A Mobile Learning Scenario improvement for HST Inquiry Based learning

J.M Gilliot
Telecom Bretagne
29238 Brest Cedex3
+33 2 00 14 53
JM.Gilliot@telecom-bretagne.eu

S. Garlatti
Telecom Bretagne
29238 Brest Cedex3
+33 2 00 14 53
serge.garlatti@telecom-bretagne.eu

I. Rebai
Telecom Bretagne
29238 Brest Cedex3
+33 2 00 14 53
issam.rebai@telecom-bretagne.eu

C. Pham Nguyen
Faculty of Information Technology
227 Nguyen Van Cu St. Dist 5, Ho Chi Min Ville, Vietnam
pncuong@fit.hcmuns.edu.vn

ABSTRACT
We investigate how the three technologies, social media, mobile / pervasive learning and semantic web, may enhance Inquiry-Based Science Teaching (IBST) approaches and digital literacy. IBST may be defined by engaging students in: i) authentic and problem-based activities, ii) experimental procedures, iii) self regulated learning sequences, iv) discursive argumentation and communication with peers. We analyzed the benefits of each technology and their combination. From an existing IBST learning scenario, we propose an innovative one based on the convergence of the three following technologies: social media, mobile / pervasive learning and semantic web.

Categories and Subject Descriptors
K.3.1 [**Computer Uses in Education**]: Collaborative learning

General Terms
Experimentation

Keywords
Mobile Learning, Pervasive Learning, Social Media, Semantic Web, Scenarios, IBST, HST.

1. Introduction
As most of resources are available as numerical data, and as many exchanges may now be managed through ICT, Digital Literacy has to be integrated in the curriculum. Social media tools (or Web 2.0) are adequate environments to foster digital literacy and collaborative knowledge sharing and building. Beyond technical tools, Digital Literacy refers to high levels of proficiency of knowledge. DIGEuLit project [1] proposes the following definition of Digital Literacy:

> "*Digital Literacy is the awareness, attitude and ability of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyze and synthesize digital resources, construct new knowledge, create media expressions, and communicate with others, in the context of specific life situations, in order to enable constructive social action; and to reflect upon this process.*"

Social media applications are relevant tools to support digital literacy. They are widespread and have already gained acceptance in learning giving raise to the concepts of e-learning 2.0 [2]. The notion of Personal Learning Environments (PLE) has emerged from the combination of Web 2.0 and social media applications to support learning. [3, 4] advocate for personalized and social environments (in other words PLE). Indeed, social media applications tools offer new opportunities for users, learners and enable new collaborative activities that are suitable for learning. M. A. Chatti defines PLE as follows:

> "*A PLE is* characterized *by the freeform use of a set of lightweight services and tools that belong to and are controlled by individual learners. Rather than integrating different services into a centralized system, the idea is to provide the learner with a myriad of services and hand over control to her to select and use the services the way she deems fit. A PLE driven approach does not only provide personal spaces, which belong to and are controlled by the user, but also requires a social context by offering means to connect with other personal spaces for effective knowledge sharing and collaborative knowledge creation.*"

Interestingly, Gilster [5] emphasizes critical thinking rather than technical competence as the core skill of Digital Literacy. Critical thinking is rather central in any Inquiry based methodology. Inquiry Based Science teaching (IBST) may be defined by engaging students in: i) Authentic and problem-based learning activities which are ill-defined and have several answers; ii) A certain amount of experimental procedures, experiments and activities involving practical experience of equipment and including searching for information; iii) Self regulated learning sequences where student autonomy is emphasized; iv) Discursive argumentation and communication with peers ("talking science"). From an educational perspective, social media applications including blogs, wikis, rich media sharing, etc. fit well with socio-constructivist learning approaches as they provide spaces for collaborative knowledge building, self-regulated learning sequences, discursive argumentation, communication with peers and reflective practices. In other words, they are very good tools to support digital literacy and IBST approaches.

History of Science and Technology (HST) may be seen as a fruitful approach of IBST, and has been investigated in a previous European FP7 Project, called Mind The Gap. Its objective was "to stimulate a more engaging and interesting science teaching based on principles of IBST so that more young people in general, and girls in particular, wish to pursue educations and careers in science and technology". Importance of Technology Enhanced Learning was acknowledged in this project as work package 5 was dedicated to the role of ICT in IBST [6, 7].

Engaging students in the above-mentioned learning activities requires defining relevant problems and corresponding scenarios that enable learners to achieve those activities, according to teacher's didactic intentions. Teaching in the context of History of Science and Technology provides a rich context for pedagogical scenarios. The three technologies, social media, mobile/pervasive learning and semantic web may enhance theses scenarios and foster the corresponding learning experience. Social media applications suit well the IBST and digital literacy features. Mobile computing promotes authentic and problem-based learning activities and practical experience because tools, communications and information access are available at any place, at any time by means of mobile devices and Internet access. By means of pervasive computing, the physical environment is more directly related to learning goals and activities and the learning system can be dynamically adapted to the learning context. In other words, pervasive computing can filter the information flow to reduce it to the most relevant ones and fit well the learner needs. "keyword" search engines cannot deal with social media applications distributed over Internet and the pervasive computing. Such engines are unable to filter and reuse automatically information to provide the most relevant to the learners. On the contrary, the semantic web approach is able to deal with such issues.

Our main contribution is to show how the convergence of social media applications, mobile/pervasive computing and semantic web can increase the constructive learning processes of HST scenarios and the digital literacy of students. We aim at proposing how to enhance an HST scenario as collaborative and pervasive scenarios, and how semantic web facilities enable such learning process. The objective is to guarantee seamless access to information across tools to enable effective collaboration in groups and to enhance tutors' activities.

The paper is organized as follows: we firstly show how mobile/pervasive can support inquiry-based science teaching. Secondly, we describe an existing IBST scenario. Thirdly, we examine how social media and mobile / pervasive tools can enhance learning experience, involving mobile and distant collaboration. Finally, we describe our current semantic integrated prototype tool, before concluding.

2. Pervasive and Social learning environment as support for IBST

In this section, we analyze the mobile and pervasive computing enabling us to enhance IBST scenarios and how their integration with social media applications complements each other. The benefit of each technology is analyzed in depth and we show how their integration enables us to provide a richer learning environment. First of all, we show how mobile devices, connected to Internet, facilitate information access. Secondly, pervasive learning is analyzed according to pervasive computing facilities. Finally, the integration of the three technologies is detailed.

2.1 Mobile Computing for Information Access

In computer science, mobile computing is mainly about increasing our capability to physically move computing tools and services with us. The computer becomes an ever-present device that expands our capabilities - by reducing the device size and/or by providing access to computing capacity over the network [8]. At the same time, it provides camera and microphone, which enables capture of User Generated Content, witnessing current situations, experiments or activities. This content may even be geo-localized thanks GPS sensor. Mobile learning is not just about learning at anytime, at any place and in any form using lightweight devices, but learning in context and seamless learning across different contexts [9] [10] [11]. It is best viewed as mediating tools in the learning process [10].

Mobile devices are especially well suited to context-aware applications because they are available in different contexts and they can enhance the learning activity according to the current context. In other words, learning may occur in location and time, which are significant and relevant for learners.

As mobile-networked technology enables people to communicate regardless of their location, using mobile devices connected together through Internet or local networks can enhance collaborative learning. Thus, mobile learning becomes a social process that links learners to communities, people and situations. Moreover, mobile learning can increase the potentialities of the personal learning environments because they will be available at anytime and at any place.

2.2 Pervasive Services to enable context aware learning

Generally, mobile learning systems do not have the capability to inquire, detect and explore their environments. In other words, the context is implicit. This is because the device cannot obtain information about the context in which the computing takes place and adjust it accordingly. In pervasive computing, the computer is context-aware and has the capability to inquire, detect and explore its environment to obtain information and to dynamically build environment models. This process is reciprocal as the environment also does it and becomes "intelligent". We consider pervasive and ubiquitous learning as an extension to mobile learning where the roles of the intelligent environment and the context are emphasized. Many definitions of pervasive and ubiquitous learning are given in the literature [12], [13], [14], [15]. We can cite the following one "Pervasive learning environment is a context (or state) for mediating learning in a physical environment enriched with additional site-specific and situation dependent elements – be it plain data, graphics, information -, knowledge, and learning objects, or, ultimately, audio-visually enhanced virtual layers" [13].

In pervasive learning, the physical environment is more directly related to learning goals and activities and the learning system is dynamically adapted to the learning context. In other words, the physical environment is directly related to learning goals and activities. In history of science and technology (HST) approach (as a fruitful approach of IBST), a pervasive learning environment can provide situated learning activities that are particularly relevant in a given context.

For instance, mobile learning environments enable us to set up activities on historical sites, which are relevant for HST approach. Pervasive learning environments can provide recommendations to foster self-regulated learning sequences by student, discursive argumentation and communication with peer according to the current context (localizations, student groups, groups and/or students activities, past history of activities and accessed resources, etc.). In other words, pervasive learning environments can filter the information flow to reduce it to the most relevant ones and fit well the learners and tutors needs.

2.3 Social, Mobile and Pervasive integrated to provide a Rich Learning Environment

In short, Web2.0, mobile and pervasive environments may be integrated to offer rich learning environments. They can reinforce proper scenario based on authentic problems.

Different Web2.0 services may reinforce the IBST characteristics. Many source management tools exist like Zotero, Diigo or

Delicious that enable documents or URLs storing, organization and sharing. They are now an indispensable complement to search engines. As noted before, knowledge construction is a collaborative process, any tool that enable collaborative writing, or sketching will be relevant, in order to annotate experimental process. Blogs, or their extensions, e-portfolios or social networks, are different tools that enable self-publication. They are well fitted to support self & groups reflection, enabling to support development's process conducting to self-regulation and autonomy. All web2.0 tools encourage group and social interactions, and thus empower peers' exchanges.

Mobile devices, by allowing data generation and access anytime anywhere, and in situation increase all previous tools effects. Finally, pervasive functionalities may ease information access and future data processing by filtering relevant resources according to the current situation.

Adopting any of these facilities is a matter of convenience, for the teachers and students as well. It may be included as scenario's instruction, or it may be socially discussed among the groups or the class itself. As we explained why and how social media applications (or PLE) and pervasive computing might support HST scenario, we can analyze an original HBST scenario and then how to enhance it.

3. An existing HBST scenario

In this section, we choose an example based on a historical problem of technology - the swinging bridge of Brest over the Penfeld (1861-1944). First of all, the complete problem to solve, dedicated to in-service teachers at primary school, is composed in the three following sub-problems: i) Problem 1: understand the industrial landscape in the area of the bridge (Brest is a shipbuilding arsenal for the Navy)[1]; ii) Problem 2: understand the historical and technological method of problem solving that led to the construction of the swinging bridge[2]; iii) Problem 3: understand the rotating mechanism of the swinging[3].

For the sake of simplicity, we focus only on the problem 1 in this paper. A typical scenario for an Inquiry-based learning approach, adapted to the problem 1 and the teachers' curriculum is as follows:

1. Problem analysis in small groups (at school): the problem will be based on an open question, such as evolution of industrial landscapes.
2. Activation of prior knowledge through small-group discussion (at school): the group has to determine the well-known keywords (as prior knowledge) and the unknown keywords (knowledge to acquire), in this case concerning bridges and cranes. Printed readings are available as gathered information. Activation of prior knowledge through small group discussion. The group has to determine the well-known keywords (as prior knowledge) and the unknown keywords (knowledge to acquire).
3. Elaboration of a common strategy to find needed information: for instance, why a bridge, where and how? The group explores the information space, quickly. It defines the set of activities, which will be achieved in cooperation (activities distribution) or in collaboration (all together).
4. Collaborative work and exploitation (at school and on site, Brest Harbour). A first work may be to localize current and ancient buildings on a map to define the track of the walk. During the walk, they have to take pictures and interact with the tutor, to gather a maximum amount of information. After coming back, they have to upload, organize and publish pictures.
5. Collaborative report writing (social knowledge construction), final problem solving in classroom by exploitation of corpus (gathered information, maps, pictures, etc.).
6. Institutionalization (tutor synthesis, in classroom).

Technically, this scenario is based on mobile devices (camera) without communication capability and on availability of a trainer during the walk and on a public site to share pictures after the walk. More precisely, the instructions given by the trainer for situated activities, at the stage 4 of the above-mentioned scenario, are: from a walk up the Penfeld from Lift Bridge Recouvrance (meeting place on the parking lot of the Tour Tanguy) and by relying on the gathered historical information before the visit about cranes, bridges and views of the arsenal, you have to: i) Photograph all elements of the current landscape with historical aspects about cranes and bridges of the arsenal; ii) Locate the different elements on a current map of Brest; iii) Identify and photograph the actual bridges and cranes linked existing bridges and cranes from previous ones: What "continuities"? What "ruptures"? on the site, iv) Store and publish information on the corresponding tools.

Three notebooks (with historical pictures) about cranes and bridges, the industrial landscape in the arsenal of Brest and maps of the port were printed and distributed to the students at school. Four groups of three in-service teachers were constituted and each group got a digital camera. The teacher trainer went with the groups. He interacted with the students to give advices, guidance and answers to queries all along the walk on the explored site. After the return in the classroom tooled up with PC and Internet connection, each group stored and published on a Google site the pictures taken during the walk.

After the walk, the next session (in classroom) was devoted to the exploitation of the corpus of pictures, guided by the trainer: i) to analyze the continuities and the ruptures observed in the history of the industrial landscape; ii) to understand the historical context and the industrial environment of the swinging bridge in Brest. The session ended by the institutionalization of the knowledge by the trainer. This is already a rich scenario with introduction of basic mobile technology as support of learning. However, collaborative and pervasive tools, involving mobile and distant collaboration, could enhance the learning experience on site and at school.

4. Enhanced scenario

According to trainers' needs, we revisit the existing scenario to propose new learning services that may be combined. These new learning services are based on personal, mobile and pervasive learning environments. Thus, PLE provides personal spaces and enable users to be connected to other personal spaces for effective knowledge sharing and collaborative knowledge creation. Combination of social and mobile activities provides additional opportunities, enabling collaboration among different sites. Moreover, pervasive learning environments enable situated learning activities (difficult before, sometimes impossible) that are particularly relevant in a given context and closely related to the

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[1]http://plates-formes.iufm.fr/ressources-ehst/spip.php?article17

[2]http://plates-formes.iufm.fr/ressources-ehst/spip.php?article18

[3]http://plates-formes.iufm.fr/ressources-ehst/spip.php?article24

learning context (the physical environment, localizations, student groups, groups and/or students activities, past history of activities and accessed resources, etc.).

Firstly, we describe potential relevant activities according to the original HBST scenario in using social media tools and pervasive computing. Secondly, we propose an enhanced scenario, based on this study.

4.1 Potential relevant activities

An analysis of the existing scenario is based on the identification of activities, already existing, or that may be potentially added. Such a review may conduct to following potential activities.

Web environment, by providing social media tools and PLE-based organization enable some relevant activities in an IBST situation:

- Shared bibliography, in groups, and among groups.
- Synchronous and asynchronous communications with distant collaborators.
- Collaborative writing or media construction (maps, pictures, mind maps,).
- Peer assessment is easy, thanks rubrics through online forms (that may possibly be defined by students themselves).
- Self-reflection, thanks personal publications like blogs or e-portfolios.

Mobile computing gives some basic, but very powerful facilities:

- Data acquisition: for instance, smartphones provide geo-localization that may be added to pictures that may facilitate map marking.
- All groups may communicate with the teacher, even if not at the same place.

As soon as Internet is available across mobile devices, it is possible (and interesting) to divide student groups into subgroups to increase information retrieval and collaboration at distance. A group can be divided into three subgroups on different locations: one at the historical site (port), one at the Navy museum and the third one at the local public records. Thus, a subgroup can search for specific information in its location, publish it, exchange with other subgroups and discussion with them according to new needs or questions. Consequently, Internet access in mobility may offer some options for groups' organization:

- Data upload: pictures taken may be directly uploaded to any site. That will facilitate post-walk work, and that enable sharing among participants. This facility may be exploited in groups, but also between groups, according to course scenario.
- According to information gathered on historical site, in museum or in public records, co-ordinations and communications must be done to enhance and to "synchronize" information seeking and knowledge discovery with other group members. The group has to share information (images, bookmarks, notes, annotations, texts, video, etc.) according to chosen tools.

Moreover, pervasive computing can provide two functioning modes the push mode and the pull mode. They are defined as follows:

1. In the push mode, the system is able to recommend suitable entities (resources, activities, tools, persons) depending on the current situation[4] without any human interventions [16, 17]. The system is thus proactive and decides when groups or individuals are notified according to the situation changes. The group/individual can select or not one of the given recommendations.
2. In the pull mode, the group/individual searches for information, activities, learners or tutors. Thus, the groups "express queries" to express their specific needs to obtain the relevant resources according to the current situation.

[4] A situation is a subset of properties accessible from the context at a given moment (localization, device, current activity, etc.)

Considering the original IBST scenario (cooperative activities), we can propose three push mode examples to illustrate the u-IBST, as follows:

- Recommend information from Navy museum and local public records retrieved by other group members or subgroup according to the needed domain concepts identified on the port and/or the current activities
- Recommend and provide information from subgroup visiting the port to other subgroups or group members
- Recommend checking some domain concepts missed by students or subgroups on the port.

The pull mode may be used at different steps of the original scenario. A query filters concepts, resources, activities and persons, for example: write queries on relevant domain concepts like "crane", "bridge", etc. according to the current context (activities and localization), on retrieved information from other group members or subgroups according to activities and/or localization.

According to social media applications, mobile computing with Internet access and pervasive computing, we can propose an enhanced scenario according to the original one.

4.2 An Innovative Scenario

The scenario we propose here is a hypothetical scenario. Its aim is to show some opportunities. The teacher may choose any activity and/or ignore another one. He will choose according to the course goals, the time available, and the confidence in chosen tools. We focus here on the fourth step of the enhanced scenario as an example:

4. Collaborative work and exploitation: i) During the work, the group will be able to communicate by means of synchronous tools, whether chat or vocal, to suggest some information seeking to other group's members; ii) Data collected on the web will be collected on social-bookmarking tool. Other sources may be digitized, to enable sharing; iii) During the visit, pictures, videos, sound may be taken, geo-localized, tagged and uploaded on the web; iv) Based on geo-localisation, mobile devices will suggest to consider some noteworthy landscape's element; v) The tutor will be able to verify thanks the keywords, conversations, and possibly tracks followed, that relevant concepts or landmarks are treated, and will be able to suggest further exploration, whether on site, in the museum or in the information space. This will be done synchronously, thanks remote communication facilities, and relevant information to guide his advice will be proposed by the system, thanks recommendation facilities; vi) After this research a meeting is organized with the whole group in order to analyse all information collected. If necessary, mind map tools may be used to build the answer' structure; vii) Each group's member will write a small post in his e-portfolio to relate her observations on group's and own methodology, and possible improvements;

As we may notice, scenario instructions, Web2.0 services, mobility and pervasive facilities are strongly intertwined to attain a potentially rich sequence. This sequence is also taking into account students level, and context. Real implementation will depend on various factors including technology availability, and sequence duration. However, such sequence makes sense in an inquiry-based teaching.

5. Semantic Web Role

According to the proposed scenario, we can identify different categories of relevant entities: learners, tutors, learners' group or subgroup, different locations, paradigmatic activities for inquiry-based learning approach distributed among learners and/or group of learners, the concepts of the domain considered (bridge, crane, etc.), communication tools and more generally web 2.0 tools, devices. For information seeking, one can see that it is necessary and/or useful to retrieve, for instance, information retrieved and/or produced by learners, learner groups or subgroups, maybe according to a specific activity and/or location and more generally to a specific situation. Retrieved and produced information is distributed across web 2.0 tools.

Thus, it is necessary to retrieve information, activities, people, etc. in different tools distributed over Internet. Unfortunately, social media applications are data silos. In other words, data are unavailable on the web. Only people may have access to data, not computers. Reuse and exchange of data among social tools are only possible by means of API – that is to say manually by mean of one API per tool. Semantic web approach enables us to solve the problem of finding information by avoiding polysemy and reducing the number of results. The semantic web offers tools and infrastructures for semantic representation by means of ontologies. The latter fosters interoperability at semantic level because it provides a unique meaning for a concept and a relationship in ontology. The semantic web goal is to improve access to information to make it reusable and shareable by all actors whatever being human or machines, which then allows the automation or semi-automation of certain tasks and thus creating intelligent services. It provides a common framework that allows data, information and knowledge to be shared and reused across applications, enterprises, and community boundaries. Moreover, linked data describes a method of exposing, sharing, and connecting data, information and knowledge on the Web [18, 19]. It provides a standardized, uniform and generic method for data discovery, distributed queries against several data repositories, integration or semantic mash-up, uniform access to metadata, data, information and knowledge. Thus, the web can be viewed as a single global database. Users and/or computers can perform complex queries against this global database using the SPARQL language. Complex queries are queries over multiples pages, web sites and data repositories whatever the tool is. It only has to expose data on the common standard and vocabularies. In conclusion, semantic web will answers our requirements about access to learning information across tools, devices and therefore enrich collaborative learning activities between learners and tutors.

In context-awareness learning systems, several models are used to manage information retrieval, adaptation, context-awareness and recommendations. We can cite: a domain model which represent the vocabularies of the learning domain, a user model including learners, tutors and groups, a metadata schema for indexing involved entities (at least information), an activity model (sometimes), a context model (devices, location, time, etc.) and adaptation model and/or a recommendation model. In most of the case, the context model is link to the domain model, the user model and the activity model. Adaptation and/or recommendation have to filter the retrieved information according to the context model. That is to say, the context model and the metadata schema are used to filter information. More generally, the semantic models, consisting of several ontologies, play two complementary roles: i) Description of the different entities involved in the scenarios (learners, trainers, learner group, activities, information, tools, context, etc.); ii) Entities' retrieval according to semantic models.

We designed the first version of **SMOOPLE** for Semantic Massive Open Online Pervasive Learning Environment. The user's view of such environment is accessed through widgets to chosen tools, as its own PLE providing relevant information - resulting from queries to the semantic data. Most of the widgets are available on the web, URL: http://www.netvibes.com/sergegarlatti#PLE_2 and #PLE1. The corresponding example does not manage a course about History of Science and Technology, but about social and semantic web. At present, the environment is not a pervasive one. Consequently, we only manage four models: domain model, activity model, user model and metadata model:

- The Domain model: defines a set of concepts and relationships about a specific learning domain of interest (i.e. History of Science and Technology) that the learners need to acquire during the learning process.
- The Activity model: the main goal of this model is for the tutor and learners to organize their learning activities: the tutor can assign learning activities to learners and/or groups, a learner can plan activities for himself, or learners in a group can assign collaborative and/or cooperative activities between them and groups. To foster self regulated learning sequences and student autonomy, the activity model provides paradigmatic activities according to inquiry-based science teaching that students can use for assign the different activities to individuals or groups.
- The User model: this model provides a common structure for different type of users: learners, tutors, groups, subgroups, etc.
- The Metadata model: it provides a common schema to index entities by means of a set of structured features. This model is linked to previous ones to associated retrieved or produced entities to the domain model, activities and users.

To define these semantic models, we can benefit from previous studies about lightweight ontologies dedicated to Web 2.0 tools. They are as follows: i) Semantically Interlinked Online Communities (SIOC, http://rdfs.org/sioc/spec/) provides the main concepts and relationships to describe information from online communities (e.g., CMS, wikis, blogs, etc.). It describes user accounts and groups, sites and their corresponding types, the site content and their topics, etc; ii) Friend of a Friend (FOAF, http://xmlns.com/foaf/spec/) aims at describing people, their social network, their online accounts (linked to SIOC), their websites, etc; iii) Online Presence Ontology (OPO, http://online-presence.net/ontology.php) is devoted to the integration and exchange of Online Presence related data. The OP4L project, similar to ours, investigates in depth the OPO Ontology usage for learning [20].

These lightweight ontologies fit well database schemas of social media tools. In other words, RDF triples describing the features of people, websites, content, etc. can be generated automatically (sometimes on the fly) from the tool databases. These RDF triples can represent partially the semantic user model, activity model, and metadata model. It is necessary to extend these vocabularies to fulfill our needs.

For the user model, we mainly combine the SIOC and FOAF ontologies. While SIOC ontology enables to describe social communities and their relations through blogs, forums, wiki, etc. The FOAF ontology supplements the SIOC ontology by focusing on the links between users in those communities. Our activity model is a specialization of the OPO ontology. For the activity model, we specialize OPO ontology to fulfill our requirements. In our scenario proposal, we have a set of paradigmatic activities linked to the six scenario stages. For the metadada model is based on a specific well known plug-in (sioc_export) which describes a post by using the following ontologies: FOAF, SIOC, RDF, RDFS, DC (Dublin core). Unfortunately, the tags chosen by users to describe the content are not always exported in such type of plugins. Moreover, it is not a semantic content description. At present, we modified the "sioc_export" to export tags equal to concept name as domain concepts and the others as tags. These semantic models enable us to provide information across tools for fostering effective collaboration in groups and to enhance tutors' activities.

6. Conclusion

Inquiry Based Science Teaching (IBST) renews science education, engaging students in authentic and problem-based learning activities and fostering their autonomy. Traditional learning management systems are unable to deal with such types of approaches. It is necessary to design new innovative environments coping with IBST fundamental features.

Pervasive Personal Learning Environments can provide such type of innovative environments. They can foster collaborative knowledge building, self-regulated learning sequences, discursive argumentation, and communication with peers and reflective practices. Pervasive computing leads to learning at anytime, at any place and in any form, by using small devices, and enables learning in context and seamless learning across different contexts. These capabilities enhance authentic and problem-based learning activities, enabling experiments and practical experience in relevant situations (location, time, etc.). In other words, they can provide rich investigative scenarios incorporating experimental parts (item 1 and 2 of IBST). Reporting services enable students to develop a self-regulated reflective attitude (item 3 of IBST). The use of interactive and collaborative services can encourage activity and arguments between peers (item 4 of IBST).

From a technical standpoint, it is necessary to retrieve relevant information available in distributed tools to be able to reconstruct a complete view of actions, traces, and content of learners, to analyze these actions and to propose relevant recommendations at relevant times and spaces. Our prototype demonstrates that the semantic approach can meet these requirements. Information, available to students, allows them to cast a critical eye on their activities and thus to progress independently (item 3 of IBST). Available to the tutors, it enables them to have relevant information to carry out their tutoring activities. For the metadata model,

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