

Mobile Learning with Linked Open Data

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Abstract— In this paper we present a learning environment based on the integration of 2 technologies that promise to shape the future of education: the mobile technologies and the semantic web. The educational potentials of mobile learning are briefly discussed in the paper, together with some of the difficulties in running and evaluating experiences of mobile learning. Amongst these difficulties, we focus on the workload for teachers who have to organize and develop up-to-date educational contents for mobile devices, followed by the risk of rapid obsolescence of the content; we argue that by integrating Linked Open Data, one of the most challenging product of the Semantic Web, with Mobile Learning technologies we can overtake these difficulties.

In order to support our arguments, we introduce MeLOD, a mobile learning environment which exploits the huge amount of dataset in the Linked Open Data cloud to provide students with contextualized and continuously up-to-date information based on students' location. The position of the student sent by the mobile device is used to interlink and explore GeoNames DBpedia and Europeana datasets and return information about all the interesting cultural heritage sites close to the student. Moreover, students produce new knowledge items that are gathered in a dataset created within the MeLOD project, which is compliant with the requirements for the LOD cloud. Finally, typical activities performed in the Social Web, such as voting and commenting, are used to enhance the knowledge base of the learning environment and to provide recommendations for next students' visits.

Keywords—Mobile Learning, Linked Open Data, Semantic Web.

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I. INTRODUCTION

THE 8th wave of the Mediascope Europe Study [1], one of the most comprehensive research studies on how people dedicate their time to the various media in Europe, reports that more than 130 million Europeans routinely use their mobile phones to access the Internet. According to the Educause Center for Applied Research (ECAR) survey on the use of mobile technologies in Higher Education [2], students want to access academic progress information and course material via their mobile devices (such as smartphones, and tablet computers), and 67% of surveyed students believe mobile devices are important to their academic success and use their devices for academic activities. Likewise, the widespread use of mobile technology, along with the availability of efficient mobile broadband connections, offers a unique opportunity to develop innovative methods of learning as well as to develop policies aimed at participation, given that the use of mobile devices transcends age, social status, economic level, gender and ethnic origins [3]. In fact, in the last decade numerous studies about the use of mobile and wireless communication technologies in education have been reported [4]. In addition to these studies we observe an important increase of mobile learning penetration rate in some country, like Taiwan, where there are national programs and strategies for e-learning to support the innovation in educational context [5]. In the same direction, we foresee a similar trend in other countries, like Italy, where there is a wide diffusion of mobile technologies, and national government is going to adopt, in the public education system, electronic books and tablet as primary tools for learning.

According to Horizon' report [6] as well as to the roadmap of the National Science Foundation [7], Spector [8] analyzing recent research on emerging educational technologies highlighted that mobile technologies will have a significant impact on future learning and instruction.

Although the effectiveness of mobile learning has been deeply explored by researchers and academics [9][10], the evaluation of a mobile learning experience is still problematic: according to Traxler [11], when we evaluate a mobile learning experience we have to consider a number of independent

variables that influence the learning process. Actually, a mobile learning experience is a ‘noisy’ phenomenon where the context is not clearly bounded, thus introducing a higher level of difficulty when we try to analyze it. The learning context should be interpreted as a comprehensive concept including the physical context (formal classroom vs. informal sites in a town), the social context (classmates; teachers; peers; etc.) and the virtual context (including Virtual and Personal Learning Environments, e-portfolios, and so on). The Semantic Web technologies offer several opportunities to effectively design, develop and evaluate mobile learning experiences, by providing mechanisms to support activities occurring in the learning context. Specifically, the Semantic Web technologies can be adopted in order to:

- highlight other students nearby with similar profiles;
- provide mobile learners with contextual learning materials;
- identify and make explicit the ties between the learners’ profile and her/his actions in the physical and virtual context (including contacts with other learners or teachers)

In this paper we focus on the possibility to provide students with contextualized and continuously up-to-date information based on their location, by introducing MeLOD, a mobile learning environment which integrates social and semantic web solutions. MeLOD exploits the huge amount of dataset in the Linked Open Data (LOD) cloud and, at the same time allows students to produce knowledge items and add new data in the LOD cloud; furthermore, it supports social mechanisms to enhance the social learning context. Finally, data collected through the MeLOD environment, when connected to the LOD cloud, can be exploited to activate Learning Analytics mechanisms and evaluate the pedagogical impact of the mobile learning experience on the students.

In the next session, the MeLOD environment is introduced; following, a practical use case scenario is reported; section IV highlights the semantic web solutions adopted to design and develop MeLOD; then, in section V, we show how the adopted technological solutions can promote Learning Analytics mechanisms, before summing up the results of our research work in the last section of the paper.

II. THE MELOD MOBILE LEARNING ENVIRONMENT

MeLOD is a mobile learning environment that has been conceptualized to support, through the use of mobile devices, the informal learning experiences that take place during the visit of a city. The MeLOD environment fosters a learning methodology based on educational models and technological advancements which characterize how people will learn in the next years. Firstly, there is a strong emphasis on the mobility of the learners and its consequences on the learning processes, which tend to become more and more contextual, informal and ubiquitous. Secondly, the social dimension of learning is encouraged through voting and commenting mechanisms that can be straightforwardly exploited in order to deliver

recommendations and promote an online community of learners.

The MeLOD environment is composed by two main modules: a mobile application, with a friendly user interface, that shows the information to the students during their visit, and a set of web services that elaborate the requests coming from the mobile application to provide interlinked information from different open datasets. The main datasets used by the MeLOD environment are three: DBpedia, GeoNames and Europeana. When a student is visiting an area of the city, the MeLOD mobile application sends his/her position to the server. The server uses the “Find nearby Wikipedia Entries” service of the GeoNames API to establish if there are Wikipedia pages concerning cultural heritage sites which are physically located near the student’s position (considering a pre-set radius). The list of nearby places will be used to access the corresponding resource on the DBpedia ontology. The *rdfs:label* of each resource is used to show this list in the students’ mobile device. Moreover, the list of the places, together with the corresponding resources, are enriched with some extra content produced by the students, content that is made available in a MeLOD linked open dataset (MLOD: MeLOD Linked Open Datasets). Hence, for instance, in a self-directed learning scenario, a student can select, before the visit, the main topics he/she is interested in. The list of topics is directly related to the DBpedia categories expressed by the *dcterms:subject* property. In this way the system can filter the results to be shown to the students according with his/her choice, as well as with the DBpedia category related to the cultural heritage sites. Instead, in a teacher driven scenario, the teacher selects a set topics to design a learning activity and to guide students in focusing their attention to the selected topics. In such a scenario, student will access only a subset of information available in the open dataset linked.

The methods implemented by the *RESTful API* of the MeLOD environment can be divided into three groups:

- Authentication and configuration: manage users authentication and personalization features, in order to configure the environment for personal learning.
- Geo-located information: provides the mobile learners with contextual learning materials, by exploiting the Linked Open Data capabilities;
- Social activities: identify and make explicit the ties amongst the learners’ profile and her/his interaction with the context (other learners and learning materials);

These aspects have been implemented with the aim of supporting the development of specific mobile learning assessment tools on top of the MeLOD environment.

A. User Authentication and personalization

Mobile devices are more and more often used to support personalized learning experiences. In the MeLOD environment specific methods suitable at supporting this aim have been developed. In particular, students before starting their visit of the city have to indicate their preferences related to language, categories of interest and preferred media type. The language

setting is used to identify the right DBpedia translation to be used for providing learning materials. Indeed, the translations of the DBpedia dataset are recently increasing, thus allowing the access to localized version of the contents. In this way internationalization issues are faced.

The MeLOD environment allows students to select the categories of interest for their visit. However, as introduced in the preview section, this choice is not available in a teacher driven activity where the categories are fixed and students cannot modify them. The list of categories are retrieved from the main topic classifications of the DBpedia category tree. These categories are queried from DBpedia using the following SPARQL query :

```
PREFIX skos:<http://www.w3.org/2004/02/skos/core#>
category:<http://dbpedia.org/resource/Category:>
SELECT ?category WHERE {
?category skos:broader
category:Main_topic_classifications
}
```

Example values from the previous query are: Education, Geography, History, Arts, Life and so on.

Finally, students can select their settings related to the preferred media type. In this way students can decide to receive contents in different formats (only text, text and images, multimedia formats and so on) depending on the technical capabilities of their device or on the reliability of the network (GPRS, 3G, Wi-fi) they are using for accessing the environment.

B. Managing geo-located Learning Material

Creating learning materials suitable for mobile learning context requires a notable effort. In fact, learning content must be usually prepared in advance by teachers and maintained during the whole lifespan of the application; in addition, teachers are required an extraordinary effort to organize the information for mobile devices, especially when they are not supported by a permanent technical group, as more and more often happens in public high schools. As a consequence, teachers can only develop a limited amount of learning materials, thus reducing the type and the number of learning activities they can plan.

The teachers' effort can be simplified if the learning is already available somehow. For example, if they plan a visit to the town (which is a common activity at school), the most popular mobile stores (Apple and Android) already include, in their catalogs, several applications providing specific information about hundreds of cities in the world. This information can be used to support successful the visit of a city, also during a visit related to learning activities. Nevertheless, the information provided by these applications is usually extracted from proprietary data source, and cannot be easily customized to be really suitable for learning settings. By exploiting the huge amount of datasets in the Linked Open Data cloud, MeLOD overcomes the previous issues

Moreover, the MeLOD allows users to add geo-localized information. In particular, students can update information

provided by the DBpedia, Europeana and GeoNames datasets by posting a photo, updating information or adding in-depth information of a point of interest (POI). Students can also create new information items to be added to the LOD cloud: for example, if MeLOD does not provide them any information about a place of interest correlated to their position (because there is no node in the linked dataset), students can create a new information node. This type of information is related not only to the geo-located position, but also to the place, or better to the concept semantically representing that place (for instance the DBpedia resource related to the Cathedral of Palermo (<http://dbpedia.org/resource/Palermo_Cathedral>)). In such a way, students produce new knowledge that will be collected in the MLOD, the dataset created within the MeLOD project. The new information nodes (updated or newly created) are then linked with other resources available in the DBpedia, Europeana and GeoNames datasets by using categories. In such a way the real world experience carried out by the students is a mean to create new Linked Data:, the data produced by them are actually linked with the concepts related to the places they have visited. In fact, the MLOD dataset fulfills the requirements for the LOD cloud, and it will be included in the LOD cloud in the near future.

At the time of writing we are developing an interface for teachers to verify the knowledge items added by the students in order to guarantee a quality mechanism in the publication procedure. In particular we are implementing a double step process: in the first step all data are stored in MLOD and a "to_be_verified" state will be associated to them. In the second step, teachers or experts of contents, verify the data and their state is changed to "verified" so that they can be moved in the part of the dataset publicly accessible (Figure 1).

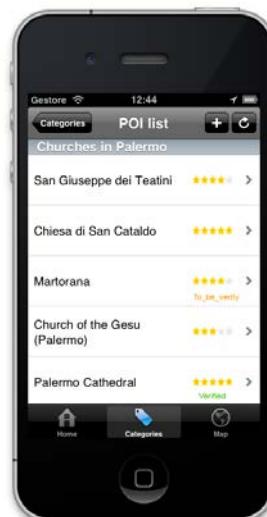


Figure 1 – Resources in the MLOD dataset shown on the mobile device screen

Furthermore, the MeLOD is capable to provide users with localized information by using the DBpedia internationalization features. In fact, DBpedia has its contents

translated in several languages, thus providing localized contents.

C. Social learning activities

Learner's profile has a significant role in carrying out personalized learning experiences. This aspect is more relevant in mobile learning than in traditional settings since personalization aspects concern not only the learner's preferences (e.g. subject, type of learning resource, editorial features, and so on) but also the technical capabilities of the devices, which influence the kind of resources accessible through the device. In the MeLOD environment students can choice the type of content to receive. As mentioned before, students can prefer to receive text and images but not video contents. The preferences of the students are properly stored in the MeLOD environment, using specific entities of the MeLOD ontology (described in section IV). Moreover, specific simple rules expressed using the RIF (RIF Rule Interchange Format) language are defined, in order to identify the layout to be used to display the information on the mobile device depending on the preferences of the students and also considering the information available for the resource. Indeed, the datasets used to retrieve information about learning resources (DBpedia, Europeana and the MLOD dataset) can contain different type of media for the resources

One of the most important and innovative features of the MeLOD environment is the possibility to enrich the learner's profile not only with the places s/he has visited, but also with information about her/his learning interests, information which is inferred by analyzing the cultural heritage sites s/he has visited. In fact, the use of the Semantic web technologies enables inferring mechanisms which exploit the potential of the Linked Open data cloud, and makes it possible to connect the specific cultural heritage visited by the learner to a upper level concept, thus moving from particular instances to general concepts. Both the DBpedia and GeoNames datasets as well as the MLOD dataset can be queried in order to connect concepts, considered that all the learners' activities are related to the location in which the activities take place.

The social activities of voting and commenting performed by students during a visit of the city are central to the pedagogical models behind the mobile learning experience presented in this paper. These activities are also used to feed new knowledge into the student profile.

Data regarding the cultural heritage visited by each learner, the educational materials accessed by him/her, the learning interests inferred by the system, the votes and comments published by the learners, in relation to the time when and location in which every single activity takes places, provide a unique data source that can be exploited in order to improve the analysis of the learning experience, for example through Learning Analytics mechanisms, provide feedback to the learners and teachers, and activate a redefinition and adjustment of the mobile learning activities.

For example, following Ferguson and Buckingham Shum [12], most of these data can be exploited to identify social

behaviors and patterns which prove particularly effective to achieve learning objectives

III. LEARNING WITH MELOD

In this section a use case scenario of the MeLOD environment is presented .

1. The first step is the Login. Users have to insert their username and password to access the MeLOD environment. After the Login, the home page shows a welcome message with a short description of the application, and a menu to access the main functionalities.

2. The second step is the setting of the students preferences (see Figure 2). In particular, the user can select language, preferred media format and categories (if applicable, depending on the using scenario). These preferences will be used to feed the user's profile. In the preferred media format menu students can select the media to be used for visualizing information. For example, the users can select the media format most suitable to the bandwidth of the available mobile network (3G, EDGE, GPRS). The preferred categories menu allows the users to select the macro categories that better fit their interest. The content will be filtered according to these preferences. As stated in the previous section the categories are directly retrieved from DBpedia through the Sparql endpoint.

3. Once the user has selected his/her preferences, the system is ready for use. By clicking on the "Map Menu" in the Home page, the point of interests (POI) near the position of the user will be shown. Only the points of interest belonging to the categories preferred by the user will appear. This view is created by integrating the information coming from the GeoNames API (for the geographic positions) with the information coming from DBpedia and the MLOD dataset.



Figure 2 - Setting User preferences

4. By clicking on each POI in the map, as well as in the list of POIs, students access a specific page related to the POI to

get further information retrieved from DBpedia and/or MLOD. The layout of the page is chosen accordingly with the students' preferred media format and the type of information available for the selected POI (photo, video, text). Then, students can update textual information or add new photos to the POI they are visiting. Finally, by clicking on the Vote button, the user can vote and provide personal comments the POI (see Figure 3).



Figure 3 - Point Of Interest page and voting interface

5. Whenever students cannot find any information about a place they consider as a very interesting point of interest for the learning activity, they can create a new POI. Providing a name, a textual description, a photo (suggested) and some other specific information, students will add new information empowering the MeLOD experience for them and further students.

IV. ONTOLOGY DEVELOPED FOR THE MELOD ENVIRONMENT

The MeLOD environment is based on semantic web technologies, all the information are stored in a *OWLIM* triple store, and an ontology has been defined in order to represent all this information. In our approach several commonly used ontology to represent people such as FOAF, or GeoNames to represent longitude and latitude of points in a map have been combined with an upper-level ontology related to learners' profile and activities. The main classes of this ontology are:

- User: this class is used to identify users within the MeLOD environment. In particular, information related to name, surname, email are stored.
- Configuration: this class represents the configuration parameters for each user in the system. In particular, this class stores information related to users preferences such as: preferred language for the learning resources, or preferred media type depending on the hardware capabilities of the mobile device of the Users.
- Session: this class represents the learning session

associated to the Users. For each User there will be more sessions.

- SocialActivity: This class represents the social activities performed by the Users. In this version of the MeLOD environment, the two social activities of voting and commenting have been represented.

- Track: This class is used to store the information connected with all the activities carried out by the Users.

Several properties have been defined to express the relationships between classes, such as *hasSession* to represent relationships between users and their learning sessions, or *hasTrack* to identify the tracks occurring within a learning session. It is important to highlight that the MeLOD environment tracks the activities of the students exploiting the expressiveness of the RDF language. In particular, the designed ontology has been used to represent specific actions supported by the MeLOD environment. In the prototypal stage in which the system is at the time of writing, the attention has been focalized to students' actions related to the request of contents during their visit, and the social activities of commenting and voting performed during the visit. Thus, each student is connected to his sessions through the *m:hasSession* property. Then sessions are connected to the Tracks through an RDF triple, with the *m:hasTrack* property. Each track is identified by its type and its location. The type is used to identify if the action is a social action or a request for contents, while the location is used to identify the place in which the action occurred

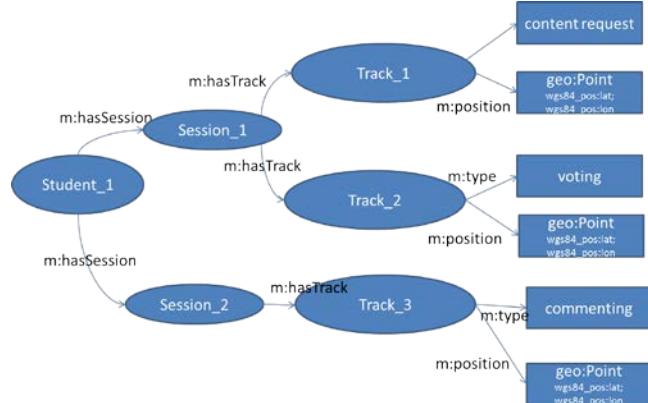


Figure 4 - RDF graph of students actions

Figure 4 shows a naïve example of three tracks for a student, two of them are related to voting and commenting, while the third one regards the request of contents during her/his visit. The activities of the student produce facts that can be added to the knowledge domain.

Tracking students' activities by means of an RDF model supports the implementation of data mining processes that can potentially take advantage of the meaning expressed by semantics contained in the relationships between concepts. The semantic approach enables further inferences on the analysis of the data. Statistical data mining can be still accomplished, since the RDF graph can be queried in order to extract information expressed by numeric values. Moreover,

the RDF model expresses direct connection with entities in popular ontologies, thus activating analysis based on semantic relationships.

To make an example, most of the municipalities provide data on the cultural heritage compliant with the LOD principles [13] thus providing interlinks with data provided by other datasets in the LOD cloud, such as DBpedia. Municipalities' data include general information on the opening hours, number of visitors, and do on.

In our environment, the students' actions that occur near a cultural heritage are connected with the corresponding concept in the DBpedia ontology. In this way, all data related to that cultural heritage contained in the municipality datasets are automatically linked with the students' data logged by MeLOD, and can be compared with available data regarding the most visited cultural heritages. In such a way, the environment can recommend popular places that have not been already visited by the students.

V. ANALYSING THE LEARNING EXPERIENCE

In the MeLOD environment the assessment of mobile learning experience is carried out using a dashboard. The dashboard is developed following a plug-in based approach in which the core of the system can be gradually expanded with new plug-ins. The developed dashboard has been designed with the aim of providing visualization tools for helping teachers in monitoring the activities of the learners. In this initial stage we addressed our attention to the analysis of social activities and how to extract interesting clues that can be used to enhance learner experiences.

The following charts are available to the teachers:

- bar charts representing the number of actions performed by each student. Teachers can also configure the dashboard to take into account different type of actions such as: voting, commenting, searching cultural heritage on the map, send message to nearby students, and so on.

- A pie chart representing the percentage of actions performed by each student

- A pie chart providing hints about the participation of the students to the activities under investigation by the teacher.

These charts can be used by teachers to respond to the following questions:

- How students participate to each activity?
- Which activities are more preferred by each student?
- What are the most used activities by the whole class?

The following SPARQL query has been used to extract the action performed by each student in their learning sessions, through the tracks related to each session.

```
PREFIX melod:<http://melod.pa.itd.cnr.it/ontology/>
SELECT ?student ?action (count(?action) as ?actionCount)
WHERE {
  ?student melod:hasSession ?session .
  ?session melod:hasTrack ?track .
  ?track melod:hasAction ?action
}
```

```
GROUP BY ?student ?action
ORDER BY DESC (?actionCount)
```

Moreover a specific section of the dashboard shows the analysis of the activities for a selected student.

This page can be accessed by the teacher selecting one of the students from the list of student, and it contains:

- the map with the cultural heritages visited by the student,
- a gauge chart for each activity under examination selected by the teacher (a maximum of eight gauge charts can be displayed). Each gauge chart indicates the participation of the student compared with the mean of the whole classroom.
- the list of activities performed by the student, ordered by date (most recent at the top).

The analysis of learner activities on the map can also be relevant to identify qualitative clues on the learning experience. For instance the following scenario can be useful to reveal cultural heritages that were not considered during the planning phase of the learning experience: the teacher defines a learning task consisting in the visit of a limited area of the city with the objective of finding and commenting several cultural heritages belonging to a specific architectural style or period (for example: Baroque churches). Teacher can select the subjects by choosing amongst the topics of the DBpedia categories (in the example Baroque Churches are represented by the correspondent DBpedia concept). During their visit, students comment the churches that – according to their knowledge – are related to the topic chosen by the teacher. When a student comments the church, his position can be used by the environment to identify the cultural heritage he has commented. The DBpedia dataset provides relationship between the cultural heritage and its corresponding categories, thus it is possible to provide indications whether the student has achieved the objective of commenting the Baroque churches or not.

Furthermore, if many students report the same place as related to the target topic, and there is no link in DBpedia with that topic, the teacher can verify if the cultural heritage (that is in that place) belongs to the target topic and add it to the environment. In this way new knowledge coming from the real experience of students and produced on-site is fed into the knowledge base of the environment, thus providing the substrate to activate social knowledge building processes. The pedagogical framework behind this approach is under investigation and will be implemented in future version of the environment.

Two new plugins are under developing and will be added to the dashboard in the near future. In particular, a plugin to provide suggestion of similar pathways followed by students is under development. This plugin exploits Association Rules technique to provide recommendation related to the cultural heritages to visit during the learning experience, based on the sequence of cultural heritage visited by students in previous learning experiences. Moreover, a new plugin to aggregate students that have performed similar social activities of voting and commenting, in the same location by using clustering

technique is also under development.

VI. CONCLUSION

The Semantic web has recently gained an increasingly interest from educational technologists, thanks to the several and different potentials offered by its technological solutions. Amongst them, the Linked Open Data mechanism has provided the technological infrastructure to publish data that can be linked to facilitate integration and interoperability. In the educational sector this revolution has led many higher education institutions to publish data related not only to the organization and administration areas, but also to courses and learning materials in general. Recently, initiatives related to the use of the LOD in the educational field are expanding towards other educational levels, such as colleges and high schools. Consequently, many datasets have been developed and a huge amount of linked data are made available and can be exploited for educational purposes.

In this paper we have presented MeLOD, an application that integrates mobile devices and semantic web technologies (particularly the LOD) to support innovative formal and informal learning strategies for high school students.

Defining MeLOD precisely is not easy: actually, it combines the results from many research fields: firstly, it can be defined as a Mobile Learning application, since it is based on mobile devices, allows users to study every time and everywhere, provides formal and informal learning contexts and students' activities depend on their physical location. Secondly, as most of the mobile learning systems developed during the last few years, it is a social learning environment, by providing specific mechanisms to support social activities by the students. Then, MeLOD is a semantic web application, by including function mechanisms which are typical of the new vision of the Web. Finally, MeLOD is an example of application of the Linked Open Data paradigm.

The combination of these different facets of MeLOD makes it a unique learning environment, and its potentials need further investigations in order to demonstrate that they can be transformed into real and practical benefits for students and teachers.

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