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ScienceDirect
Computers in Human Behavior 00 (2015) 1–13
Computers in Human Behavior

A Social Network-Based Teacher Model to Support Course Construction

C. Limongelli[a], F. Sciarrone[a], M. Temperini[b,*]

[a] Roma TRE University
Engineering Department, AI-Lab
Via della Vasca Navale, 79 - 00146 Rome, Italy
[b] Sapienza University of Rome
Department of Computer, Control, and Management Engineering
Via Ariosto, 25 - 00185 Rome, Italy

Abstract

On line education is a student centred activity, and most of the research in this field focuses on students; yet the quality of teaching is undoubtedly the basic ingredient for a successful learning. In particular, fostering new forms of collaboration between students and teachers, i.e. pursuing co-learning aspects of e-learning, probably needs giving teachers new means of collaboration, also among themselves. In this paper, we tackle the aim of providing the teacher with social collaboration tools, to support the process of course construction. Such a process comprises several distinct steps, from concept mapping, through selection of suitable learning material, to the final stages of delivery in a Learning Management System. It is an heavy process, through which teachers have to spend a lot of time to build or to retrieve the right learning material from local databases or from specialized repositories on the web. The support we foresee should exploit the knowledge of the whole teaching community, in which the teacher acts, to help her/him in doing the above described job. By "knowledge" we mean basically a representation of the ways of usage of learning materials, by the teachers in the community for their courses. To start on a solid footing, here we address the topic of modeling the teacher. The model we define aims to give teachers a personalized support, encompassing consideration for their own pedagogy, teaching styles, and teaching experience during course creation. It is deemed to consider all those issues in a dynamic way and to guide the teacher towards the best didactic choices.

Keywords: Technology Enhanced Learning, Social-Collaborative e-learning, Learning Material Reputation, Teacher Model, Teaching Style

1. Motivations and Goals

Nowadays, several studies, about the use of Artificial Intelligence (AI) techniques for e-learning aim to enhance the experience of web-based education. Traditionally in education there are two main roles: the student and the teacher. Obviously in e-learning we have the same roles, but the usual trend of AI in e-learning gives more attention to the student side than the teacher's one. This situation highlights that most works on AI in e-learning are student-centred. In particular, AI techniques try to support sharing and reuse of learning materials, for course construction

*Corresponding author
Email addresses: limongel@dia.uniroma3.it (C. Limongelli), sciarrone@dia.uniroma3.it (F. Sciarrone), marte@dis.uniroma1.it (M. Temperini)

and adaptation based on students personal needs and preferences. However, these works do not consider the effort (possibly quite heavy) made by teachers to build on-line courses; putting apart the activities related to authoring, such "effort" is needed in tasks such as the devising of a concept map for the course (usually represented through ontologies (Devedzic, 2004; Limongelli et al., 2010; Gentili et al., 2001), or the selection of learning material (*LM*) from networked repositories, or the metadatation of *LM*s to make them suitable for the learning environment in use. Only in the last years some works have been centred on teacher support (Cañas & Novak, 2008; Casali et al., 2013; Rossi & Fedeli, 2013; De Marsico et al., 2014a; Sciarrone, 2013).

Also in the field of co-learning a somewhat more teacher-centred attitude, of the services offered in an e-learning environment, could be significant. Co-learning focuses on the investigation about new forms of collaboration among the actors of an e-learning system. One of its aims is of course in the redefinition of the mutual roles of such actors, namely the student and the teacher. On the other hand a focus has also to be on the support the development, use, and reuse of learning materials, with particular interest on the side of open educational resources. Especially in a formal learning environment the teacher is the main channel through which a flow of *LM*s is made available in the system; then, any additional support given to the teacher, in order to make her/him more aware of reputable *LM*s and to help channeling that material toward the students, will turn out to be a way to make the system richer for the students too, and more profitable for all the abovementioned factors.

1.1. Teacher Oriented Services of an e-learning Environment

We have previously hinted how some services, primarily oriented to the teacher's aid, could be important in the whole picture of an e-learning system. Yet, most e-learning systems in literature are centred on how to assist a student during course fruition through course ontologies, student models, social interactions, etc (see (Brusilovsky & Peylo, 2003; Brusilowsky & Vassileva, 2003; Brusilovsky & Millan, 2007; Sangineto et al., 2008; Sterbini & Temperini, 2009a; Limongelli et al., 2011; Magnisalis et al., 2011; De Marsico et al., 2010; Akbulut & Cardak, 2012; Mikic Fonte et al., 2012; Shi et al., 2013)). The teacher has the entire responsibility of building an online course without any support and with the addition of further tasks as well. For example, in some systems (e.g.: (Sangineto et al., 2008)) the teacher has to compose a course ontology following an ad hoc workflow imposed by the system. The more these systems are sophisticated on the student side, the more is the effort required to teachers in terms of time spent and uneasiness of system usage and understanding. Therefore, a main lack can be pointed out on the ability to support the teacher, and to facilitate her/his approach to course construction. As matters stand, one can find adaptive systems that may come out to be very good for students as well as very hard to handle for teachers.

Although quality of teaching is undoubtedly one of the most important ingredients for student learning, and consequently for a successful course, in literature there are only few contributions to support teachers. The process of preparing a new on-line course is a very complex one and the teacher is involved in several tasks such as: i) building the concept map; ii) retrieving or building learning materials; iii) building a didactic storyboard; iv) delivering the course on a Learning Management System (*LM*S). It can be quite a burden, in spite of the fact that often some of these activities are performed in team.

To reduce such burden, some AI techniques have been focused on these issues.

Concept maps are represented by ontologies, where each node is a concept and an edge is the prerequisite relationship between two concepts (Devedzic, 2004). Several ontology-based projects (Cañas et al., 2004; Grandbastien, 2009; Neri & Colombetti, 2009) try to improve *LM* retrieval given a course ontology. Unfortunately, they do not make difference between a student-user and a teacher-user, offering retrieval based only on *LM* metadata and course ontology, with no user modeling (except sometimes for Learning Styles). Thus, none of these systems is either focused on the realization of the overall ontology or on the experience comparison among teachers, excluding the possibility of building an effective useful environment for teachers.

Metadatation is the operation of filling in the metadata of a Learning Object (LO), that is the information stated as necessary, by a standard definition, to allow for a mechanical management of the *LO*, and of the *LM* in its contained. In literature, it is largely widespread the idea to encapsulate *LM* into Learning Object (LO) providing in this way descriptive information (metadata) for sharing and reusing didactic material (Sosteric & Hesemeier, 2002).

However, *LO*s are as well popular as problematic to use: i) there is no a standard de facto for metadata definition ((Chawla & Singla, 2010; Botsios & Georgiou, 2011)), and ii) *LO*s require a considerable effort to manually specify all the descriptive information of their content (*LM*) (Currier et al., 2004).

As we will see in the next section, the problem of metadata definition is central in all *LO*-based projects. In these projects the importance of high quality metadata is fundamental for a successful *LO* retrieval (Palavitsinis et al., 2014). However, although some systems try to extract automatically high quality metadata from textual *LO* ((Casali et al., 2013; Alfano et al., 2007)), the metadatation problem is not solved yet. There are also some interesting recommender systems for *LO*s retrieval ((Bender, 2012; Manouselis et al., 2011)). Yet they don't seem to take teachers' pedagogic characteristics and needs into account, so in effect the help that a teacher can have is still quite limited. In particular, these recommender systems have yet to manage the issue of what kind of standard to adopt for metadata, and how to allow interoperability between systems with different standards. Finally, all the projects based on *LO*s implicitly assume that the author of a *LM* does duly fill in all the *LO* metadata related to that *LM*. There are specific editors for metadata, but the more relevant information such as keywords, target level, prerequisite concepts, and all that is related to the *LM* content, have to be manually written by the author. Unluckily, teachers are not interested in creating and using *LO*s, as it is stated in (Ochoa & Duval, 2009), because of the *LO*'s complex and demanding structure (issuing many, and sometimes intricate, metadata). Moreover, fine grained metadatation turns to be further less profitable by the existence of different standards for the metadata.

1.2. A Teacher Model Acting in a Teaching Community

Basing on the observations presented above, and considering the importance of model based approaches (Candillier et al., 2007), we propose in this paper a *Teacher Model*, deemed to be used in an e-learning environment also to support the whole *Teaching Community* made up by the teachers working in that environment. Such a support would be on teachers' activities such as course construction, and sharing of learning materials and of ways how to use them. The Teacher Model (TM) we propose allows to automatically track the experience of a teacher (intended as her/his usage of *LM*s). In particular the TM is composed by such Teaching Experience (TE), and by a component representing the Teaching Styles (TS) of the teacher.

In particular, the TS is based on the related Grasha pedagogic model (Grasha, 1996), while the TE is implemented by a novel dynamic didactic network, where the concepts used by the teacher in her/his courses are connected to the learning materials used to teach them by the whole teaching community. This network is dynamically updated, evolving with respect to the evolution of the teaching activities maintained in the e-learning system. It is represented by a directed acyclic graph where nodes are concepts and arcs represent the prerequisite relationships between two concepts, like an ontology. In addition, each node of the network is linked to all learning materials used to teach that particular concept. Those links have an associated weight which changes every time the teacher makes a didactic action, inspired by the temporal law of the Ant Colony Optimization theory (Gambardella, 1999). This model well represents the teacher (Limongelli et al., 2013a) and its information is useful to contextualize the usage of *LM*s and ontologies (Limongelli et al., 2013b), without any additional effort for teachers.

Ultimately, the use of the TM we designed can help in providing support to a kind of social collaboration among the teachers working in the e-learning system and in the related teaching community, not much differently than in systems for student social collaboration and in Communities of practice (Kirschner, 2001; Kreijns et al., 2003; Yu & Chen, 2007; De Marsico et al., 2013a; Wenger, 1998; Weller, 2001).

Such social dimension is given by the possibility, for a teacher, to influence the community through her/his choices of *LM*s in courses, and, in turn, to be influenced, when those choices are made during course construction, by the reputation of *LM*s used in the system. Also this use of the concept of reputation is taken by social collaborative system, with not much difference (Wei et al., 2003; Yang et al., 2009; Sterbini & Temperini, 2009b).

The next section provides a description of the state of the art (according to authors knowledge) of the support to the teacher in the definition of a course. This will reveal that the teacher, while building a course, has to accomplish several tasks, on which a variety of mechanical support has been designed. The available support is yet still limited and new approaches could be useful.

In Section 3 we define an approach based on both the modeling of the teacher and the social interaction of teachers. We show the theoretical definition of the model and exemplify its use, showing in particular the method to update the model, that is the way to maintain it adherent to the evolving characteristics and preferences of the teachers, in the teaching community. It should be pointed out, right here, that we are not proceeding to an experimental validation of the model in this paper. Actually, the (laborious) definition of the model is to be interpreted as the first step toward the effective development of a teaching community in an e-learning environment. Without it there would be no way to establish the community in the first place. With it, we will have the possibility to experiment in a real system.

Conclusions and discussion of future developments are drawn in Section 4.

2. Background

In this section we present the most relevant literature as regards the way to help teachers in course configuration. The contribution (Cañas & Novak, 2008) has proposed a tool to facilitate the definition of a didactic ontology to represent the conceptual map. Using this tool, the teacher finds a user-friendly interface for a simple and quick composition of ontologies. In addition, it is possible to use it to share LM associated with a concept, having a LM retrieval as well. This idea of using ontologies for LM retrieval is just a starting point for all the other works presented afterwards. More recent ontology-based systems use LO to support sharing and reusing of LM associated to a given concept in a course ontology the LM retrieval is integrated in these systems with the management of the course ontology (see (Grandbastien, 2009; Neri & Colombetti, 2009)), as the ontology ”facilitates knowledge sharing and reuse” (Devedzic, 2004).

The use of LO brings forward the management of metadatation, that is the methodology to provide a sufficiently general and uniform specification of a LO. Metadatation answers to the need for systems able to collect and make available LOs by firstly storing them in a repository and then making the repository searchable, basing on the common metadata specification. Several systems for sharing and reusing LOs have been proposed. They are known as Learning Object Repository (LOR) (e.g. MERLOT[1] , WISC-ONLINE[2], CONNEXIONS[3]). Studying these systems and the idea behind them, it is possible to highlight the problem of LO standard. Each LOR is free either to use one of several existing standards (IEEE LOM, SCORM, IMS, etc) or to define an own one. Therefore, a huge European project called ARIADNE (Najjar et al., 2003; Klerkx et al., 2010) and a Canadian one called EduSource (Hatala et al., 2004) have started to face the problem of LORs interoperability, building an open network for learning services with a unique metadatation standard. In particular, they need a specific driver to translate the own standard of a LOR into the standard used in their network. After that, different systems have been developed to retrieve LOs from these wide networks and local LORs (see (Simon et al., 2005; Ternier et al., 2008; Limongelli et al., 2012a; Yigit et al., 2014)). They focus on how to enhance the users query and to filter the resulting LOs. In order to achieve their goals, these systems have developed several metadata translation tools to match the user's selection criteria with the metadata values in each LOR.

The ontology-based systems cited earlier integrate the provision of LO, granted by the LORs, basically by i) using ontology and LOs associated with it, ii) building a unique overall network where all teachers' LOs are located, and iii) performing query adaptation to the teaching context to retrieve LM from the overall network.

Unfortunately, LOs are not an effective solution to satisfy the three tasks above, in order to design and develop a useful LM retrieval system with a good teacher help module. Our research tries to reach those goals using a different way: we adopt a teacher modeling approach instead of metadatation.

A collaborative environment is a valid way to help both teachers and learners (Monahan et al., 2008): teachers can share didactic experiences each one another; they could then profit of the automated detection of learning issues and related proposals of solution, based on the overall teachers' experience stored and managed by the system. Such a collaborative environment would then be useful to learners too, since a (future) intelligent agent could use the overall teachers' experience to identify a student didactic issue and make decisions to solve or report it.

Hence, using an appropriate teacher model it is possible to build a community of teachers represented by their virtual models. In this way, the teacher does not have to make additional effort to be involved in this community as an active member. What we want to realize is a modeling system which is able to automatically contextualize all the information regarding to didactic actions. For example, it should be able to understand the main features of LM usage in a specific didactic situation.

Moreover, another interesting field of research is about student monitoring in virtual learning environments. Currently, some of these environments have a pedagogical 3D avatar of a teacher ((Hu & Zhao, 2010; Soliman & Guetl, 2010; Limongelli et al., 2012b)) that can identify specific students behavior and have a consequent reaction in terms of

[1] http://www.merlot.org
[2] http://www.wisc-online.com
[3] http://www.cnx.org

gestures, facial expressions and so on. So, they have only a pedagogical approach to students. Other virtual learning environments issue an intelligent tutor that controls the student progress and suggest to teachers some tips in order to improve the course quality (Rossi & Fedeli, 2013). The main ideas in this approach are based on predictive models (Gaudioso et al., 2012) and virtual appliances (Romero-Zaldivar et al., 2012; Limongelli et al., 2010). Therefore, recently different works design intelligent tutor to support teachers in terms of student issues identification and solutions suggestion. However, they are mainly based on forecast of possible students issues through statistical models, but it would be a good challenge to include into them an intelligent didactic agent. This intelligent didactic agent would be able to understand, as well as to identify, student difficulties and propose an ad hoc solution for him/her using the overall experience of all teachers in the community, being almost like a real expert tutor. To achieve this objective, we need a representation of each teacher in the community, so this is another reason to design a proper teacher model.

To sum up, all the discussed contributions do not involve a didactic intelligence able to handle learning materials, considering the teachers characteristics and actions reported automatically into a teacher model. This is a good ability that on the one hand can reduce the effort required to teachers in building and managing intelligent e-learning courses and on the other hand can improve students monitoring.

3. Teacher Model

3.1. The rationale of our proposal of Teacher Model (TM)

When a teacher has to start a new course, (s)he has to tackle some problems like the designing of the conceptual map and the designing of new learning materials. These two phases often require a lot of time, and it is here that providing teachers with social communication/exchange facilities could be the most useful. With such a support teachers could help each other, by sharing knowledge and experience, and exchange learning materials for their courses.

So, our aim is to build a community of practice by which teachers can grow up sharing their professional skills, i.e., the learning materials they used in old courses together with the concepts they thought through such materials.

Following these guidelines, we based our TM starting from the following considerations:

- Very often, teachers need to speed up their course building process;
- The Internet makes it available a huge quantity of learning materials, under the form of structured learning objects or of different kinds of resource files (e.g.:pdf, ppt, doc,...);
- Each teacher has her/his own didactic characteristics, i.e., teaching styles and didactic experiences;
- When several teachers do actually teach the same course (same subject matter for similar classes of students), the social support we mentioned above can provide them with a kind of social recommender system, where the teacher's personal characteristics are exploited to give suggestions about learning material to use and put into action the sharing of professional skills and materials.
- The personal characteristics of the teacher (her/his sharable professional skills and materials) are dynamic by nature: they change in time, while the teacher changes the arrangement of concepts to be taught and selects learning materials to use for explaining them.

3.2. Introduction to the TM

Having in mind a system that supports teachers in course configuration, we need to gather all the information about teacher's actions and pedagogical approach. In this way, it will be possible to contextualize *LM* usage over several experiences of a teacher, allowing for didactic knowledge sharing and reuse. The first issue is how to represent this kind of information describing: (i) how (s)he teaches, (ii) what courses (s)he has taught and (iii) what learning materials (s)he has used in her/his subjects.

In particular, the first aspect is a pedagogical component, that is going to be represented by the teaching styles. It is meant to help identifying similar ways of teaching, shown by different teachers regardless of the specific course.

Then, the courses taught (the concepts assembled in them) and the learning materials used for them, describe the teaching experience of a teacher (the personal *didactic context* of her/his activity).

An additional aspect in the didactic context of a teacher is the indication of the cognitive level to which the concepts in a given course are to be taught: as a matter of fact, usually a teacher selects learning materials for a course according to the expected classroom level.

In conclusion, the proposed Teacher Model is composed by:

1. Teaching Styles (TS), as the pedagogical component, and
2. Teaching Experience (TE), as the more directly didactic one.

Overall: $TM =< TS, TE >$.

3.3. Teaching Styles

As we said in the previous Section, Teaching Styles are devoted to taste pedagogical attitude of the teacher, as proposed by Grasha (Grasha, 1996) that presents five categories of teaching styles:

1. Expert: teacher has the knowledge and the experience that students need.
2. Formal Authority: teacher maintains her/his institutional role.
3. Personal Model: teacher bases her/his teaching by personal example and establishes a model for thinking and acting.
4. Facilitator: teacher emphasizes personal interaction between students and teacher.
5. Delegator: Teacher develops student's ability so that they can act autonomously.

These five categories are represented by a set of 5 values each of one in [1.0..7.0] and are deduced by a questionnaire[4] that computes a weight for each individual style, through a value between 1.0 and 7.0. Each style is independent from each other. Therefore, each teacher has five Teaching Styles that describe his way of teaching, and that influence the course building and the choice of teaching materials.

3.4. Teaching Experience

Teaching Experience sets teacher actions and preferences in a didactic context. It is composed by information coming from all the courses built by the teacher. A course is represented by an ontology, which contains all the concepts involved in that course.

In addition, a cognitive level is associated to each concept of the ontology. In this way a given concept is distinguished in different concepts at different levels. For example a concept as *The Cold War* can be distinguished by three distinct concept levels: elementary, middle and high. In the ontology, the different concepts levels can come out with as well different prerequisites. For instance *Marxism* could be a prerequisite for *Cold War* at a middle cognitive level, while it would be unnecessary at an elementary level.

To model the teacher experience, we defined the concept of *Didactic Network* (*DN*), which is discussed in the next subsection. A *DN* is basically constituted by all the ontologies related to a teacher, and by the learning materials associated with them in the courses of the teaching community. Fig.3.4 shows an introductory example of DN.

3.5. Didactic Network Representation

For a given teacher, t, the didactic network $DN(t)$ provides a representation of the teaching practice of t, in terms of the concepts addressed in t's courses, and of the learning material used to teach them.

This representation is meant to reproduce the teacher-bounded relationships holding between the concepts, occurring in her/his courses, and the learning materials that can be used to teach such concepts, in both a *personal* and *social perspective*.

The personal perspective is given by the fact that $DN(t)$ is made of nodes representing only concepts taught by t in her/his courses.

The social perspective consists in the visualization of how the learning materials are selected/neglected against the concepts, by the whole community of teachers (of which the teacher is a member). This is meant to allow for a degree of reciprocal influence between the teacher and the teachers community. That would in turn provide the single teacher

[4]http://longleaf.net/teachingstyle.html

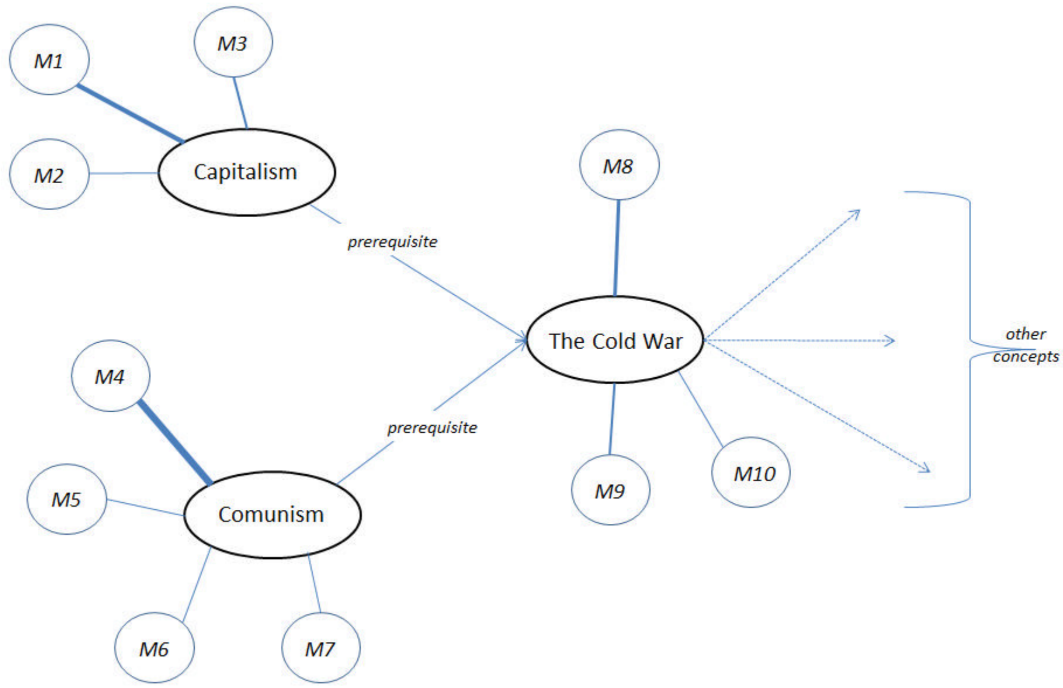

Figure 1. Example of Didactic Network for a given teacher. The network contains nodes, that represent concepts and related learning materials, that were used in the courses taught by the teacher. In the graph, each concept (with bolder border, e.g. *Capitalism*) is connected to other nodes, representing learning materials used for that concept in the teacher's courses. The arc connecting a concept to a learning material is weighted. It is rendered increasingly bold as the didactic relationship is higher between the nodes. Such didactic relationship is basically the frequency of use of the learning material for the connected concept, by all the teachers monitored in the system. Two concept nodes can be linked by a prerequisite relation, represented as a directed arc (e.g. *Communism* and *The Cold War*). In this example, the nodes M1-M3 represent the learning materials to teach the concept *Communism*; likewise, the nodes M4-M7 represent the learning materials used to teach *The Capitalism*. Both concepts are prerequisite to *The Cold War*, for which the learning materials M8-M10 have been used. Finally, the more a learning material is used for a concept (in general, by all the teachers in the system, that taught those concepts), the higher is the weight of the connection (and the bolder it is rendered in the figure). In particular, here M4 is the most used learning material to teach *Communism*, so the corresponding arc is the boldest.

with an opportunity for mediated inspiration, about the possible choices of learning material to teach the concepts included in her/his course.

Let's consider a teaching community TC, composed by teachers, and the *Teaching System* $< TC, C >$, where $C = \{C(t)\}_{t \in TC}$ is the set of courses taught by the teachers in TC, and $C(t)$ is the set of courses taught by the individual teacher $t \in TC$.

In particular, given a teacher t, the set of her/his courses is the enumerable set $C(t) = \{C_1, C_2, \ldots, C_{n_t}\}$.

Moreover, in general each course $P \in C$ is characterized by a triple, as follows:

$$P =< L_P, T_P, O_P >$$

where L_P represents the target classroom level of the course (Elementary, Middle and High School), T_P indicates how many times the teacher has taught that course, and O_P is the ontology related to P, i.e. the set of concepts appearing in the course (with their reciprocal connections).

In particular, each concept, $c \in O_P$ is represented as

$$c =< c_{name}, L(c), RC(c), LM(c), e(c) >$$

where

- *name* is the concept name,

- $L(c)$ is the level associated to that concept. The level classification is the same as above, yet it could be acceptable that some concepts in a course have cognitive levels different than L_P (after a free choice by the teacher).
- $RC(c)$ is the set of all concepts $c_p \in O_P$, that are required in order to start learning c according to the ontology (prerequisites).
- $LM(c)$ is the set of learning materials associated to c by the teacher. Each one of them can be used during the course to support the study of c.
- $e(c)$ is the experience that the teacher has acquired having taught c_k. In other words, e_k represents how many times the teacher has taught c in all her/his courses.

We can finalize the definition of the $DN(t)$ once we have defined the following sets, where $t \in TC$ is given.

1. $N_C(t) = \bigcup_{P \in C(t)} O_P$ the set of concepts taught by t in her/his courses.
2. $N_{LM}(t)$ = the set of learning materials used by any teacher $s \in TC$, t included), to teach concepts in $N_C(t)$

Then the didactic network for the teacher $t \in TC$, $DN(t)$, is defined as the graph composed by

- a set of nodes $N_C(t) \cup N_{LM}(t)$
- a set of arcs $< c, lm > with\ c \in N_C(t)\ and\ lm \in N_{LM}(t)$, each one connecting a concept (c) to a learning material (lm), according to the usage of lm by the TC.

The graph $DN(t)$ is to be drawn showing the weight of the arcs. The weight of an arc, $< c, lm >$, denotes the intensity of the connection between c and lm, that is how much the learning material appears to be suitable to teach the concept, according to the teaching community. This intensity is computed as the number of times the learning material has been used by teachers of the TC, to teach the concept in their courses. (Notice that the teaching system will maintain a wider range information about the usage of lm for c, besides the frequency of general use; namely what teacher used it, how much, and in what courses).

3.6. Weight of the Connections between Concepts and Learning Materials

To some extent the weight of an arc $< c, lm >$, in the didactic network of a teacher, $DN(t)$, corresponds to the *reputation* of the learning material lm as a valuable teaching resource for the concept c.

Here, given for granted that we are operating in the "closed world" of the teaching system TS (that we will not mention in the following formulas), we materialize the above concept of reputation by considering three aspects:

- the **personal** aspect of how many times t selected lm for treating c in her/his courses:

$$p(t, c, lm) = \sum_{P \in C(t)} \sum_{c \in O_P} Card(LM(c) \cap \{lm\})$$

  In other words, we consider, for each course P in the teaching system, the number of times a concept $< c_{name}, L(c), RC(c), LM(c), e(c) >$ occurs in it (i.e. it is in O_P), being taught by the lm (i.e. it is not empty the intersection between the singleton set $\{lm\}$ and the set $LM(c)$ of the learning materials used for the c in the course).

- the **social** aspect of how many times, teachers other than t, selected lm for treating c in their courses:

$$s(t, c, lm) = \sum_{t' \in TC \setminus \{t\}} p(t', c, lm)$$

- the **further social** aspect related to the *dispensability* of a learning material lm, in the didactic network at hand $DN(t)$, as a teaching resource for c, in the whole teaching system. This is expressed as how many times teachers (any) in TC selected a learning material lm', different than lm, to teach a concept c:

$$n(t, c, lm) = \sum_{t \in TC} \sum_{lm' \in N_{LM}(t) \setminus \{lm\}} p(t, c, lm')$$

Notice that the first two aspects above regard an "adoption rate" for learning materials, which is declined separately from the personal and social points of view; on the contrary, the third aspect takes into consideration a kind of "neglecting rate" for *lm*, managed as an overall measure on the whole teaching community. We considered that the separation, between the social and personal concerns, could be sufficiently appreciated out of the functions dedicated to the adoption rate, and decided to avoid further notational complications in the neglecting one.

In summary, a weight combines the social and individual reputation (or "popularity") of a learning material, as per its use for a concept. This reputation is then updated continuously, while the teaching community evolves, that is while its teachers add or modify courses, concepts and choices of learning materials. An analytical definition for the weight follows.

Given a teacher $t \in TC$, and one of her/his courses

$$P =< L_P, T_P, O_P >\in C(t)$$

where $O_P = \{c_1, \dots, c_{n_P}\}$ and each concept is represented as a

$$c_k =< c_{k_{name}}, L(c_k), RC(c_k), LM(c_k), e(c_k) > (k \in \{1 \cdots n_P\})$$

Moreover let $LM(c_k) = \{lm_1^k, \dots, lm_{q_k}^k\}$ be the set of learning materials associated to the concept c_k in P.

Then, the *intensity* (weight) $\rho_{k,i}$ of the arc $< c_k, lm_i^k >$, connecting the concept to the i_{th} of its associated *LM*s, is defined as a linear combination of the vectors

- **(influence)** $\overrightarrow{F} = \{p(t, c_k, lm_i^k), s(t, c_k, lm_i^k), n(t, c_k, lm_i^k)\}$ expressing the reputational data coming from the teaching system, about the uses of lm_i^k for c_k (according to the three aspects we introduced in the beginning of this subsection).
- **(tuning)** $\overrightarrow{T} = \{\alpha, \beta, \gamma\}$, where $\alpha \in [0, 1], \beta \in [0, 1]$, and $\gamma \in [-1, 0]$ are coefficients expressing what emphasis is to be given, in the system, to each one of the abovementioned aspects. They are "tuning factors" in the computation of the weight, and they are configurable in the system according to the guidance (*amplification of the influence of connections*) that the teaching community wants to give to the system.

We define $\rho_{k,i}$ as the inner product of $\overrightarrow{F}$ and $\overrightarrow{T}$, bounded between $[-1 \cdots 1]$ by the available cosine similarity metrics:

$$\rho_{k,i} = \frac{\overrightarrow{T} \times \overrightarrow{F}}{\sqrt{\alpha^2 + \beta^2 + \gamma^2} \cdot \sqrt{s_{k,i}^2 + p_{k,i}^2 + n_{k,i}^2}} \quad (1)$$

In conclusion, while the functions in $\overrightarrow{F}$ provide access to the continuously evolving state of affairs in the teaching community (regarding the popularity of learning materials in their use to treat concepts), the computation of the weight, and the consequent drawing of the didactic network of a teacher, allows to give a meaningful representation of the teacher's experience (the second component in the TM), comprising the possibility to see the alternative choices of learning materials that the teaching community could suggest as a whole.

3.7. Example

A key feature is in the updating mechanism of the weights: this implements in the system the dynamic evolution of the *DN* and is based on the latest actions of the teacher.

The evolution of the didactic network is reproduced by strengthening the connection between a concept and a learning material, correspondingly to a selection to that effect produced by the teacher. A connection could weaken too: in correspondence of the strengthening of the connection between the *i*-th LM and the *k*-th concept, all the other connections with the *k*-th concept are weakened.

In this way, we have the possibility to know what is the best *LM* that explains a concept for a given teacher against all the other *LM*s previously used. At this step, $\rho_{k,i}$ can say to us, for the association between LM_i and concept c_k, how much LM_i is appreciated by the community ($s_{k,i}$) and by the teacher her/himself (p_k), and if that LM_i is the last chosen didactic material for c_k.

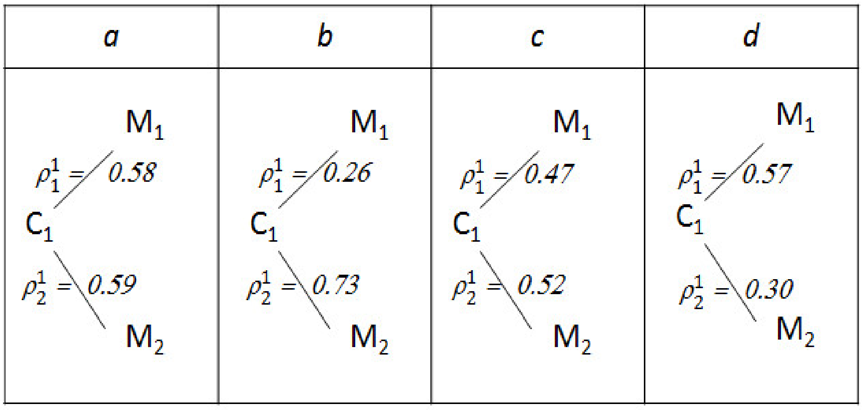

Figure 2. (*a*) The teacher *t* has already used twice M_1 to explain C_1, and other 3 teachers have already used M_2 to explain C_1. (*b*) *t* chooses M_2 to explain C1. (*c*) Another teacher selects M_1 to explain C_1. (*d*) Still another teacher selects M_1 to explain C1.

Let us show with an example the weight updating in the case of two concepts C_1 and C_2 and a learning material M_1. Let us suppose that M_2 has been already chosen 3 times from other teachers ($n = 3$) and the teacher has already selected M_1 twice for explain C_1. In Fig.3.7 is presented the weight evolution for some steps.

The entire computation is shown in Tab. 1.

4. Conclusions

Studies on e-learning concern a variety of topics, from the design and development of e-learning systems (Silius & Tervakari, 2003; Limongelli et al., 2011; Mikic Fonte et al., 2012; Garcia Peñalvo et al., 2012), through the support to personalization and adaptivity (Limongelli et al., 2008; Sterbini & Temperini, 2010; Magnisalis et al., 2011; Akbulut & Cardak, 2012) and of the dynamics of training at the workplace (Lytras, 2010; García Peñalvo et al., 2010; Lytras & Ordoñez de Pablos, 2011; Damiani et al., 2012), to the exploitation of collaborative work with pedagogical aims (Panitz, 1997; Kirschner, 2001; Kreijns et al., 2003; Yu & Chen, 2007; Shi et al., 2013; De Marsico et al., 2013b, 2014d).

In particular, social and collaborative interaction makes an e-learning environment more valuable and effective (Sterbini & Temperini, 2008; Kotsovoulou, 2013; Benson et al., 2012; Ströele et al., 2011).

This research topic is usually addressed in regard of the interaction between students an teachers, or students and students (Karacapilidis et al., 2013; Christensen & S., 2011; Sielis et al., 2011; Sterbini & Temperini, 2012; De Marsico et al., 2014c,b).

We have seen, in Section 2, as the support presently given to teachers is still limited, with respect to the many and quite complex tasks that have to be accomplished while building a course, especially when personalized configuration of courses is involved.

Table 1. Weights updating.

	(C_1, M_2)				(C_1, M_1)			
	p	s	n	$\rho_{1,2}$	p	s	n	$\rho_{1,1}$
a	0	3	0	0.59	2	0	0	0.57
b	1	3	0	0.73	2	0	1	0.25
c	1	3	1	0.52	2	1	1	0.47
d	1	3	2	0.30	2	2	1	0.57

To represent a teacher in the framework of a system it is necessary to model both her/his way of teaching and her/his teaching experience. Teacher's teaching style and information about the association between concepts to teach and learning material, selected to teach such concepts, are also important components of the representation of the teacher in a system. A model available to represent the abovementioned issues can be very effective in helping the teacher during the phases of selection and arrangement of learning material for a course.

In this paper we have proposed a Teacher Model that automatically tracks the experiences of a teacher. Our model is based on both Teaching Experience (TE) and Teaching Styles (TS). The TS is an application of the Grasha TS pedagogic model (Grasha, 1996), whilst the TE is a novel dynamic didactic network composed by those concepts and those learning materials actually (and persistently) used by the teacher to build her/his courses. A crucial aspect in the didactic network, representing the TE, is its openness to the data flowing from the course construction activity of all the teachers participating in the *Teaching Community* that operates in the e-learning system, not much differently by the ways of a Community of Practice (Wenger, 1998; Weller, 2001) (at least potentially).

We preview to use the defined model to build teacher profiles regardless of the specific course taught. Being based on the correlation between learning materials and concepts, and being the concepts participating in an ontology not necessarily limited to a single course, the model can be maintained and updated along the whole teaching experience of a person. This, in our vows, allows also to extend the use of the model in a social dimension, where similarities among teachers' teaching preferences can be detected and exploited to advise automatically about most suitable learning materials associated to requested concepts.

Although the concerns we have addressed, in this paper, are mainly "teacher centred", in our opinion they can have, in turn, a valuable effect for the students too. In an e-learning environment, where the teacher's activity is seen as part of the teaching community operating in the system, and where the teacher model we defined is managed, the teacher would be allowed to feel safer and have an easier job, while adopting learning materials for her/his course. (S)he could as well add alternative material, basing on a less cumbersome and lonely process, such as the one allowed by the social feedback coming from known colleagues. Ultimately, (s)he might make the course a richer place, where students could undertake more varied learning paths and interact/discuss, about such alternative possibilities, with the teacher.

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