PROBLEM-DRIVEN NETWORKED LEARNING

Michele Missikoff

UniNettuno International Telematic University and Institute of Sciences and Technologies of Cognition - CNR (ITALY)

Abstract

The paper addresses the theme of education and learning on the job, proposing an innovative methodology based on a semantic (ontology-based) approach, positioned in the context of problem solving episodes. In contrast with the continuous demand of life long education, people busy in their workplaces have difficulties in stopping activities to dedicate the time that a course requires. Furthermore, there is a growing demand for personalised education that carefully considers the competencies and the background of the learner, but also the operational context and her/his role in the organization.

The proposed methodology, referred to as Problem-driven Ontology-based Learning (POL), is based on an agile, focused approach capable to provide learning opportunities on the job, when a problem is encountered. The problem is then turned into a positive opportunity for the user to better understand the ‘whys’ and the ‘hows’ connected to the problem.

The POL methodology relies on a knowledge infrastructure having the Problem Ontology (ProblemOnto) as its core, and a networked repository of learning material. The platform, currently under development, offers to the user two different but intertwined environment: A Problem Solving environment and a Networked Learning environment.

Keywords: Education on the job, problem-driven education, problem ontology, networked learning, collaborative learning community.

1 INTRODUCTION

This paper illustrates a learning methodology conceived in the context of a Life Long Learning program, addressed in particular to people who are already employed, busy in their everyday work, who nevertheless need not stopping their learning experience. The proposed methodology is centrally based on a shared knowledge infrastructure, and in particular on a problem ontology [1], therefore we refer to it as Problem-driven Ontology-based Learning (POL) method.

One of the major problem here is to capture the attention of the people and engage them into a virtuous learning experience that is compatible with their working situation and capable of bringing immediate and practical benefits to the learner (high payback).

The proposed method starts from the idea that in a large number of cases it is important to consider that:

- traditional teaching approaches, based on the notion of courses that cover a ‘standard’ set of disciplinary content, do not work;
- the recipients have already a good base of skill and experiences, therefore many practical topics can be given from granted, but such topics may vary from person to person;
- often, they already have a high school or university degree, therefore some disciplinary knowledge can be assumed, but again such knowledge may vary from person to person;
- they work in a complex scenario with little time available and, even if there is a coordinated group of learners, participants may be available in different moments;
- when studying, they need to see that the learning effort will bring tangible benefits in their work (immediate payback);
- but at the same time, it is important that a focused, quick learning episode is positioned in a wider learning scope, aiming at an educational objective.

The proposed POL methodology starts with the idea that a powerful trigger for a learning episode (we prefer this term as opposed to ‘course’) is a problem that one incurs into during her/his (working)
activities. Then, the challenge is to present to the user (we will refer to the learner with this term, to emphasise the active role) a coherent, personalised, interlinked set of learning units (see below the definition) intended to equip her/him with the knowledge useful to address the problem at hand.

In this way, we dis-articulate the notion of a course, intended as a sequence of logically organised set of teaching units that address a predefined sequence of topics. We challenge the notion of ‘sequential learning’ adopting a pedagogical method based on contextualised, interlinked learning objects (e.g., Reusable Learning Objects.)

Please note that the proposed approach is twofold. On the one hand, it draws upon the Problem Solving discipline, since at the end of the learning episode the problem that has triggered such an experience will be (hopefully) solved; on the other hand, the whole experience will end up with a greater understanding of the matter related to the encountered problem, with opportunities to elaborate more on connected topics.

In the paper, to make the description more concrete, we introduce a running example, presented with a ‘storytelling’ approach.

“Ann is working hard to terminate the report on the new marketing strategy by Friday. She already collected all the figures and the supporting documents; furthermore, she already elaborated a few Excel files, drawing interesting evidences, and she has already drafted a first Table of Content (ToC) of the report. This morning Ann arrives early in the office but starting the computer she noticed that the response time is very slow. She starts the usual applications (Word, Excel, Firefox), but she has to wait several minutes before they start. Opening a document also takes several minutes, typing is enervating, since letters do not appear immediately, and often the mouse gets stuck. She tries to restart the computer but the situation does not improve. Ann understands that she has a serious problem and she will never complete the report in the due time with the computer in this situation. The problem need to be solved, and in addition the colleague who always helped her in similar situation is in a business trip and will not come back before next week.”

2 NETWORKED KNOWLEDGE INFRASTRUCTURE

As anticipated, the proposed approach has two tightly intertwined environments: Problem Solving, necessary to provide the payback, and Ontology-based Networked learning, necessary to turn a problematic accident into a positive opportunity of learning new skills, and be educated accordingly. The POL methodology should not be confused with traditional methods and tools that are used for problem solving, where the objective is focused to support the user in finding a solution for the problem at hand. The problem solving services are guided by the problem ontology and connected to the learning environment.

Ontology-based Networked Learning can be considered as a natural evolution of the Web culture (in turn, rooted in the hypertext model), and in particular its advanced version: the Semantic Web. Networked learning takes place in the context of a Networked Ontology-based Learning Ecosystem that has two main components: one is the social media, that supports the learning community, and the other is the Educational Knowledge Infrastructure (EKI), composed by a reference ontology and the educational resources (e.g., Reusable Learning Objects) that are interconnected accordingly. The ontology, called ProblemOnto, is mainly shaped in accordance with a problem meta-model; it is used to organise, at a conceptual level, and access, at a factual level, the educational content and the human resources with their competences. In this paper we focus on the latter.

An Educational Knowledge Repository can be traversed in many different ways, along different dimensions. The EKI content is organised according to disciplinary clusters, with learning units and strata. Strata are used to move along the vertical axis, where increasing depth implies a deeper (more detailed) material on a given topic. Moving horizontally, implies the navigation throughout a sequence of related learning units. In the content network there are oriented arcs indicating a logical dependency (with preparatory topics that precede more specific topics), and crossing boundaries of different topics. The arcs can be solid, when there is a strong dependency (i.e., you cannot address topic B if you did not understand topic A) or a broken arc in case of ‘soft dependency’, i.e., when topic A is suggested to better (and quicker) understand topic B, but the absence of A will not prevent the understanding B.

A Networked Learning Programme can be build dynamically, depending on the user needs; it is represented by a path on the 3D graph traversing a sequence of learning units, with a sequencing that best matches the needs of the learner. Cycles are not excluded: when a given topic needs to be
studied again in a later moment, e.g., when the learner understands that her/his study is not satisfactory and a further review of a given topic is need to be better clarified the matter.

3 THE PROBLEM SOLVING ENVIRONMENT

There are several approaches methods that support and guide a Problem Solving (PS) process, and there are very many definitions of what a problem is. First of all, we wish to provide a definition that will be functional to our work.

Def. Problem

A problem is a significant deviation from the expected course of actions and / or the expected outcome of such actions.

In general, the kinds of problem that can be encountered are extremely varied, in their nature, scale, causes, effects. They go from a global scale, such as the Global Warming of the Planet, to very specific and mundane, such as a flat tyre. Our study is focused on the enterprise context and the problems that a worker can be confronted with.

In this paper we propose a Problem Solving method on top of which the proposed learning method is constructed. Among the very many PS methods in the scientific literature, this work has been inspired by the TRIZ methodology [2], from which we emphasize the fact that it significantly relies on the availability of knowledge resources.

In Fig. 1 we provide a high level description of our reference framework, based on a four quadrants scheme. The two top quadrants are of an intentional nature (i.e., they represent conceptual knowledge, essentially types and attributes) while the two lower quadrants are of an the extensional nature (i.e., they represent factual knowledge, i.e., data). Then, the two left quadrants represent the problem spaces (conceptual and factual) and the two right quadrants represent the solution spaces (again, conceptual and factual). Here we describe in more details the different components of the OPL Framework.

- **Intensional Problem Space (IPS).** Here we have a collection of problem types organised according to a hierarchy, from very general (the root is Problem) to very specific. Each element in the hierarchy is characterised by a number of attributes that define its nature and possible manifestations, In essence it is represented by the ProblemOnto ontology.

- **Intensional Solution Space (ISS).** Here we have a collection of correcting actions and countermeasures that have been experimented in the past and showed their effectiveness in solving the problem(s) they refer to. Also the correcting actions are hierarchically organised and represented by an ontology, referred to as SolutiOnto.

- **Extensional Problem Space (EPS).** Here we have rich repositories of problem cases that have been encountered in the past, with their characteristics and evidences. When a new problematic case arises a new position is opened and it is progressively populated while the problem solving process proceeds. In this way, we have at the same time a log of the activities and eventually a new case that will be added to the EPS repository.

- **Extensional Solution Space (ESS).** Here we have a repository of actions, connected to the problem cases in EPS, that have been undertaken, both in the exploration phase, to identify the problem at hand, and in the resolution phase, when the identified solutions that have been successfully adopted (but also negative results are reported, to avoid the same mistakes in the future).

In Figure 1 there are also various arrows having different meanings.

- **Problem Solving Methods.** It represents the linking of a problem in the IPS to possible solutions in the ISS. Please note that the link is not functional, it means that given a problem type there is not just one kind of solution.

- **Actual Problem Solving.** This arrow represents the concrete (factual) evidences of past problems and the solutions that have solved them.

- **UX - User Experience.** These two arrows represent the concrete activities of the user who, on the left side, explore his/her evidences to define the specific case, checking if it matches with (i.e., it is instance of) a problem type reported in the IPS. On the right hand, a similar checking is
carried out to implement (or build, if new) the specific solution that (hopefully) will end up solving the problem.

- **Problem-driven Learning.** This complex structure represents the second side of the proposed methodology. It consists of a supporting tool that follows the actions of the user in the problem solving process. Then, it keeps track of the visited knowledge items, the data entered, and then proposes to the users suggestions on how to proceed in building a solution and, in parallel, the learning items (e.g., OERs) that can support the user in her/his problem solving endeavour, but also in acquiring the competences and skills related to the specific case. Furthermore, to avoid an educational offer that is limited in scope, some more general themes and framing perspectives are also offered.

**Figure 1. Overview of Ontology-based Problem-driven Learning Framework**

### 4 THE PROBLEM ONTOLOGY

The problem ontology collects and organises in a hierarchical structure, all the concepts pertaining to problem solving. Figure 2 represents an excerpt of such an ontology, where the key concept is *Problem*, and then we have a first level of specialization, organised according to the enterprise dimensions where the causes of the problem may arise.

In our running example we focus on the D-Dim, i.e., the Digital Dimension, where we further specialise into 3 subtypes: *Hardware*, *Software*, *Network*. In our case, the addressed problem *Computer_Stuck* is initially positioned below Software, but there can be more complex situation where we stumble into a problem that lays at the intersection of Hardware and Software (without becoming too technical, we can mention that this is a case of *multiple inheritance*).

- **Problem**
  - H-Dim (Human Resources)
  - O-Dim (Organization). It includes rules and regulations that need to be enforced during the process
  - M-Dim (Material Resources)
  - C-Dim (Competencies)
  - F-Dim (Finance)
  - K-Dim (Knowledge & content)
  - D-Dim (Digital Infrastructure)
    - Hardware
    - Software
      - Computer_Stuck
    - Network
  - Symptom
    - Cursor freeze / Slow App Start / Slow typing / Slow Web Navigation / Slow App Switch [all specialization of Symptom, linearized for sake of space]
The ProblemOnto will drive the problem discovery process, but it represents also a sort of ‘semantic directory’ to access the rich section of the platform that organises the learning material. For sake of space, this part is not elaborated in this paper.

5 PROBLEM-DRIVEN ONTOLOGY-BASED LEARNING: POL

In essence, the PS process consists in exploring the intentional level, aiming at identifying problem types, matching the current problem instance, and related solutions types, while populating the extensional level. It may be the case that the user encounters a new kind of problem, that eventually requires a new solution, not previously represented in ISS. In this case, also the intentional level of the knowledge infrastructure is revised and enriched (or updated, in case that a better solution for an existing problem is identified.)

Please note that in the POL methodology is heavily based on the support of a rich knowledge infrastructure that initially is populated by a few experts, and then it requires a community of people contributing, with their experience, to then continue enrichment and validation of the knowledge repositories, including the two ontologies: ProblemOnto and SolutiOnto.

Typically, we can articulate such a process according to the following phases:

- **Manifestation.** When there are evidences that something is not going as expected: the user has a problem.

- **Problem discovery.** It consists in the exploration of the operating context to acquire new evidences that may guide us to eventually identify the type of problem at hand.

- **Solution identification.** Once the type of problem has been identified, we travel along the upper arrow to lend on the possible solution(s). If more than one solution is possible, then a further investigation is required and, eventually, a decision making.

- **Solution implementation.** Once a candidate solution type has been selected, then it needs to be instantiated according to the actual parameters of the case at hand.

- **Solution assessment.** Here we observe if the adopted solution actually brings the expected outcomes, and to what extent. If the results are not satisfactory, then we need to start a refinement cycle.

Besides the two ontologies, aimed at supporting the PS process, the knowledge infrastructure includes the learning section, that represents the second side of POL proposal, where the educational material is collected and organised. It is highly critical that the learning units in the Networked Knowledge Infrastructure are suitably organised and linked to the elements of the IPS and ISS, but also to the methodological knowledge areas represented by the arrows of Fig.1.

6 THE LEARNING ENVIRONMENT

On the Learning side, our proposal is inspired by a number of methods that in the last period are attracting a growing interest. We briefly report the most relevant ones.

- **Education on the Job.** Also known as Work-Based Learning (WBL) or Work-Related Learning (WRL) [3], it is an educational approach that does not require people to interrupt their working activities, typically moving into a class to follow courses in a formal educational setting. It is conceived to allow for learning while working.

- **Collaborative Learning** [4]. This is a method that requires a group of people to share the learning experience and accept to help each other. Collaboration takes place in a working and learning context, as opposed to a more traditional approach positioned in a classroom, where people cooperate in the courses, but apart from their working setting. In our proposal, the collaboration is deployed in all the phases of real world problem solving and, in parallel, accessing of the educational material connected to such working activities. The second key aspect here is the collaborative knowledge creation and curation, to constantly enriching the knowledge infrastructure.

- **Situated Learning** [5]. This is an approach that perfectly integrates with the two previous methods, where in addition to the community that shares interests and learning experiences, we need to consider the context in which the working activities, the problem solving, and the learning experiences take place. In fact, it is important to note that the same kind of problem in
different contexts may require different solving strategies and may induce different learning content.

- **Networked Learning** [6]. This is another articulation of a learning method that relays on networked communities, where each member is a node of a proactive network and contributes to improve the learning experience of everybody. In our case, as anticipated, the networked communities are extremely important to build and maintain the knowledge infrastructure, according to a crowdsourcing philosophy.

- **Problem-driven Learning** [7]. This approach is a central reference for our proposal. It mainly consists in the idea of learning in a classroom starting from a given problem that is proposed to the students, both to test their skill and to give a more concrete perspective to what they have learned. In our work, we adopt a similar approach but instead of operating in a classroom with a in artificially generated problem, we deal with real world problems in a real working context.

The above process is necessarily described in a sketchy way. This is a very complex process, where the steps are tightly intertwined. It may be the case that we acquire evidences that turn to be irrelevant in our investigation, or even misdirect our pursuit. In other cases, there are evidences that lead us to further investigations, opening a promising pathway that needs to be traversed all the way, along a lengthy journey. Below we address the learning side of the POL framework.

### 7 THE POL METHODOLOGY IN ACTION

The following table, referred to as Problem Solving Support Table, provides a sketchy example of the proposed method. The content is built according to the running example that concerns the problem of a computer that exhibits a substantial degradation in performance and response time.

As anticipated, the method has a twofold objective: firstly to support the user (learner) in solving the problem; secondly, provide resources that will contribute to the learning experience of the user. In particular, for every possible cause there are more than one learning resource; typically, one has a practical nature, aimed to support the user in solving the problem, and the other has a more educational nature, to provide the opportunity to acquire a better understanding of the problem and the technical field (in our example) where the problem is positioned.

#### Table 1. Problem Solving Support Table

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Possible cause</th>
<th>Action</th>
<th>learning suggestions</th>
<th>Learning Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cursor freeze</td>
<td>malware</td>
<td>run antivirus</td>
<td>Malware Analysis</td>
<td><a href="https://www.cybrary.it/course/malware-analysis">https://www.cybrary.it/course/malware-analysis</a></td>
</tr>
<tr>
<td>Slow typing</td>
<td>files fragmented</td>
<td>run defrag</td>
<td>Defrag Methods and Tools</td>
<td><a href="http://www.pcadvisor.co.uk/how-to/windows/hard-drive/defragment/">http://www.pcadvisor.co.uk/how-to/windows/hard-drive/defragment/</a></td>
</tr>
<tr>
<td>slow web navigation</td>
<td>greedy app</td>
<td>check app resources</td>
<td>Analysis of running processes</td>
<td><a href="https://www.k-state.edu/its/security/training/2016">https://www.k-state.edu/its/security/training/2016</a></td>
</tr>
<tr>
<td>slow app switch</td>
<td>insufficient ram</td>
<td>check ram usage</td>
<td>Ram usage understanding</td>
<td><a href="https://superuser.com/questions/437918/how-to-check-ram-on-mac">https://superuser.com/questions/437918/how-to-check-ram-on-mac</a></td>
</tr>
</tbody>
</table>

To summarise, the table is used to achieve the following objectives:

- guiding the user to explore the problem space to identify the problem (diagnosis)
- support the user in finding the way to fix the problem
- trigger a learning episode connected to the relevant discipline and knowledge
provide a number of open educational resources to support the user in her/his learning.

8 CONCLUSIONS

In this paper we presented a sketchy description of the Problem-driven Ontology-based Learning (POL) methodology. POL has been conceived primarily addressing people involved in intense working activities with little time available for 'traditional' learning programs. Furthermore, busy people need to have a fast and evident payback for the time they dedicate to learning. Then, the key idea of OPL is to connect a learning experience to a difficulty or, more precisely, a problem that the user encounters during her/his working activities.

The proposed methodology is centrally based on the Problem Ontology (ProblemOnto) that organises the problem space, according to a hierarchy of problems with the associated attributes. Furthermore, each problem is associated to competencies and skills necessary to solve it. In this way, it is possible to generate a PS Support Table that guides to user in order to solve the problem at hand. Such a generation is interactively provided by the POL platform, based on the user input.

As anticipated, the success of this methodology mainly depends on the presence of an active community that will cooperate in building and maintaining the knowledge infrastructure, and in particular: (I) the ProblemOnto ontology; (ii) the repository of past problem solving cases; (iii) the directory of references to the educational resources.

From the technical point of view, the project is in its early stage and currently we developed a first version of ProblemOnto. In the future we will achieve the POL platform and set a first experimentation.

REFERENCES


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