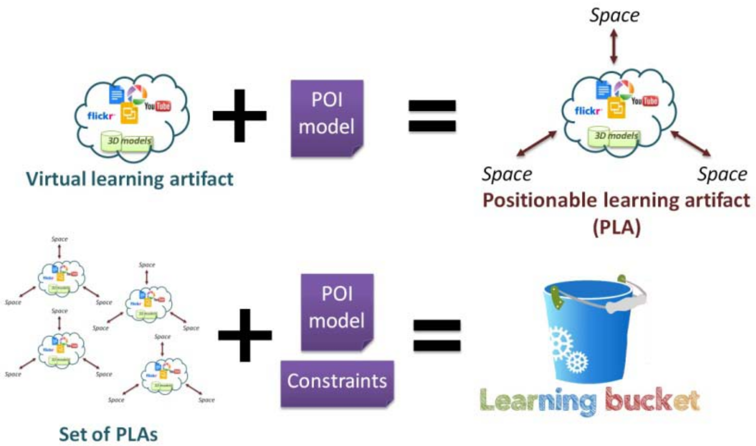

Figure 1. Converting a virtual artifact into a PLA using the POI model (top), and a set of PLAs into a learning bucket using the POI model and constraints (down).

2. To use a multi-to-multi architecture to integrate multiple existing technologies

Instead of adding new educational tools to the already complex technological ecologies of the educational spaces, an alternative can be to leverage existing learning tools to support across-spaces learning situations. A solution for integrating existing technologies of different types and allowing their interoperation is to use a multi-to-multi architecture based on the well-known adapter pattern of software engineering. Figure 2 (left) illustrates such architecture, based on the integration of the multiple systems by means of adapters. Different approaches in this line have been proposed in our GSIC/EMIC research group during the last years for integrating VLEs with third party tools (Alario-Hoyos et al., 2013) and for integrating learning design authoring tools with web-based distributed learning environments composed of VLEs and third party tools (Prieto et al., 2013). In the case of ULEs, we have proposed two systems based on the multi-to-multi architecture: *GLUEPS-AR*, and the *Bucket-Server*. GLUEPS-AR (Muñoz-Cristóbal, et al., 2015), is a system that integrates multiple learning design authoring tools, mobile AR clients (physical space), Virtual Globes (3DVW space), and VLEs (web space). GLUEPS-AR also enables the access to PLAs of multiple types from the different spaces, thus converting the set of isolated learning spaces in ULEs like the one shown in Figure 2 (right). Using GLUEPS-

AR, teachers can deploy learning designs created in any of the integrated authoring tools (not necessarily conceived for across-spaces learning) into different ULEs composed of web, physical and 3DVW spaces. In such ULEs, the PLAs can “flow” from one space to another (e.g., a Google Docs document can be accessed by different groups of students from a VLE and afterwards from an AR-enabled physical space).The Bucket-Server is another system with a multi-to-multi architecture, which implements the notion of learning bucket, and enables the integration of buckets in third party applications (e.g., orchestrating systems [such as GLUEPS-AR], VLEs, AR apps and VGs). The buckets can contain artifacts of multiple types, since the Bucket-Server can be also integrated, using adapters, with several artifact providers. We have integrated the learning bucket with GLUEPS-AR, thus enhancing the default flexibility offered by GLUEPS-AR, which was somewhat rigid due to its learning design basis (in which everything is typically predefined at design time). In addition, we have integrated the Bucket-Server with multiple VLEs, mobile AR clients and VGs, enabling also ULEs of the type shown in Figure 2 (right). Thus, learning buckets can be created from a VLE and be embedded in a VLE course, allowing students to create (under the constraints configured by the teacher) PLAs accessible later on from other spaces (e.g., physical ones using any of the integrated AR apps). It is interesting to highlight that the use of web-based or mobile artifacts/tools make this kind of architecture easier to implement by developers and easier to use across spaces by teachers and students.

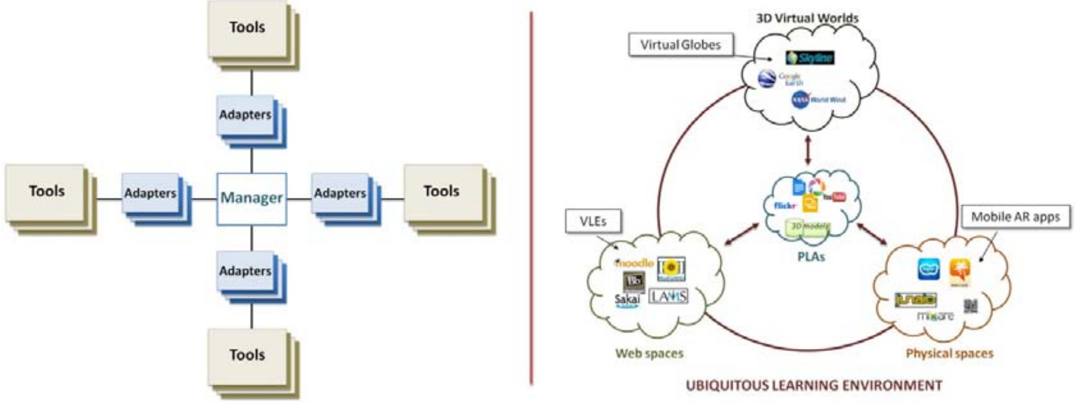

Figure 2. Multi-to-multi architecture (left) and Ubiquitous learning Environment (right).

3. To provide alternatives for different user profiles in order to comply with teachers and institutions’ constraints

Different teachers and institutions may have different constraints, beliefs, and profiles. The proposal of architectures allowing them to choose among a range of technologies of different types could not be sufficient, since the underlying approach might not fit well with some teachers and institution. This is especially important in orchestration technologies, which tend to add a layer of complexity to the already complex educational ecologies of technological resources (Sharples, 2013). Therefore, proposals adaptable to different teachers’ profiles would improve their possibilities of adoption. During the research, following an interpretive research perspective and a responsive evaluation model, we detected that GLUEPS-AR fitted well with some teachers’ profiles (e.g., those planning and designing everything in advance, highly methodical and tending to reuse their designs). However, GLUEPS-AR showed to be not so appropriate for other teachers’ profiles (e.g., those taking several last-minute design decisions, with a certain degree of improvisation, overloaded, and with a high level of innovation in their designs from one year to another). Thus, for the latter, the direct integration of the Bucket-Server with their usual VLE fitted better than the use of two additional systems (an authoring tool and GLUEPS-AR), even though learning buckets are less suitable that GLUEPS-AR for supporting complex pedagogical settings (e.g., those based on collaborative learning techniques). Thus, as Figure 3 illustrates, we proposed two alternative solutions for enabling teachers to create and orchestrate across-spaces learning situations conducted in ULEs: using learning design authoring tools (GLUEPS-AR), or creating directly the learning situations in their usual VLE (learning buckets).

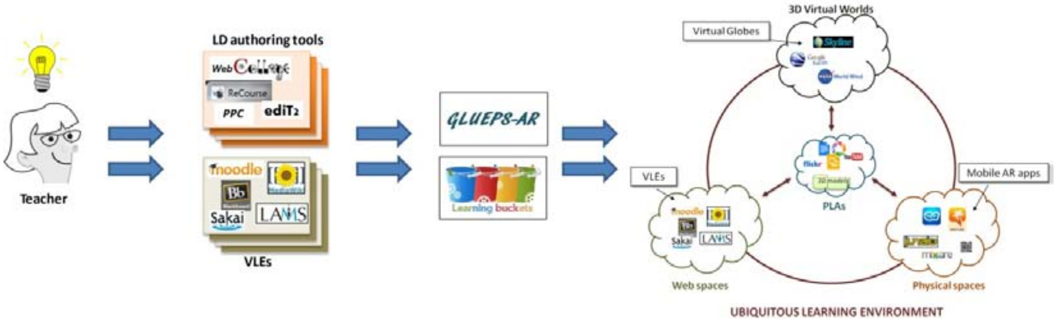

Figure 3. Options for deployment of across-spaces learning situations into Ubiquitous Learning Environments.

Conclusions

We have presented some guidelines for the integration and orchestration of heterogeneous existing technologies, that we have obtained from the lessons learned during four years of research in the field of across-spaces learning orchestration. However, it is worth highlighting that a distributed architecture based on adapters has also different inherent problems, which we plan to research in the future. Some of them are: the scalability (e.g., towards massive approaches, such as MOOCs); the delays (due to the multiple elements involved in the interactions between systems), the direct communication between applications; the maintenance (since changes in the contracts or APIs imply development in the adapters); and the scope of supported systems (only those with APIs can be integrated). All in all, the results using the guidelines described in this document have been positive, enabling multiple rich educational scenarios with a loosely-coupling of technologies and a simple “flow” of learning artifacts between spaces.

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