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Metacognitive Learning Environment: a semantic perspective

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In the last years, Knowledge Technologies have been exploited to realize innovative and challenging self-regulation scenarios in e-learning systems. The learning environments as metacognitive artifact suitably scaffolding learners to improve their self regulated abilities, is still lacking though. In this work, we propose an innovative Web-based educational environment that sustains metacognitive self-regulated learning processes by means of Semantic Web and Social Web methods and technologies.

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1 Introduction

Learning processes, especially when linked to "conceptually rich domains" (Azevedo, 2009; Lin, 2001), require strategic environments, where learning experiences are the result of a design phase that looks at a metacognitive perspective (Tsai, 2009) as a vehicle to stimulate reflexive processes on knowledge and self-knowledge (Schunk, 2008).

Metacognitive knowledge, the highest level of knowledge, as presented in didactic taxonomies, refers to the ability and opportunity for learners to understand, control, direct and manipulate their knowledge and their learning process (Azevedo *et al.*, 2009).

A significant educational action able to guide the learner along a more extended and comprehensive learning process, through formal and informal activities, is not only focused on learning (cognition level) but also on cultivating (in learners) a correct learning behaviour that empowers learners to achieve their learning goals in a controlled and directed way (metacognition level).

Metacognition regards what are called Higher Order Thinking Skills (HOTs) (Vockell, 2009), i.e. skills that allow learners to effectively support the "learning to learn" and to understand, control, steer and manipulate their cognitive knowledge and processes.

The authors of (Vockell, 2009) also divide metacognitive skills in three categories:

1. Meta-Memory, referring to the learners' awareness and knowledge about their own systems and strategies for using their memories effectively;
2. Meta-Comprehension, referring to the learners' ability to monitor the degree to which they understand information being communicated to them, to recognize failures to comprehend, and to employ repair strategies when failures are identified;
3. Self-Regulation, referring to the learners' ability to make adjustments of their own learning processes in response to their perception of feedback regarding their current status of learning.

Self Regulated Learning (SRL) is a pedagogical approach that puts learners in charge to control and direct their learning process (Zimmerman, 2008), planning learning experiences for attaining these goals, deploying a diverse set of effective learning strategies in pursuit of the goals, continuously monitoring their own understanding of the material and the appropriateness of the current information, and making adaptations to their goals. SRL is considered a cross-competency whose acquisition aids self-directed management of individuals' learning processes (Zimmerman, 2001) and allows to learn to learn (van den Boom *et al.*, 2004).

The self-regulated approach has especially been adopted in the field of technology-enhanced learning and is based on the premise that learners adaptively regulate their cognitive and metacognitive behaviours during learning. The self-regulation competency is a key element to be considered in designing learning environments (Lee, 2004)that are seen as compounds of socio-cognitive artifacts (Shih *et al.*, 2005).

SRL includes three major phases, namely self-instructioning, self-controlling and self-reinforcement (Greene & Azevedo, 2007; Witherspoon *et al.*, 2008). These phases foresee several specific processes (Azevedo, 2009) that must be supported by a metacognitive-driven solution (Kemp *et al.*, 2009).

In the Self-instructioning phase we identify Self-planning and Self-evaluation processes. During Self-planning activities, students pursue course outcomes through activities they design themselves (Zimmerman, 2000). Moreover, Self-evaluation process enables students to view their fruition state and the evidence of their cognitive status (Sperling *et al.*, 2004) with respect to the attainment of their educational objectives (Zimmerman, 2000)

In the Self-controlling phase we identify Goal setting and Self-control processes. Goal setting refers to the possibility students have to autonomously express their objectives and control the specification of their needs (Zimmerman, 2000). Furthermore, the Self-control process refers to the assessment the students themselves carry out during their goal setting activities (Crippen *et al.*, 2009).

In the Self-reinforcement phase we identify Help-seeking and Self-reflection practice processes. The Help-seeking appears when the student identifies and seeks further human resources in order to obtain assistance on specific learning tasks (Dabbagh & Kitsantas, 2004). Self-reflection practice is a process, based upon social comparison (Dettori & Persico, 2008), where students reflect on their learning process and react by modifying the way they face their learning activities (Dabbagh & Kitsantas,2004).

Although several scientific works confirm that e-learning environments necessarily have to pay attention to the self-regulated learning process (Steffens, 2008), modern e-learning systems are still characterized by a weak relationship between self-regulated learning and technological-driven functionalities.

This work proposes a Web-based metacognitive environment for the definition and execution of self-regulated learning activities, that leverages on Semantic Web and Social Web technologies and methods. Finally we provide conclusions and future works proposals.

2 Towards Metacognitive Environments

Based on the principles and processes SLR's, the open discussions on the topic by the scientific community over detailed and widely shared, and recent studies have emerged in relation to the potential development of technology environments for teaching metacognitive (Steffens, 2006) present a model of the whose strengths are related to watch the self-regulated learning in three functional components to one another: Personalized e-Learning Experiences, Objective-driven Learning, Educational Social Network.

2.1 Personalized e-Learning Experiences

The first component provides a set of tools enabling the definition (for instructors) and the execution (for learners) of personalized e-learning experiences helping learners execute self-regulated learning activities and, as side effect, enhance their self-regulated learning abilities (Zimmerman, 2000; Code & Zaparyniuk, 2006). These features are allowed adopting a Learning Model defined in (Albano *et al.*, 2006).

The model leverages on the explicit representation of knowledge about educational domains (e.g. Mathematics, Physics, Chemistry, etc.) and learners (with their learning preferences and cognitive status).

Construction and delivery of personalised e-learning experiences are realized through the execution of specific algorithms (Capuano *et al.*, 2009) able to generate courses tailored to single learners.

The "Learning Model" allows to automatically generate a Unit of Learning (i.e. a course, a module or a lesson structured as a sequence of Learning Activities represented by Learning Objects and/or Learning Services) and to dynamically adapt it during the learning process according to the learner's preferences and cognitive status (personalization process).

A Unit of Learning (UoL), in its execution, represents what we have previously named as e-learning experience.

The knowledge on the educational domain relevant for the e-learning experience we want to define, concretize and broadcast, is formalized by means of a machine understandable e-learning ontology. An ontology is an engineering artifact, constituted by a specific vocabulary used to describe a certain reality, plus a set of explicit assumptions regarding the intended meaning of the vocabulary words. Ontologies used in our approach are described in (Gaeta *et al.,* 2009).

E-learning experiences are defined as:

(i) a set of Target Concepts (TC), i.e. the set of high-level concepts to be transmitted to the learner;

(ii) A Learning Path (LP), i.e. an ordered sequence of atomic concepts (subjects) that is necessary to explain to a learner in order to let him/her learn TC. Given the personalization on a particular learner, the sequence does not contain subjects already ”learnt” (i.e. known with a grade greater than the fixed threshold) by that learner (these information are managed by means of Learner Model);

(iii) A Presentation (PR), i.e. an ordered list of learning objects the learner has to use in order to acquire knowledge about subjects included in LP.

Fig.1 shows an overview of the personalized e-learning experience definition process.

Several assessment points are inserted within PR. During the learning experience execution, assessments results (implemented as multiple choice tests, etc.) are used in order to automatically build remedial works. This component provides an effective solution to combine personalized learning with self-directed learning so to define an instructional learner control environment.

At the macro-adaptation level, the individual component allows an open-looped control of the personalization system taking into account both the instructional domain and the best learning method.

Furthermore, the component acts at a micro-adaptation level where learning paths and learning contents are adapted just-in-time by processing learners' knowledge, preferences and performance score.

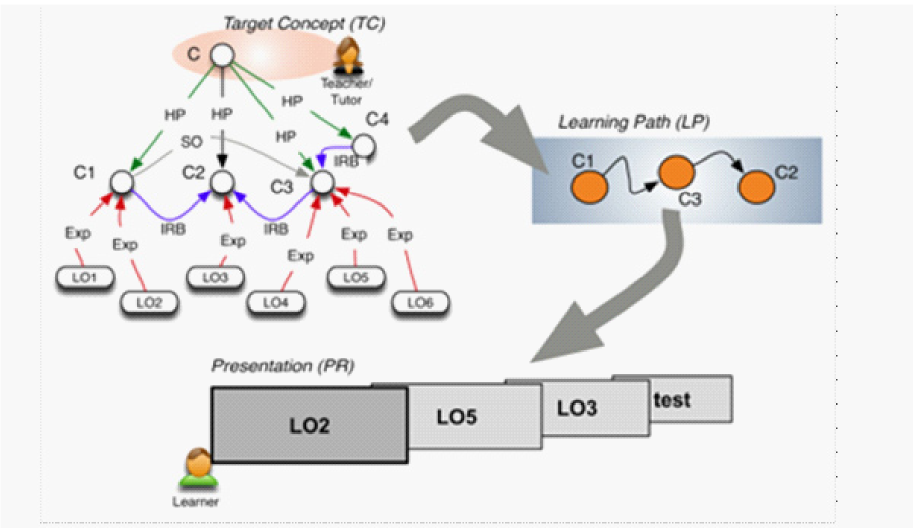

Fig. 1 - e-Learning Experiences Definition Process.

Learners perceive it as a direct participation in learning experience personalization process (self-planning) being consistent whit self regulated learning main principles. They can constantly observe their cognitive status evolving and the results of their assessment activities (self-evaluation).

2.2 Objective-driven Learning

This component allows learners to declare in simple natural language their Learning Needs in order to receive a personalized e-learning experience matching to their needs. So, a Learning Need (LN) is a sentence like “I would like to learn Java Programming”. In our approach, a LN can be processed by performing a matching with a set of Learning Objectives.

A Learning Objective is defined as: (Title, C_1, C_2,..., C_n). Title is a text representing the Learning Objective in a natural language, C_i is a piece of knowledge required by the objective, representing a reference to a subject of an e-learning ontology. The matching operation consists in executing the Sentence Similarity Algorithm between the text representing the expressed LN and the texts of all the Learning Objectives (LO_i) stored into the repository. The result of the algorithm execution is a list of all sentence similarity measures $S_i = S(LN, LO_i)$. Only the objectives LO_i, such that S_i is bigger than a given threshold, can be presented to the learner who can select one (or more) of them and request the delivery of a personalized e-learning experience (with respect to modalities indicated in the above sections) in order to meet his/her needs.

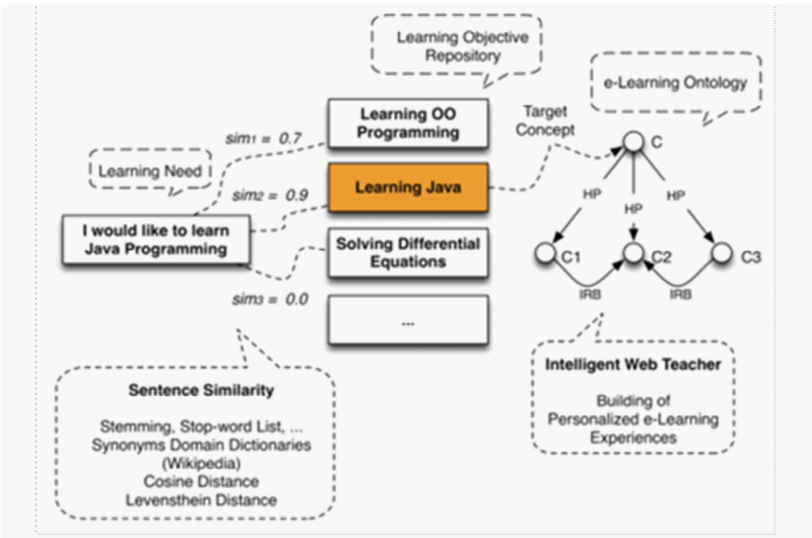

Fig. 2 - Processing of Learning Needs with Learning Objectives

The definition of a personalized e-learning experience starts from one or more Learning Objectives and can adapt Learning Path and Presentation using information stored inside the learner profile. Learners have also the possibility to compose more Learning Objectives for the specific Learning Need.

The provided composition could become a new Learning Objective in the repository. In the case that no Learning Objective in the repository satisfies the expressed LN there are two alternative ways to process it. The first way (Fig.2) foresees that the simple natural language sentence corresponding to the expressed LN is matched on the subjects of the available e-learning ontologies.

Once a set of subjects are identified on the ontologies, the involved learner can select one or more of them as set of Target Concepts (TC) to start the definition and the execution of a new personalized e-learning experience. The ontology navigation and the selection of TC sets (Fig. 3) are activated only if the involved learner owns some specific and basic self-regulated skills (Dabbagh & Kitsantas, 2004; Teng & Benson, 2006).

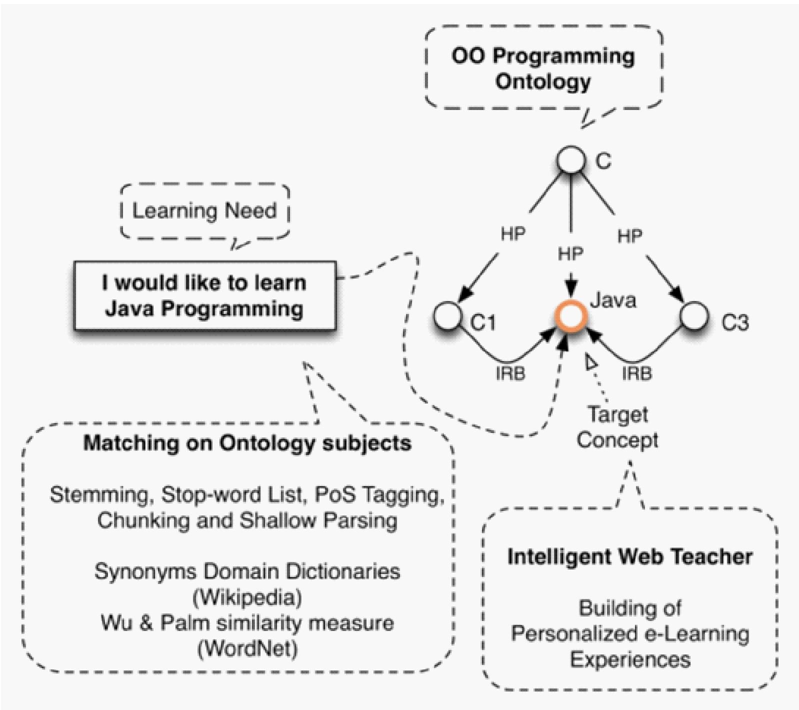

Fig. 3 - Processing of Learning Needs without Learning Objectives.

A third process of course building starting from an implicit Learner Need rather then from an explicit one.

In other words, a methodology to recommend Learning Objectives basing on the analysis of a learners' cognitive state and on the comparison of this cognitive state with cognitive states of similar learners is provided. To do that we will adapt and extend an user-to-user collaborative recommendation algorithm.

The method consists of the following steps.

- Concept mapping: for each learner, known concepts plus concepts currently under learning (i.e. part of units of learning the learner is enrolled in) are identified.
- Concept utility estimation: for each learner, the utility of each unknown concept is estimated by looking at concepts known and under learning by similar users (i.e. by users with similar concept mappings).
- Learning Objectives utility estimation: the utility of each available Learning Objectives is calculated for each learner by aggregating utilities of composing concepts. Once the utility of each Learning Objectives is estimated for a learner, the n Learning Objectives with the greater utility can be suggested to him.

This component allows the learner to define their learning needs and direct their learning experience (goal setting), to explore the conceptual space developing a larger locus of control (Kinshuk *et al.*, 2000) and to determine when individual goals have been adequately addressed (self-control).

2.3 Educational Social Network

The third component proposed is the Educational Social Network where social activities and social objects become educational. The educational use of social networking meets the need for support what literature (Douglas & Brown, 2011) calls collective indwelling, i.e. an advanced modality of inquiry that links personal needs to information provided by the blogosphere or by other the collective spaces.

The most important aspect in our Educational Social Network model is represented by the Educational Social Profiles (ESP).

An ESP is a structured description of several characteristics (e.g. skills, knowledge, attitudes, learning preferences, expertise, and so on) that identify people (learners, instructors, etc.) from the educational point of view.

An ESP allows individuals to be discovered by people who would benefit from an association with them. The Educational Profile Pages (EPP) are exploited in order to publish ESPs on the Web.

An important feature of EPPs is provided by the Educational Micro-Blogging (EMB). Typically, Micro-Blogging tools (e.g. Twitter, Jaiku, Tumblr, etc.) enable users to share ideas, activity descriptions, etc. using a few characters and, as illustrated in (Dong *et al.*, 2010), they are more and more used in educational contexts.

In our work we propose the Educational Micro-Blogging tool for sharing information generated by software modules enabling the formulation of learning needs and the execution of learning experiences. In particular, every time a learner executes a new learning activity, achieves a learning objective, expresses a learning need, achieves a considerable result, acquires new knowledge and skills, his/her EPP is updated via the EMB and his/her followers are notified with a new activity description.

EPPs also allow to follow other users in the Educational Social Network so to be notified for their new activities shared by the EMB. Users can be automatically found basing on two main principles. The first one is the similarity principle, i.e. a learner follows users with the same learning needs. The second one is based on the assumption that a learner follows users/experts with knowledge, skills, expertise, etc. able to support him/her in his/her learning activities.

The proposed component upholds social presence dimension supporting the development of self-regulated learning. Educational Micro-blogging serves as a pedagogical advance organizer (Mcmanus, 2000) for the learners' community, as it anticipates and spreads needs, knowledge and learning paths. Furthermore, the component facilitates the expert finding and peer finding, it also supports help-seeking and self-reflection practice processes improving the students' self-regulation over learning (Fitzgerald *et al.*, 2007).

In the end, the proposal of new visions exploiting social networking in synergy with formal learning approaches and tools fosters new scenarios supporting the development of behavioral and cognitive competencies like "continuous learning", "self-control" and "decision making" skills on the basis of distributed seeking and inquiry.

Final Remarks

This work proposes a metacognitive educational environment based on three functional blocks: personalized e-learning experiences, objective-driven learning and educational social network. From the technological viewpoint, the metacognitive educational environment is designed on the top of Intelligent Web Teacher (IWT), that is a Semantic Web-based Educational System. IWT provides the definition and execution of several learning scenarios by exploiting knowledge representation and reasoning techniques. The integration of the aforementioned functional blocks and the extension of the IWT Platform enable the development of the addressed metacognitive processes:

self-planning, self-evaluation, goal-setting, self-control, help-seeking and self-reflection practice.

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