Supporting Teachers in the Generation of Ubiquitous Learning Situations Across Multiple Domains and Spaces Based on Linked Open Data

Pablo García-Zarza

GSIC–EMIC Research Group, School of Telecommunications Engineering, Universidad de Valladolid, Paseo de Belén 15, 47011 Valladolid, Spain

Abstract

This doctoral thesis will exploit the advantages that can be obtained by leveraging ubiquitous learning and Linked Data benefits to support teachers in creating ubiquitous situations. In the literature there are several research proposals that explore this combination. However, to the best of our knowledge, existing proposals offer ubiquitous learning experiences that are limited to specific knowledge and tied to a single (virtual or physical) space. For this reason, the research question "How to support teachers to exploit Linked Open Data to generate and reuse multi-domain and multi-space tasks for ubiquitous learning?" is been addressed. This proposal aims at answering this research question following the Systems Development Research Methodology using an iterative approach throughout the thesis lifespan. Two contributions are expected from this thesis: 1) to characterise the stages to be followed by teachers in order to generate ubiquitous educational experiences from different Linked Open Data sources; 2) propose and materialise a distributed software architecture that provides support to complete the above stages.

Keywords

Linked Open Data, ubiquitous learning, teachers, learning tasks

1. Introduction

The widespread use of mobile devices (laptops, tablets, mobiles) offers an excellent opportunity to use them in education, blurring the limits that may exist between learning that takes place in- and out-the-classroom [1, 2]. This type of learning is called ubiquitous learning (u-learning) [3]. Among the main advantages of u-learning [4] is the increased autonomy of learners, as they can learn without the limitation of location or time [5] through different spaces. As indicated in [1], a space is understood as "the dimensional environment in which objects and events occur, and in which they have relative position and direction." An application that could be considered u-learning is "Google Arts & Culture".[1] This application enables students to explore cultural places around the world. SmartZoos [6] is another u-learning application that allows students to carry out ubiquitous learning tasks. These learning tasks are created through an authoring tool.

Teachers may encounter difficulties in facilitating pervasive activities with their students if they are unable to include learning tasks customised for individual needs. For this reason, existing solutions, as authoring tools [7], facilitate this management data. Authoring tools make it simple for teachers to generate content for their students using technologies with which they are familiar. Over the years, different authors have tried to take advantage of the benefits of u-learning and the growing popularity of personal mobile devices by developing systems that include authoring tools. An example is QuesTInSitu [8], a map-based application that supports the enactment of learning tasks located in geospatial objects through mobile devices. This application allows teachers to create learning tasks (multiple-choice questions (MCQs), multiple response and true or false) and routes. Another example of u-learning application is the aforementioned SmartZoos [6]. It includes an authoring tool that allows to position learning tasks (information, MCQs, multiple responses, freeform answer, match pairs, photo and embedded content) and to create activities (or routes) composed of different tasks. Its graphical interface is also based on maps.

In the above two examples of u-learning systems, the teachers must create the learning tasks positioned for their students. Repeating this process for a large number of tasks can become tedious and the workload can become excessive. In addition, it is possible that the information entered by teachers in such tasks may only be valid for that application ("isolated data silos" [9]) forcing teachers to repeat the creation of the content if they wish to use it in another environment and avoiding that teachers' work can be reused by other teachers. Teachers who want to generate activities on u-learning systems may also be confronted with the cold–start problem [9].

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pablogz@gsic.uva.es (P. García-Zarza)
0000-0001-5121-0786 (P. García-Zarza)

[1] https://artsandculture.google.com/

The cold–start problem occurs when users have to use a system that still lacks content because only few previous users have made contributions up to that moment.

The principles of Linked Data [10] (LD) were introduced to enhance the data sharing and reusability (avoiding silos) and its use by both humans and machines by means of so-called Semantic Web technologies. Furthermore, when LD is shared with an open license, it is called Linked Open Data [10] (LOD). There is a lot of LOD information available (as in the projects Wikidata[2] and DBpedia[3]) and some of them are already being used in the community of Technology Enhanced Learning (TEL) as LOD is suitable for education [11]. LOD datasets can be from many domains.[4] For u-learning, the geospatial domain plays a key role as it allows for more contextualised learning. For example, Wikidata repository –a general purpose repository– stored[5] more than 300,000 items that have geographic coordinates in Spain. Therefore, education-related LOD-based systems seek to take advantage of the huge amount of open data shared by different providers (in many cases, governmental agencies following open data policies), which can help to avoid cold–start problem [9].

The GSIC–EMIC[6] research group has created some applications that combine the use of u-learning and LOD to take advantage of the benefits mentioned in the previous paragraphs. An example of an application that uses u-learning in combination with LOD is "Casual Learn" [12]. It is a distributed application that offers students the opportunity to carry out ubiquitous learning tasks related to Art History via a map-based interface. The learning tasks used in this system are located in Castile and León (Spain) and were generated semi-automatically using information from multiple open repositories and a series of templates validated by teachers [13]. This early attempt is limited to a single domain (Art History) and to a specific area of Spain due to the scope of some of the sources of information used. "Casual Learn" does not have an authoring tool for teachers to generate or adapt new information or learning tasks. Another application from the same research group is LOD4Culture [14], an application that allows the visualisation and filtering of LOD information related to Cultural Heritage and it has a global coverage (its LOD sources are Wikidata and DBpedia). This application does not allow to create or carry out learning tasks. As with "Casual Learn", LOD4Culture is an application limited to a single domain and it does not allow teachers to generate or adapt existing information.

Due to the advantages offered by LOD, some of them highlighted in the preceding paragraphs, LOD-based ap-

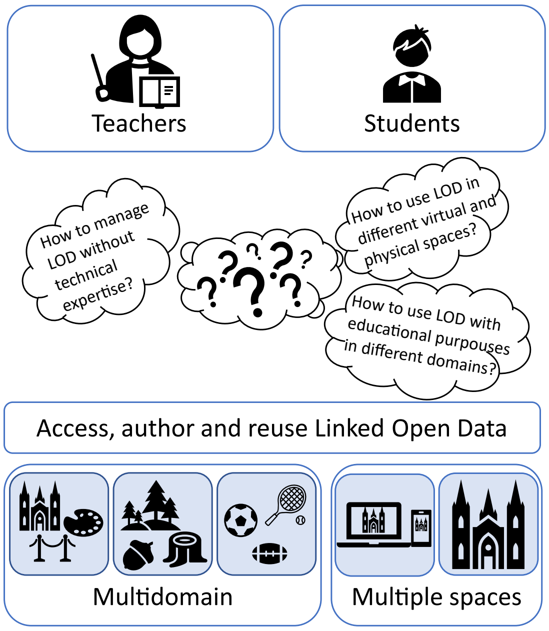

Figure 1: Stakeholders to be supported and issues to be addressed in the doctoral thesis.

plications are an excellent tool for teachers to generate ubiquitous activities. However, as Figure 1 shows, we have identified the problems shown in the following paragraphs that none of these systems fully address. A summary of the limitations overcome by each of the existing solutions in the literature can be found in Table 1. This dissertation aims to bring together the benefits of u-learning and LOD to answer these problems.

With respect to the **first limitation**, for an educational solution based on LOD it is necessary for teachers to be able to adapt and personalise information represented by means of Semantic Web technologies to their educational needs. By adapt and personalise information, we mean accessing, adding, and editing existing information so that teachers can enrich it whenever possible. Teachers are not used to working with Semantic Web technologies, so, for example, they cannot be asked to use the SPARQL language to query RDF data.[7] Similarly, teachers cannot be asked to make SPARQL Update requests to carry out modifications to information. It is necessary to provide them a human–centered interface for accessing and managing LOD in order to support u-learning. This may be of particular interest in domains where little or incomplete information is available because, as we have previously indicated, they will be able to complete and enrich it. However, the annotation of places and learning tasks can be a very tedious job for teachers if they want

[2]https://www.wikidata.org/
[3]https://www.dbpedia.org/
[4]http://cas.lod-cloud.net/
[5]https://w.wiki/6hzx
[6]https://www.gsic.uva.es/index.php?lang=en
[7]http://www.w3.org/TR/sparql11-query/

Table 1
Summary of some of the solutions found versus their limitations. Although the scenarios shown in [8] are related to Cultural Heritage, QuesTInSitu could be used in multiple domains as there is no limitation in the creation of its geolocalised questions. CHEST is the current prototype of one of the contributions of the thesis.

	Manage LOD (limitation 1)	Multi-domains (limitation 2)	Multi-spaces (limitation 3)
SmartZoos [6]	Authoring tool but no LOD		
QuesTInSitu [8]	Authoring tool but no LOD	Yes*	Yes
Casual Learn [12]	Only access		
LOD4Culture [14]	Only access		
CHEST proto.	Yes		Yes

to conduct ubiquitous activities involving many places if they have to do it manually. In an analogous way as in non-LOD-based applications for u-learning, they would have to add the places, which, in the simplest case, should include their location and description. In addition, teachers would have to add to each place the learning tasks they would like their students to carry out, and possibly some of these tasks would be similar (or the same task could be reused for several places). For this, the automatic (or semiautomatic) creation of learning tasks and places from LOD information can be helpful. Moreover, even if one teacher had to enter this information manually, other teachers could reuse it. Other authors have studied the problems of access and management of LOD outside the educational domain [15, 16].

The **second limitation** identified is related to the fact that some solutions in the literature are often related to a single domain (e.g., [12, 14, 6]). This is inefficient as teachers developing ubiquitous educational activities will have to learn to work with multiple tools. In addition, multiple tools are being developed to do similar activities in different domains (e.g., [12, 6]). Both problems could be addressed by proving an approximation that could be generalised to as many domains as possible.

Similarly, the existing solutions (e.g., [14, 6]) limit students to work in a single physical or virtual space. The **third limitation** can be a disadvantage if teachers wish to conduct activities that involve multiple spaces. Let us imagine a high school teacher that wants to explain to her biology students what the distinctive features of some species of local trees are. To do so, the teacher could base her explanation on different electronic resources (e.g., virtual maps, pictures, videos) and assess her students through an electronic form while they are in–class (virtual space). Learners who have done the preliminary activity with their teacher, on their way home from school, can use their mobile devices to physically (physical space) check the characteristics of the trees and complete the tasks proposed by their teacher (e.g., take pictures of the different types of leaves, record a video explaining the main characteristics of the tree they are looking at). In this example, learning is not being limited to a single space, it is continuous across several [17, 18] (physical and virtual space). Providing support to multiple spaces would foster one of the desired features of u-learning.

The rest of this document is structured as follows. Section 2 will present the research question and the goals to be achieved in the thesis. The methodology and the temporal organisation will be the focus of Section 3. Section 4 will discuss the current work that has been completed and the prototype's status. Finally, there will be a brief discussion in Section 5 showing the main conclusions reached and the future work.

2. Research question and goals

Given the research context and problem described before, this dissertation aims to answer the research question (RQ): **how to support teachers to exploit Linked Open Data to generate and reuse multi-domain and multi-space tasks for ubiquitous learning?**

Figure 1 shows teachers and students as the stakeholders of this thesis. Teachers are the main stakeholders of this thesis since they will be supported for making use of LOD to create and enact u-learning situations. These experiences will be composed of learning tasks and geospatial objects (known as"features" in the spatial domain [19]) positioned according to some coordinate reference system [20]. Students will also be, to a lesser degree, stakeholders. Teachers will generate ubiquitous activities so that students can learn in multiple spaces. In addition, they could also suggest new learning tasks to be carried out by their classmates.

To answer the RQ, and as can be seen in Figure 2, three goals have been defined. The first of these goals is stated as "*to enable teachers to access and author geospatial objects based on Linked Open Data for educational purposes*". Therefore, the first objective aims to work on supporting teachers to access and reuse information stored as LOD and to reduce the workload involved in generating new information or enriching existing data.

The multidisciplinary nature of the information stored as LOD is aimed to be used to answer the RQ as can be seen in the second objective, "*To provide teachers with support to generate learning tasks for different domains based on information from Linked Open Data*". The meaning of automatically (or semiautomatically) generated learning tasks for some learners or others will depend on the quantity and quality of LOD available. If the domain data to be used by the teachers is very detailed (because the data was already that way originally or because the

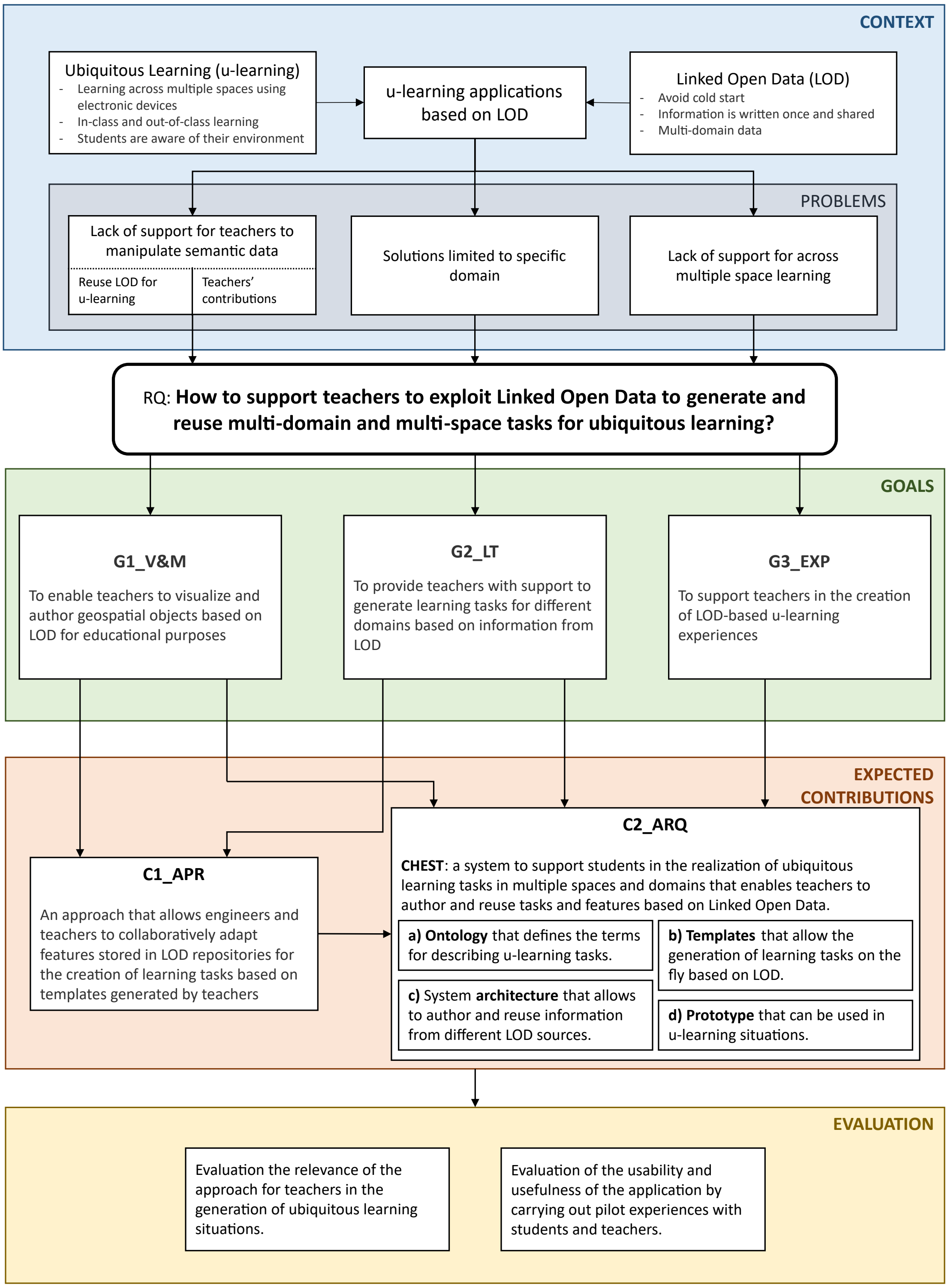

Figure 2: Thesis diagram providing an overview of the context, the research question, the goals to be pursued, the expected contributions and how the evaluation will be carried out.

teachers have enriched it through the results of the first objective) students of different academic levels will be able to use the learning tasks generated from it. However, if the available information is not detailed enough for the academic level at which teachers want to work, they may need to manually generate some of the learning tasks. An example case is a tree where only its location, a brief description and that *Pinus sylvestris* is the tree species. For elementary school teachers this information may be enough to generate a learning task to distinguish *Pinus sylvestris* from *Picea abies* (these species are often present in the same areas). However, for university teachers this information may be insufficient if they want that their students select the tree species and have automatic feedback.

Finally, the objective "*to support teachers in the creation of Linked Open Data based ubiquitous learning experiences*" aims to enable teachers to provide meaning to educational tasks by grouping them. As indicated in the example of the third limitation in Section 1, there will be teachers who want to make the experiences ubiquitous in various places (in– and out–class) by connecting the tasks that their students will carry out. To this end, teachers will need to be able to choose which tasks they want to be part of their experience and in which space learners will complete them.

3. Research methodology

The methodology chosen to answer the RQ and achieve the proposed objectives is **Systems Development Research Methodology** [21] (SDRM). This methodology is composed of iterative stages. Iterations make it possible to answer the RQ and refine it. The choice of this methodology for the development of the dissertation is due to the pragmatic worldview [23]. For me it is particularly important that the expected results of the thesis have a practical meaning (at least in the educational domain). Thanks to the composition of the phases of SDRM and the possibility to refine the research question, the results obtained will solve a latent need of the main stakeholders (teachers). Figure 3 shows the tasks to be carried out in each of the SDRM stages. These tasks have been distributed over the four years in which the RQ is expected to be answered.

SDRM consists of five iterative stages. Its first stage "*construct a conceptual framework*" the researchers have to justify whether the RQ is meaningful. In this case, the framework will be related to u-learning and LOD and it will be built using current state of the art. At this stage, efforts will also be made to define some of the domains in which the expected solution can be used. There are domains in which LOD will be able to contribute more to the educational field than in others. This is due to the amount of LOD that exists in that domain or the level of detail of its information. This phase should also define the types of tasks that can be generated and that can be most useful for teachers and students. When defining the types of learning tasks, it should be considered that the solution will support multiple spaces. It makes sense to ask students to take a photograph in the physical space but not in the virtual space. Although, for the virtual space, students will be able to search for a photograph. Another task to be undertaken in this phase will be to determine the process of creating places and learning tasks for teachers. This will also be solved by reviewing the existing literature.

After this first step, SDRM defines the stage "*develop a system architecture*" which will allow researchers to build the system by specifying its functionalities and components, and defining the relationships between these components. At this stage, the actors that will interact with the system will also be established. To this end, the lessons learned from the state of the art will be used. In the final phase of this second step, the researchers present an architecture for the system. For this thesis, the proposed architecture should take into account the different stakeholders (teachers, students and LOD repositories), and the functions they will perform (visualisation, management and reuse of content and performance of educational tasks), and the relationships that exist between them (e.g., teachers visualise and reuse LOD to generate educational tasks, students perform educational tasks designed by their teachers, LOD repositories take advantage of the new relationships generated by teachers' annotations, etc.).

The third stage of SDRM, "*analyze and design the system*", researchers will have to design how the data will be structured, the design of the interfaces to be used by users, how the communications between the distinct parts of the architecture will be designed, etc. [22]. In our case, the design of the data structure has taken into account that part of the data will be public (annotations generated by teachers) and part will be private (access credentials of users, metadata of students' answers, etc.). Moreover, popular design guidelines such as "Material Design"[8] will be used for user interfaces.

The design created in the previous stage will be used in "*build the system*" for the implementation of the prototype. This prototype should, at least partially, solve the problems highlighted in Section 1 (and shown in Figure 2). We will review existing options to ease the development of the prototype.

In the last part of SDRM, "*experiment, observe, and evaluate the system*", the researchers can check the system that their has implemented against the requirements that were established in the design stage. At this stage,

[8] https://m3.material.io/

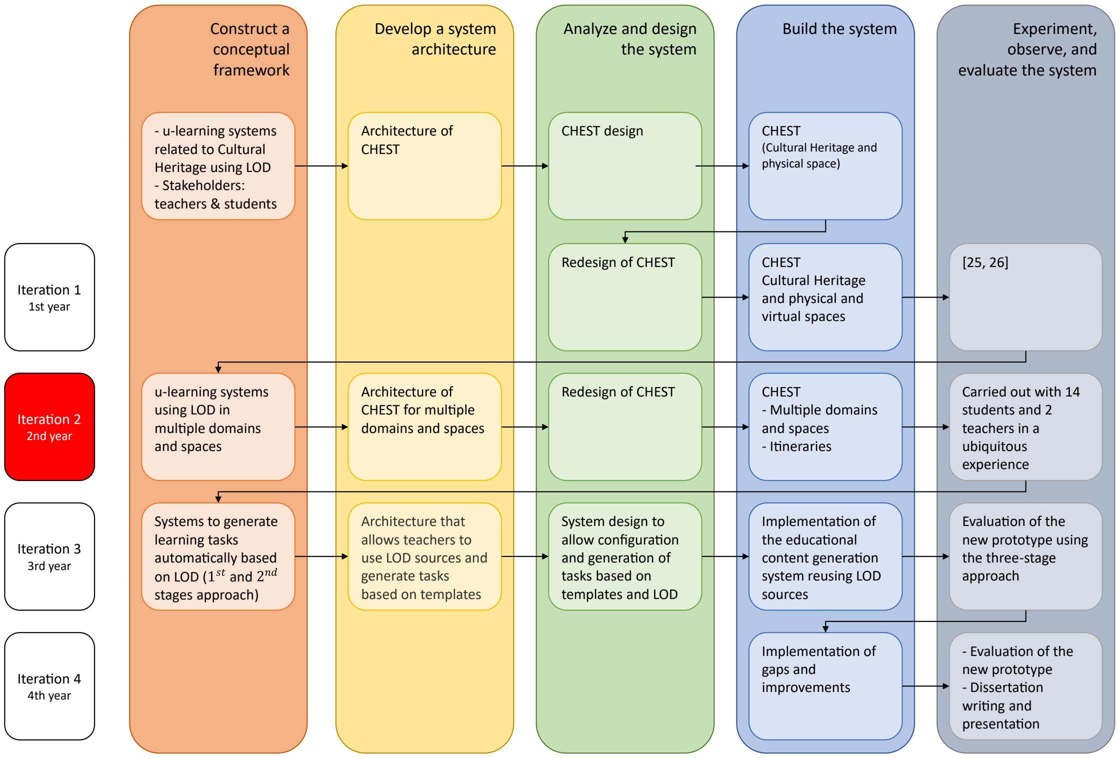

Figure 3: Representation of the SDRM [21] lifecycle in a similar way as [22] does. It shows the iteration number (in red means it is the year in which this document is being written) and the SDRM stages.

together with the teachers, the pilots for the evaluation of the system will be designed. These pilots are expected to involve both teachers and real students in which the system will be monitored. After the educational experiences have been carried out, the system will be evaluated to verify whether it is answering the research question or whether it needs to be refined. As Figure 3 shows, dissemination of the results has also been included in this stage.

4. Current progress

As it has been seen throughout the previous sections, main stakeholders to be supported in this thesis are teachers. To help them in the design and implementation of ubiquitous educational experiences based on Linked Open Data, this doctoral thesis aims to have among its expected results two contributions (as can be seen in Figure 2 and schematically in Figure 4). With the first contribution we want teachers, data engineers, and knowledge engineers together to be able to adapt information from LOD repositories to be used in education. To achieve this goal, in a first stage data engineers together with knowledge engineers must analyse the information sources to be used and relate their terms to a general ontology that will be common to all domains. This ontology will be based on the SLEek ontology [24] and has been previously extended as indicated in [25].

In a second stage, templates [9] will be generated with which learning tasks will be created on the fly. Templates are defined in [13] as a set of rules for generating learning tasks from some specific types of data. Knowledge engineers and teachers will be involved in the template creation process. At this stage the knowledge engineers are aware of what kind of data are stored in the LOD repositories to be used. These engineers should be able to pass this information on to the teachers, who are the people to provide educational value to the LOD data. They will be able to create a set of templates that can be applied to the different entities for the creation of the learning tasks. To do so, they will establish a series of restrictions (**filters**) that will limit the scope of each of the templates (e.g., for this type of question only Gothic style cathedrals are valid). In the **builder** of the template the structure of the question will be indicated (e.g., in the {{{`cathedralName`}}} take a picture of the {{{`elementName`}}}). These templates will be saved as LODs in case other people want to reuse them. The ad-

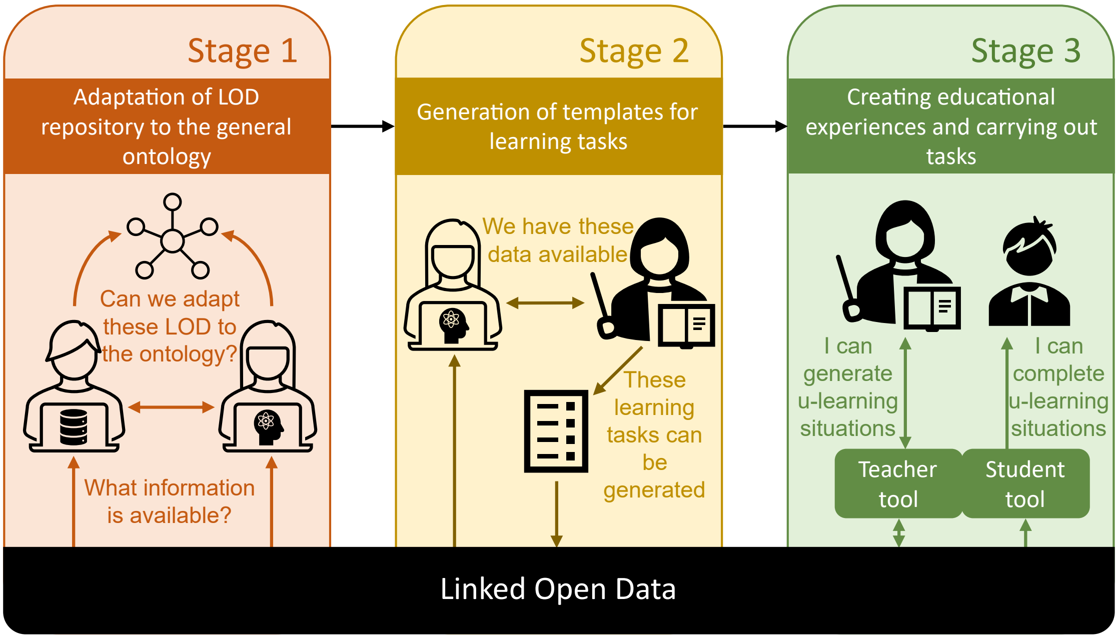

Figure 4: Stages that need to happen to incorporate a new LOD domain for educational experiences. Main stakeholders (teachers and students) are represented with a black background. Data engineers (Stage 1) and knowledge engineers (Stage 1 and Stage 2) will manage aligning the LOD information to the general ontology (Stage 1) and support teachers in knowing what information teachers can use (Stage 2). The tool to be used by teachers and students is the expected prototype of the software architecture from the second contribution.

vantage of using templates to generate learning tasks on the fly instead of materialising them is that it avoids having to store a large amount of information. In addition, the information used to generate a learning task on the fly will be carried out with the most updated data possible. However, it is possible that generating learning tasks in this way may have several disadvantages associated with it, such as the time required to recover the information necessary to generate the task. This technical problem will be studied in the thesis to decide the viability of this solution.

In the last stage shown in Figure 4, teachers will be able to add geospatial objects that are not in the LOD repositories used, generate specific learning tasks for characteristic elements of geospatial objects (tasks that would not make sense to generate from a template since they could only be applied to a single entity) and group learning tasks and geospatial objects into itineraries in order to give a broader educational meaning to the experience (as was already done by [8, 6] systems). The teacher will be free to decide whether the students must complete the itineraries in a specific order or let the students decide how to complete them. Students will be able to complete learning tasks individually or simply visualise the description of the geospatial objects. Access, and creation in the case of teachers, to the information will be done through an intermediate tool that facilitates the use of this type of data by people who are not experts in the Semantic Web. Currently, within the thesis, this is the stage in which most work has been done.

The second contribution expected from the thesis is the proposal of a distributed software architecture that makes it possible for teachers and students to utilise the results of the first contribution. In the last year, a distributed soft-

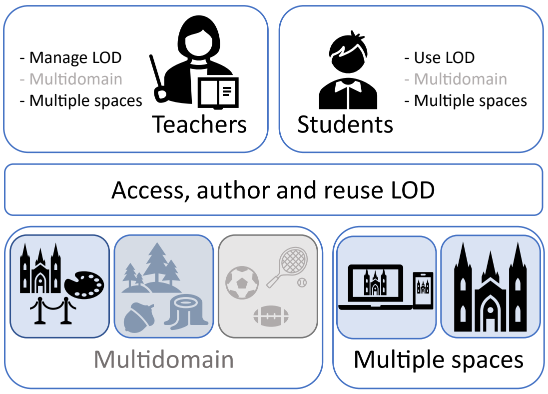

Figure 5: Problems that the current CHEST prototype aims to address.

ware architecture [25] and a prototype [25, 26] related to Cultural Heritage has been designed and developed to support teachers in the creation of ubiquitous educational situations. CHEST (Cultural Heritage Educational Semantic Tool) allows teachers to add new geospatial objects, learning tasks and itineraries to a LOD repository. The preliminary version of CHEST[9] has already been used by real teachers and students in several pilot experiences. In this preliminary version, CHEST is a Stage 3 system. As shown in Figure 5, CHEST has attempted to solve the problems related to the access and authoring of LOD information and to the possibility of carrying out ubiquitous activities in multiple spaces. However, for now it is limited to the domain of Cultural Heritage. To see if the experience gathered with the Cultural Heritage domain can be transferred to other domains, work has started with the forest domain. In this exploration, the low volume of LOD data Wikidata, the LOD repository that had been used as a reference until now, has been detected. For this reason, other data sources are being explored for domains different from Cultural Heritage. Now we are working with the information stored in OpenStreetMap[10] whose information is generated by a large community of users (over 10.6 million registered users)[11]. As future work, as shown in Figure 3, the possibility of the creation of learning tasks based on LOD and the templates explained in the first contribution remains to be explored with CHEST.

5. Discussion

In the analysis of the state of the art that brings together ubiquitous learning and Linked Open Data principles, it has been found that none of the current systems, to the best of our knowledge, jointly provide support for teachers to manage Linked Open Data and support multi-domain and multi-space ubiquitous activities. For this reason, this research thesis aims to answer the RQ: "how to support teachers to exploit Linked Open Data to generate and reuse multi-domain and multi-space tasks for ubiquitous learning?". To answer this question, it has been further subdivided into three goals: 1) to enable teachers to access and author geospatial objects based on Linked Open Data for educational purposes; 2) to provide teachers with support to generate learning tasks for different domains based on information from Linked Open Data; 3) to support teachers in the creation of Linked Open Data based ubiquitous learning experiences. It is expected that by the end of the dissertation the objective will have been achieved through the completion of two contributions. The first and most theoretical will propose a sequence of stages. These stages will indicate how, starting from a repository of LOD where a set of geospatial objects can be found, teachers can generate ubiquitous learning situations that their students can follow and other teachers can reuse. The second contribution aims to propose an architecture that supports the first contrition.

Over the development of the thesis, we have implemented a prototype that allowed teachers to generate learning tasks, LOD-based geospatial objects, and itineraries (ordered or unordered clustering of learning tasks and geospatial objects) related to the domain of Cultural Heritage. The initial data used by this system had been generated in previous work. For this reason and considering what is represented in Figure 3, CHEST is a type of Stage 3 system. As future work, the steps taken to materialise the learning tasks used as initials for CHEST should be extrapolated. In this way, we should try to extrapolate the steps followed and establish an approach that would allow the implementation of other domains such as the forestry domain or the school preservation education domain (domains where other researchers in the GSIC–EMIC research group have worked).

To check that the research question is being answered, an evaluation of the results achieved will be carried out. This evaluation will consist of testing the sequence of stages in domains that have not been worked with. For this, the involvement of teachers (who teach at different levels of education) and domain experts (data and knowledge engineers) external to the research group where the thesis is being developed will be desirable. On the other hand, a series of pilots will be developed to study how the architecture (and the prototype implementing this architecture) is able to support teachers in generating ubiquitous educational experiences and how students can carry out learning tasks in different spaces and domains.

The collaborative system that can be obtained as a contribution of this thesis is not without problems. For example, allowing teachers to create geospatial objects can lead to several teachers annotating the same object, which can hamper the overall usability of the system. This could be because, for example, teachers want to include different information in the geospatial object (e.g. a description adapted for their students), they want to own it so that they can modify it, or they simply did not realise that it was already present in the system. To avoid this problem, a number of checks will have to be made (e.g., checking that the new feature has a different name from the other near geospatial objects) and enabling a community validation system at the time of creating these features. In addition, it could be asked whether this information on geospatial objects could be more useful if instead of being stored in a public repository of the research group, it could be stored directly in a more general repository (e.g., Wikidata).

[9]https://chest.gsic.uva.es
[10]https://www.openstreetmap.org/
[11]https://planet.openstreetmap.org/statistics/data_stats.html

Throughout the Doctoral Consortium paper it has been indicated that teachers are the ones who will annotate learning tasks and geospatial objects, but why limit this annotation to teachers? Why not allow students to generate ubiquitous learning situations? It is probable that more verification systems would need to be implemented when making public the information generated by students. However, students could create activities for their classmates (and the rest of the community) with a different focus than their teachers might have.

If the expected contributions of the thesis are achieved and the contributions are successful (a large number of teachers and students from multiple domains use the system), besides the technical problems associated with all the information that could be created (and even more so if students can also annotated LOD), it could be very difficult to find specific information. For this reason, it will be necessary to adapt the information displayed to each user (for example, only show the user the tasks that correspond to their educational level) or let them filter it (e.g., students who are using the system in the domain of cultural heritage may at a certain moment want to see only the palaces of the area where they are located).

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