Semantic Web and Internet of Things Supporting Enhanced Learning

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This paper outlines possible evolution trends of e-learning, supported by most recent advancements in the World Wide Web. Specifically, we consider a situation in which the Semantic Web technology and tools are widely adopted, and fully integrated within a context of applications exploiting the Internet of Things paradigm. Such a scenario will dramatically impact on learning activities, as well as on teaching strategies and instructional design methodology. In particular, the models characterized by learning pervasiveness and interactivity will be greatly empowered.

1 Introduction

Owing to the wide availability of affordable mobile devices and the variety of connectivity networks, users are changing their approach to the World Wide Web and they are assuming both the roles of active participants and producers. Interactive platforms and tools, especially online social networks, are the technological enablers to support cooperation and collaboration. Besides, they have the characteristics of multidimensional networks (Contractor, 2009), in which users can interact with many different entities through explicit relationships (e.g., to be *friend of*, to *like* something, to be *at* a location). The above-cited entities refer to multimedia content accessible over the Web, which are associated to semantic meanings, giving raise to the so-called *social objects* (Knorr-Cetina, 2007). Social interactions and information exchanges happen around such objects (Marie & Gandon, 2011; Kinsella *et al.*, 2007), which can be both virtual and real-world entities, as in the new perspective of the Internet of Things (IoT).

Additionally, a set of standards exist, both de *jure* and *de facto*, widely accepted and used to enable information interoperability and exchange, to describe data and metadata, as well as for the knowledge management, organization and re-use. In particular, the Semantic Web is the place where information is organized according to common and formal representation models. Its infrastructure makes information machine-understandable so that computers can perform automatic reasoning and inference, as well as give significant answers to well-formed questions.

In this situation, novel Technology Enhanced Learning (TEL) models are challenged to exploit the opportunities offered by distributed and heterogeneous environments (Caviglione & Coccoli, 2012), in which knowledge is structured according to a semantic model, to implement pervasive learning strategies, both customized and sustainable (Vinu *et al.*, 2011). Such a scenario can be considered a well-suited field of application for traditional education strategies, such as collaborative learning. At the same time, it is a fertile playground for innovative models, such as *mobile learning*, *micro learning* and *ubiquitous learning* (Ru *et al.*, 2011). Owing to the synergic action of such new learning models and the described technological scenario at large, future learning services and tools will offer novel functionalities with advanced personalization features, exposing characteristics of modularity, extendibility, adaptability, thus enabling the creation of highly customized learning services.

The innovation scenario described above is changing the outlook for instructional designers too. Traditionally, educational material are created relying on a corpus of notions to arrange in a specific learning object. Instead, according to the new scenario, information is semantically annotated and both cultural

and technological enablers are already part of the system. Then, the existing infrastructure is exploited as a scaffold for a "shell", suited to the educational context, to link external objects provided with specific didactic aim.

The remainder of the paper is structured as follows. Section 2 recalls the evolution of e-learning techniques and methodologies. Section 3 introduces the basic characteristics of both the Semantic Web and the Internet of Things. Section 4 presents the educational paradigms that would benefit from the proposed innovation. Section 5 illustrates the instructional design point of view. Section 6 concludes the paper outlining some examples of applications and with final remarks.

2 E-learning advancements

In recent years, methodologies and strategies for education have been changing according to the evolution of technology and tools, whose requirements were driven by the needs of both teachers and learners. In short, the evolutionary path has been the following: (i) the power of computers has been continuously growing while their dimension and cost decreasing, to become Personal Computers. This has been the starting point for CAI (Computer Assisted Instruction) methodology; (ii) the era of Internet has come and the network has further empowered the model of distance learning fostering the adoption of specific LMS (Learning Management Systems), delivering educational contents more and more composed by multimedia objects; (iii) the rising of the Web2.0 has pushed the evolution of collaborative learning methodology, resulting in the so-called *e-learning 2.0* (Downes, 2005) and in an *open* model; (iv) the affordability of modern mobile devices offering multimedia play-back capabilities and advanced connectivity features, coupled with the ubiquity of the connection networks and their relevant architectural advancements, according to the paradigm of NGN (Next Generation Networking), have fostered the development of *ad-hoc* applications for learning outside formal contexts (Caviglione *et al.*, 2011). Specifically, the emerging scenario of the Internet of Things (Gershenfeld *et al.*, 2004) can transform e-learning into a continuous and distributed process, in which the social objects assume an educational role. Owing to their characteristics they can modify their behavior and adapt the interaction mechanisms to the person they are exchanging information with.

In such a scenario, one can guess that new directions in e-learning are tied to grid, distributed and pervasive computing systems, as well as to the social interactions among users and between users and objects, resulting in personalized services. This enables instructional designers to draw new education paradigms, characterized by the usage of mobile devices, which allow perva-

siveness, modularity, and adaptability to the interaction context. The semantic web infrastructure grants the representation aggregation and readjustment of learning objects. Thus its availability is a mandatory requirement to make this feasible.

3 Semantic Web and wireless technologies infrastructure for enhanced learning services

In this section we sketch the main features of the enabling technologies for new e-learning paradigms.

3.1 Semantic Web technologies

The basic concept of the semantic Web is the use of metadata to describe resources and their relationships, by means of formalisms allowing them to be processed by software agents. As is well known, ontologies are tools, which allow concepts to be formally defined and used to annotate resources and their properties. The standard languages for ontology definition are RDF and OWL, while languages for ontology querying are RDQL (RDF *Data Query Language*), SeRQL (*Sesame RDF Query Language*) and SPARQL (*Simple Protocol and RDF Query Language*). SPARQL is the W3C standard and the most used one. It includes three specifications: the protocol for remote queries on RDF database, the query definition language and the document format for representing the results. Query languages make possible exploring ontologies but not making inferences. Inferring non-explicit relationships among ontology resources requires ad hoc rules and a reasoner to apply them. Several languages can be used for rule definition. WRL and SWRL (based on RuleML and OWL) are the languages defined specifically for the semantic Web.

Considering the e-learning domain, ontologies allow describing learning objects, their users and the context of interaction; rules specify how to aggregate such objects and how to adapt them to the user and to the usage environment. Together, they enable learning objects to become components of non-predetermined learning processes, based on the possibility to compose such objects dynamically, as required.

3.2 Wireless tecnologies and the Internet of things

The term Internet of Things is used to describe a paradigm to make objects in the real-world interconnected. It requires that physical objects are provided with a unique identifier, which enables them to be connected to a network of physical and virtual objects. Examples of systems that can be used to identify the objects are: the RFID (Radio Frequency IDentification) technology, QR-

Code (Quick Response Code) and Semacode and the geographic coordinates (*lat*, *lon*). The objects on the net can be equipped differently: they can have memory capability, processing capability or even capability to be proactive and to communicate with other objects and persons at different levels.

A common way to enable the interaction between users and real-world objects is based on the use of smartphones and tablets. Most of the recent handheld devices are equipped with sensors (e.g., accelerometer) and tools (e.g., camera, GPS) and are provided with Internet connection capabilities (by means of IEEE 802.11 technology, GPRS/UMTS, etc.).

An example of user-object interaction based on mobile devices is given by QR-Code and Semacode. These technologies use two-dimensional codes attached to objects. Such codes are similar to barcode, but they can store more data and can be easily accessed by a reader, installed on the mobile device. The user takes a picture of the code and the reader identifies the object. Another technology that can be used on mobile devices is RFID. RFID systems are based on three components: the RFID tag attached to the object, a read/write device for accessing the tag and a system to manage the data transfer. No direct contact nor direct view is required in order to enable the communication and the setting of point-to-point micro-nets. As a last example of technologies for the identification of objects we mention the global positioning system (GPS), which allows to identify people and objects and to provide location-based services (Espinoza *et al.*, 2001).

The natural evolution of this technological context is the provision of personalized services, based on users' position, their current status (e.g., static vs. moving) and on the surrounding environment. A basic architecture for the interaction of learners with an IoT environment is described by Gonzalez et al. (2008) and a user-centered approach for the same technology is described by Domingo and Former (2010).

4 E-learning paradigms fitting the new context

Some of the e-learning paradigms that could highly benefit from the new technological scenario are *mobile* and *micro learning* as well as *lifelong learning*. These paradigms have been introduced in the last decade or even before but are still far from maturity.

Mobile learning (Sharples *et al.*, 2002) is more than one decade old. Connected to mobile learning, micro learning (Lindner, 2007) is more recent. Introduced in 2004, it has been getting more attention in the last years. The approach is based on micro learning units, which are pushed to learners as fragments of a whole. According to the model, learning units have to be frequent and have to require short time for their fulfilment. Delivery is fragmented, but the micro

units have to respect a rigorous instructional design. The formal organization and annotation of units, combined with wireless technologies, offers enhanced possibilities to this approach since it allows to compose the units dynamically and to provide new modalities to access learning materials: using mobile devices and interacting with real world learning objects. Lifelong learning (Cheng & Liao, 2012) refers to a model conceiving learning as a continuous process, based on formal teaching integrated with learning activities in informal and distributed contexts. The IoT can offer the technological support to make learning more pervasive: knowledge is embedded within objects, which can have the ability of transmitting it but also of adapting it to the user needs. Simulations and smart interactive environments go in this direction.

The *-learning* models mentioned above share a common underlying principle: the idea that instructional projects have to fit the user and context variability. In other words they have to be personalized (Power *et al.*, 2004; Hatala *et al.*, 2005). *Adaptive personalized systems* have the ability to modify their behaviour according to the user's features and needs and the usage context (Kobsa *et al.*, 2001). In the tutoring domain, there is a rich history of adaptive systems and in particular of semantic adaptive systems (e.g. Dolog *et al.*, 2004; Henze, 2005; Torre, 2009). The literature in this field faced the issue of adaptation taking into account different dimensions of the learner: her/his knowledge, skills, cognitive model and learning style. Some Intelligent Tutoring Systems (ITS) date back to '70 and can be considered the ancestors of adaptive systems. The new technological scenario provides new opportunities to make learning more personalized and effective: beside personalizing educational materials and learning paths, new opportunities of personalization concern the form of interaction with real an virtual learning objects, the time and mode for pushing the learning activities and the filtering criteria to associate users with objects.

In addition to these paradigms, it is worth mentioning computer-supported collaborative learning (Dillenbourg *et al.*, 2009). From a pedagogical point of view, this approach refers to the social constructivism theory. Learning is conceived as a collaborative process, which leads to knowledge building by means of sharing and negotiation of meanings with other people. Furthermore, *mashup learning* (Colazzo *et al.*, 2009) is a technique which benefits from collaborative learning processes and which can be enhanced in the new environment. In Web 2.0, mashup is a very popular technique to merge information from different sources, aimed to produce new knowledge and new services. In this way it is also possible to create different views of the same problem, enabling learners to model their mashup and learning process according to their perspective. As for the other approaches mentioned above, the semantic representation of knowledge makes possible and more flexible the composition and reconstruction of knowledge.

5 Issues for the instructional design

In such a new context, the main task for instructional designers is keeping into account the many variables and opportunities raised by new technologies. To this aim, we notice that goal-oriented analysis can help identifying the best-suited methods and techniques, with reference to the mentioned variety of learning models.

In the following, we try to perform a design exercise, identifying some of the goals, which may characterize education in the depicted scenario. For each of these, we list methods and techniques available that should be used to achieve them.

TABLE 1
Methods and Techniques for Instructional Design

Goals	Methods and techniques
Continuity of learning *Lifelong learning* *Pervasive learning* *Micro learning*	• Multi-device platform • Pushing of e-learning activities • Frequent and short activities • Adaptation of learning material to the user's device in terms of accessibility and usability (they are relevant factors influencing the continuity of learning) • Annotation of the learning content and of their technical features aimed to accomplish the technique in the point above
Personalized feedback *Personalized learning*	• Logging of the learning activities • Diagnostic evaluation of the learner's activities • Annotation of didactic activities in order to enable diagnostic reasoning
Knowledge Internalizing, retention and reinforcement *Collaborative learning* *Learning by doing* *Micro learning*	• Knowledge building and internalizing favoured by collaborative learning activities • Interaction with learning objects (simulations, serious games, etc.) • Frequent repetition • Diagnostic services aimed to stimulate reflective learning

Goals	Methods and techniques
Reusability for different goals *Open learning*	• Content (documents, simulations, activities, exercises, etc.) structured as autonomous micro-components that can be aggregated into more complex objects • Annotation of micro-content in order to ease reusability and componibility of materials, both user- and system-driven

As shown in Table 1, the achievement of every listed goal requires specific techniques, which are based on the annotation of resources and interconnection platforms. The design and realization of a data structure in the form of ontology allows making significant the descriptions inside the e-learning system, as well as associating relations among them, which can be interconnected on the basis of different criteria. Moreover, the addition of one more layer to the knowledge representation, which keeps into account associations with users, makes personalization possible for both contents and activities.

Conclusion

The objective of this paper was the description of novel scenarios to keep in mind while designing modern e-learning services. The technology and paradigms discussed can enhance traditional techniques as well as engender new learning models, in new fields of application, not yet considered sufficiently by the instructional designers, which could improve learning activities. Among these, we cite some examples.

As a first example, let us consider a specific kind of education, oriented to the acquisition or change of attitudes such as in environmental education. In this situation, a pervasive education in non-formal context can be very effective. Many researchers highlight the failure of most education strategies adopted in this specific field, either traditional or formal and non-formal such as, e.g., mass-media campaign. On the opposite, an approach based on the use of a pervasive, collaborative and interactive system has more chances to both improve knowledge about specific topics and interiorize new attitudes and behaviors, through unconscious assimilation (Potter, 2010).

Another example refers to the emerging model of the *smart-city*, which makes a city "browsable" and interactive, through a public access network. The *links* are specific points of interest (for history, architecture, culture, sports, etc.), which must be duly tagged. By using a semantic-enabled system for the management of relevant information, objects within the city can be enhanced with an educational component, which will be personalized, based on individual

preferences and needs. In addition, objects can interact and people can "socialize" with the surrounding environment as well as with neighboring people, thus enlarging the space of possibilities.

The presented approaches allow empowering the dimension of natural interaction between the actors involved in the learning process and the environment, including the objects therein.

All the outlined scenarios require a careful annotation of information. To this aim, authors and editors are requested to create contents and to perform a supplementary activity. The request of extra effort has slowed down the development of the Semantic Web, yet this problem could be overridden thanks to a renewed social and collaborative dimension.

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