Dynamic Ontologies and Cooperative Learning

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Abstract. The process of learning, especially in creative cooperative environments, has to be properly supported. A central role is played by knowledge organization and information sharing across group members. Within the ATELIER project functionalities for giving support to architecture and design students through ontologies that are dynamically generated and maintained have been developed. This work presents how this has been done, referring to the underlying learning model, elaborated scenarios and project experiments. Our proposal is finally contextualized into recent literature.

Keywords. Cooperative Learning, Ontology.

Introduction

Every cooperative workspace defines a common language shared within its context by all internal operators. People working on the same field (e.g. architects and designers in our special case) but also people having the same background or education need to use the same terminology while referring to concepts and ideas they elaborate altogether. Being able to rely on a common framework (given by the lexicon) people are also usually able to elaborate a shared set of inferences on objects in the domain. This goal is achieved generating a common grammar that gives sense to words, the ontology semantics. The aim of an ontology is to map and formalize these capabilities to make knowledge accessible from generic users of a collaborative system.

Starting from these properties our work is aimed towards the development of a specific module for a cooperative learning support system. Considering the rising importance of meaning-making in learning processes [18], especially in collaborative environments, where several small groups of students carry on their work in parallel, it is important to notice the way common understandings emerge and how they are driven to finally achieve the goal of each workgroup: the creation of some artifact representing innovative concepts and ideas.

This paper is structured as follows: first a panoramic description of what kind of environment our research is being developed in and on what an ontology is will be given. Then problems arising from the creation and use of an ontology in a creative learning environment will be described. Last sections will focus on a comparison with another recent work which will show some interesting topics such as how ontology is generated starting from multiple points of view.

1. Learning model

In the following section the background for our work is outlined and a learning model is given to describe the process to be supported by the system.

1.1 Background works

The background for our research has been the ATELIER (Architecture and Technology for Inspirational Learning Environments, IST-2001-33064) project. The aim of the ATELIER project is to contribute to inspirational learning environments, which are grounded in an understanding of creative practices within design, architecture and art [6]. The project starts out from interactions between people and material artifacts in physical places and asks how such an environment should be enhanced with digital technologies to turn it into a resource for inspiration and creative learning by an integrated design of learning materials, interactive technologies and architectural space [6]. Research is then focused on creative work in architectural master class and interaction design studio.

A common infrastructure has been implemented to integrate many devices being developed for previously listed purposes, meanwhile our workgroup was in charge of the creation of an ontology and, more in general, a knowledge management system for this whole infrastructure. This management functionality is supposed to act as glue for the system, keeping information collected within the environment coherent both from logic and pragmatic point of view. One example of digital device will be later presented. We developed two kinds of functionalities for the software environment: the first one is for indexing items in a shared database according to an ontology and the second is for helping users in finding inspiration through material previously inserted by themselves or someone else. This second activity will not be treated in detail in this paper but it can shortly be said that ontology driven selections are very powerful for leading imagination to non-conventional paths for reasoning. An algorithm for ranking documents according to 'inspirational interest' has been studied and implemented in an application for conceptual navigation of a knowledge base. This is a specific use for the ontology, but many others can be envisioned or found in existing literature (e.g. semantic web and other similar applications).

Being our application part of a comprehensive framework, designed for a whole integrated platform, design principles have been drawn both from scenarios and real use observations. Our ontology and knowledge management functionalities have been developed keeping in mind what end users needs were and for what the final aim was: cooperative creative learning.

1.2 The learning model

First of all a learning model has to be found and to be used as a reference. In the following one well-known approach is presented and definitions for experiential and inspirational learning are given according to it [11].

David Kolb's theory [11] has been widely discussed from various learning methodological perspectives (see also [9] for some further references on critiques) and it seems to well fit both to scenarios developed in earlier stages of the ATELIER project [20] and experiments being used for prototype testing. Synthesis in [3] has also been used as a reference.

Core concepts of Kolb's model [11] are those of *experiential* and *inspirational* learning. Both of them are considered as cyclic phases and their combination is stated to result in the generation of meaning. The concrete world of experience and the personal

sphere of insights operate in turn, but this has not to be intended as a temporal constraint of the process, in order to acquire and refine learner's knowledge and understanding. Kolb also suggests [11] that learning is the creation of knowledge through the transformation of experience, and that exactly is what came out scenarios and experiments in our project.

The process of learning starts with the immersion of the learner in a concrete experience from which as many observations as possible are gathered and perceptions stored. ATELIER project students are provided with digital devices for multimedia data recording while they are visiting sites and collecting data, further tools for organization and knowledge sharing are the main topic of our group research and will be discussed with a greater detail later in this paper. Returning on Kolb's theory [11], information-gathering period is then followed by a phase of thinking, which aims to understand at a deeper level what has been experienced. At this point, according to achieved understanding, plans are made and an action is taken. The experiential process can then eventually restart as a cycle to create some more knowledge. Experiential learning can thus be envisioned as a recurrent process of adaptation to change, based on a rigorous process of transformation. In reality of course, this learning process is far less systematic than this and steps can be taken back and forth or even skipped and repeated in the process itself. At the same time an inner process takes place into the learner: it can be named as inspirational learning. This can be seen as a rather spiritual and meditative process but the meaning is that new ideas are elaborated while awareness grows into the learner and focus is gained on most relevant topics and knowledge fragments. When considering groups this process can also be seen from a collaborative perspective, with concepts and ideas spreading among people and being elaborated altogether with a series of interactions, discussions and shared reflections.

Meaning thus emerges from the 'systemic interaction' [3] of insights gained through inspirational learning with abstract concepts learned through experiential learning. In our specific context, as in cooperative learning, the convergence between the two processes is reached within projects each time a group coordinates itself and each time work is discussed with teachers or external audience.

2. Ontology

> "*An ontology is similar to a dictionary or glossary, but with greater detail and structure that enables computers to process its content. Ontology consists of a set of concepts, axioms, and relationships that describe a domain of interest*." (http://suo.ieee.org/)

In order to achieve a complete coverage of the whole domain to which the ontology is going to be applied, the first engineering phase in ontology design is to enumerate as many terms as possible and to later identify the ones among them which can be considered as equivalent, the most relevant ones and those others that simply are properties that can be referred to other objects. The core element around which each ontology is built is that of *class*. Classes are collections of items having the same set of characteristics or objects having similar properties. A class can be seen as a formal or schematic representation of a concept in the domain. All the people sharing it address each concept using the same word. If the term used is not strictly the same one then probably it will be just a synonym but the final representation of the two words will at the end map onto the same ideal object, the class. The *is-a-synonym* relation is the first relation that can be introduced to group classes. In common practice there can however be plenty of other relations among concepts. The simplest relation to discover is probably the *is-a* relation, meaning that a particular object is just a particular form of another one. For example everybody can say that a *Church* is a kind of *Building*. It can also be said that a *Skyscraper* is another kind of building and nobody would say at a first glance that skyscrapers and churches are the same, even if they

have some properties in common. Using the *is-a* relation a hierarchy of classes can be defined. Another relation that can be used to enrich the meaning of a hierarchy is the *is-a-part-of* relation (conversely *is-composed-of*) giving information on aggregated items. For example a *Church* is typically composed by a *Transept*, a *Pulpit*, one or more *Naves* and many other elements.

Unfortunately the classical, straightforward way of building an exhaustive ontology of a consolidated field usually starts with the steps above but they cannot be applied to a context where the knowledge base, and the underlying ontology in particular is dynamically defined either by users or by some external maintainer. Another case is that in [17] where the ontology is "discovered" by investigating a community, through the mediation of some people bridging the community and the researcher. We found some interesting similarities and differences with [17] and they will be discussed later.

In our case the aim of the ontology is to help students organizing material they collected while working on field for some project. In order to do this they have to be provided with some few general categories but they then also need the possibility to enrich such a schema following their own mental and creative processes. Nevertheless external interventions from some qualified figure are still needed, and these usually are the moments when students interact with their teachers or among themselves within a master class or during some presentation or exhibition.

2.1 A practical Scenario

In this section a practical scenario is given, in the sense that what is described is the scheme of a real ongoing experiment within our research project but, as it is ongoing, some details are still missing and from a certain point on they are just inferred by authors on the base of earlier scenarios [20]. Even though these inferences might at the end result in some slight differences from real experiment results they do not affect our reasoning.

When the experiment starts a global project or topic is first assigned to a whole class, while different tasks are pointed out and then students are split into smaller groups. Each group is given a small set of keywords and starts then to visit places that are considered interesting. Each group collects data on field and annotates it using mainly given keywords but also additional ones according to their contextual needs. No technical constraint is given. Means and devices to do such an investigation were implemented by our project workgroups. For example a suite of devices is available within a 'jacket' component [4]. The Jacket was developed by ATELIER workgroup at Oulu University (Finland) [8]; it is a real cloth with which some digital devices are carried along. A digital camera is used to take pictures onto the sites. A PDA (Personal Digital Assistant, a Compaq IPaq) is used to record sounds and is also provided with a compass and a GPS (Global Positioning System) card using which the exact position of the user into the landscape while capturing pictures and sound is traced. A digital map is later attached to GPS data and then a three-dimensional path for the whole visit is created with all the movements, including altitudes. Spots where digital snapshots were taken are marked on the map as dots and are then later browsable on a desktop PC or any other display device within the system when data, after being outdoor collected is added to the whole infrastructure database. Since all groups are supposed to work within the same room, it happens that investigation are done by a small group or eventually by a single person, but a shared collection is then created with all the digital material collected during all trips. This way information can flow across the class and students can interact to achieve some higher degree of understanding and creative effort. Items are reorganized first by group members who enrich descriptions and eventually create new documents and collections or folders. Ontology will now be composed by all keywords used but since students are free to use keywords they like most and they are not constrained to the ones initially given ontology needs to be

cleaned and maintained by some trusted, skilled user who can be the teacher himself or the group responsible as well. All this further data re-organization steps are part of the creative process itself and drive students to the creation of new ideas, artifacts and presentations. Confrontation is always present with teacher and other students interaction and this phase loops until project reaches its end.

2.2 Ambiguities

If the possibility to enrich the ontology and to create new categories and relationships is openly left to users, it means that it might happen that ambiguities are accidentally inserted into the knowledge base. An ambiguity may occur at two different levels: formal and pragmatic. With respect to the first kind, all the instruments given by logic could be used to avoid this event [14], systematically preventing users from inserting definitions that could be contradictory within the actual state of the system.

Ambiguities at a pragmatic level cannot be treated only by technical means because such situations also involve social dimensions. For example if two users inserted in the systems two contradictory descriptions it has to be understood why it happened and what it means. Are those users speaking about the same concept from different points of view, but with respect to different objects? Are these differences really eradicated into their vision and formal conceptualization or do they just depend from a different perception and use of the language, of the same term? Could these differences be reduced by finding a common agreement or, on the other hand, such a compromise would in the end reduce the richness of domain reality? Different approaches to these themes are already available (e.g. [12]). Considering that an omniscient and omnipotent agent does not exist, as stated in [15], we suggest that instead of trying to automatically solve contradictions or ambiguity in general the only solution is to make it clear to the users, asking them to engage themselves in a dynamic process of collective negotiation. Our hypothesis is that such a process can be fruitful for the learning dynamic that the system is aimed to support.

Since the publication of "Plans and situated actions" [19] it is widely recognized that the context in which actions take place is what allows people to find it meaningful, therefore the system has to provide the whole context in which the ambiguity was created. Considering that every object uploaded in the system probably came from a field study session, providing the context means also to recreate the situation in which the information was collected: this is useful both to help the author of the first definition to recall in his memory the experience that leaded him to choose such a formalization and to share such an experience with others students, so to allow people to reach a mutual understanding. Hence the dialog between the authors of two discrepant descriptions will probably assume the form of a story telling. The importance of using stories to share experiences was already demonstrated by the success of systems like Xerox Eureka [5],[10] a well-known example of how to leverage the existing social practices through which sharing takes place for implementing a socio-technical system to enhance these work practices. As pointed out by Bannon and Kuutti, "it is not the stories per se but the discussion and debate that they stimulate that is important in developing real understanding" [1]: in fact Atelier ethnographic fieldwork showed that story-telling both, as part of learners discursive practice and as supporting project memory and history, reinforces the learning process and the availability of insights across time and space [20]. To show the effectiveness of ontology building in stimulating such a debate, a comparative illustration now follows.

3. Methodology

A good example of a community-generated ontology comes from a recent paper by Ramesh Srinivasan [17]. The aim of Srinivasan's paper is to demonstrate the effectiveness of an ontology-based design versus a keyword-based representation in enabling community media systems to focus on issues that are really relevant to users. We both focus on the effectiveness of the process of building the ontology in triggering discussions and comparisons within the community but our works somehow differ in the way this process is lead as a whole, and on the roles assumed by people inside it.

Village Voice [17] is a digital environment for knowledge sharing, for collecting stories, traditions and concerns across a physically bounded Somali refugee community located within the Boston-area, in the U.S.A. The project is based on the premise that the oral process of storytelling is strategic for the preservation of tradition through its re-creation. It exploits the possibilities that computer networking and digital technologies offer by leaving users freedom to re-articulate collected contents according to their personal sensitivity. Village Voice system consists of a web-accessible archive of video-recorded story. The interface is built atop an ontology illustrating the intersecting issues of the community. The Somali community was actively engaged in building such an ontology by several interviews and group discussions. Fifty stories created by community members were videotaped and then showed during two workshops. The concept of ontology was introduced by examples to the participants and then community priorities and relationships among them were discussed. The community had to come to a consensus on whether an issue that came up should be included in the ontology or not and on where to place it into a diagram. The process of using stories to allow attendants to articulate their opinions ended up being the key process for the design of the emerging ontology.

In the Village Voice project the ontology was implicitly already present in the mind of community members or, at least, in the memory of the community as whole. In fact the ontology they designed is a representation of community's perceptions and vision of the world. As a consequence the author and the community designed the ontology once and for all, without needs of a continuous maintenance process (even if the participants could redesign the ontology, according with issues changing, during preliminary discussions). In our specific case, on the other hand students do not share any ontology about the subject they start working on. Earlier phases of designers and architects works consist of developing an idea on a subject, as it is a project base work. In current experiment students are dealing with warehouses: they have to first visit a large set of existing warehouses, to extract some core concepts and then to design some new ones to be embedded into an urban landscape. They do not necessarily share opinions and concepts about logistic, storage processes or organizational issues in advance. According with this fluidity, the teacher provides just an ontology draft that students can follow or edit during data collection fieldwork, accordingly with their needs to create new classes and different relationships among them. By doing so, students have to reach a consensus on the conceptual perception of the subject they are working on. The teacher supervises the process, preventing personal interpretations going too far from the final goal. Nevertheless ontology administration “cannot really seek to impose a unique point of view” [6] but only to facilitate quicker convergence to common understanding. In the second phase of the work students have to make up a project. This requires them to reorganize their ideas in a creative way. Work phases are just analytically separated: they actually are interconnected, as already stated while describing the learning model. Ontology management thus becomes not only a need but also a bearing to collective inspirational learning, requiring a conceptualization effort.

The choice of leaving to the users the possibility of managing ontology structure depends from the very nature of the process the system is conceived to support. In fact learning could be seen as an iterative shift from a conceptual disorder to a structured, organized situation. As students advance within the project, their vision of the matter

evolves from a jumbled heap of single ideas, toward a harmonious conceptual frame. As a consequence ontology cannot be designed as a monolithic entity, because it has to flexibly follow and to support this evolutionary process. Asking to the students to organize classes and concepts into an ontology means facilitating a process toward the understanding of the formal analogies on which is based human possibility of communication and reasoning [2]. Moreover, ATELIER users being architecture and design students, their work involves project dimensions, related with sharing a view of a concept to develop; but "the 'shared-goal' is not there in advance; it is constructed by the members in the course of the project, and it is in the process of agreeing to a 'shared-goal' that the designers arrive at an agreed-to design" [16]. Hence it becomes necessary to support such a process of reaching a shared understanding through an evolving ontology managed directly by the users.

In the Village Voice project the process of building the ontology took shape as a knowledge capture process with the aim of building a memory repository. A shared meaning was already present: community members shared cultural assumption about their life and about most of the topics raised up during the workshop. Obviously individual differences existed, but they were a sort of conjugation of a common grammar: in a word, it can be said that community members share a single identity. The discussion primed by the videos during ontology definition workshops served to explicit to Srinivasan the articulation of the heterogeneous factors that shaped that particular identity. In the ATELIER project, students at the beginning do not share a common vision or, neither individually, a clear idea about the subject they are working on. Referring to Nonaka and Takeuchi model of knowledge transformation process [13], it can be said that while during Village Voice workshops only socialization practices took place, in our case students act, throughout the project, a continuous interplay between socialization and internalization practices. In these processes the collaborative activity of sharing and the personal moments of clarifying an idea are affecting each other, like in Kolb's [11] integration between reflective insights and experiential learning. Through this essentially collaborative dynamics, the community moves toward a shared context: "it is the very practices through which such orderliness is accomplished that must be supported" [16].

4. Conclusions

This work follows observations and guidelines drawn for the particular case of the ATELIER project, with its peculiar needs and scenarios. The topic we tried to outline in this paper is nevertheless very sensitive with respect to a wide range of domains, from learning to corporate to any other case in which a community needs to agree on a set of meaningful terms and concepts.

Starting from ethnographic input about users practices, we looked for a way to conciliate both ambiguity prevention and flexibility in a community-based ontology. Considerations about situated work-practices and some suggestions from the literature leaded us to focus on ontology building process more than on his value as knowledge base. We presume that the need of reaching a consensus about an ontology structure will strengthen existing social practices of comparison and knowledge sharing allowing at the same time a useful conceptualization in inspirational learning process.

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