Educational Recommender Systems and Technologies:

Practices and Challenges

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Chapter 3
Context-Aware Recommendations using Topic Maps Technology for the Enhancement of the Creativity Process

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ABSTRACT

Learning can be observed in the creativity process. When this process is supported by a Creativity Support Tool (CST), considering the context in which ideas are developed, as well as the context around the user himself and the task he is carrying out can potentially enhance creativity.The tool's awareness of such context can be exploited in the offering of useful context-aware recommendations to the users on topics such as relevant resources, people, ideas, projects, et cetera. These recommendations can help users during the creativity process and the learning involved, by providing productive stimuli. In the work presented in this chapter we focus on describing a method for enhancing the creativity process through context-aware recommendations. The method uses ontologies for the knowledge representation of context and the topic maps technology for storing, managing, and delivering content used as recommendations. Furthermore we present the software system that has been developed to support this method in a particular collaborative CST, as well as its evaluation.

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INTRODUCTION

Creativity is recognized as a psychological term and is usually measured using psychological methods. The transition of creativity from a psychological term to a computer related term was achieved by modelling it through several creativity techniques and simulating these techniques in Creativity Support Tools (CSTs). A creativity process on the other hand is a sequence of steps, during which context dynamically changes: different contextual factors can influence the process according to the stage of the process.

The current work aims to facilitate the creativity process through the integration of a context aware recommender system within a CST. It is in our belief that the use of context awareness within CSTs will be able to enhance the creativity process by offering the user useful recommendations. A first step towards the establishment of this task is the definition of the context awareness ontology related to creativity. Defining the contextual elements of creativity and modelling them as an individual ontology offers the flexibility to use the Topic Maps technology. The ontology that has been designed for a specific CST is described in detail.

The context of a CST was modelled by defining and describing the most important contextual entities and their role in the creative process. Following context modelling, the context reasoning procedure is described, a method that reasons upon context in order to provide the most relevant recommendations based on the user and the task he is carrying out at that point in time. In the next section we will introduce areas and background work relevant to our work.

BACKGROUND

According to Dey's definition (Dey, Abowd, & Salber, 2001), "context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application including the user and applications themselves". (Jun-Zhao & Sauvola, 2003) mentions that context entities can be structured into three domains: the user domain, the computer domain and the environment domain. Modeling the context considering these three domains, it is important to ensure that they interact with each other. In this way it is ensured that the context data can be collected as an ensemble of the context data for an entity. According to (Jun-Zhao & Sauvola, 2003) the representation of context is a description of the internal and external features that constitute the context information. Internal features describe characteristics that exist inside an entity or its domain. External features are those which describe the context information that can be retrieved from the interaction of an entity with other entities. (Brown, Bovey & Chen, 1997) use the Standard Generic Markup Language (SGML) for the representation of context information, aiming to prove that the representation of context information can be achieved as easy as the development of a web page in HTML. In the same work they give emphasis on the syntax of the languages that are commonly used for context representation.

In the existing literature several methods and techniques for modelling context can be found (Key-value models, Mark-up schemes, Graphical models, Object oriented models, Logic Based models and Ontological based models). Based on an evaluation of context modeling in the work of Strang and Linnhoff-Popien (2004), ontologies are the most expressive models and fulfill most of the requirements for context modeling such as simplicity, flexibility, extensibility, generality and expressiveness. For the purpose of the work presented in this chapter, ontological modelling is assumed to be the most suitable method for context modelling of creativity. The proposed context model constitutes an ontology schema supported by the Topic Maps concepts.

The development of context aware applications dictates the use of combined technologies for modelling the context, as well as for the design and development of context reasoning techniques. Topic Maps technology is one of the well known methods used for the representation of context. It is part of the ISO standards of the Semantic Web Technologies. The ISO standard of Topic Maps is formally known as ISO 13250. In general, Topic Maps are used in semantic web applications for finding and exchanging information using topics. Topic Maps are designed for the enhancement of navigation and information retrieval. This is achieved by the addition of semantics into the resources and their representation as context data sets (Hatzigaidas, Papastergiou, Tryfon & Maritsa, 2004). Topic Maps technology consists of frameworks which support the design of topic maps ontologies and also include Topic Maps Query Languages for data retrieval and reasoning. An example is the Ontopia Knowledge Suite (OKS) (Anonymous, 2010) and Tolog Topic Maps Query Engine (Anonymous, 2010).

Creativity on the other hand, which is a term difficult to define, can be simply explained as "the ability to create". The conceptualization of creativity process is seen as a sequence of steps, in which the context changes dynamically: different contextual factors can influence the process according to the stage of the process.

In the literature however, a contextual model for the creativity process has not yet been proposed. Foreseeing the benefits that context awareness may offer in such a process justifies that context aware applications are able to operate upon contextual data and provide services that will enhance the creativity process. An example is a recommender system utilizing the context for recommending resources to inspire the user during the creative process.

The usage of a recommender system in a learning platform aims to the facilitation in finding resources and learning material (Shen & Shen 2005; Simon, Mikls, Nejdl, Sintek & Salvachua 2003). In the same way an e-commerce recommender system aims to stimulate the curiosity of the user to view products that belongs in the area of his interests. Research work presented by Tintarev & Masthoff (2007), presents seven advantages of the usage of recommender systems. The usage of a recommender system for the enhancement of creative process highlights two of the advantages identified by Tintarev & Masthoff (2007): Effectiveness and efficiency. For the aims of this article it is necessary to make an overview on creativity in order to define its context and model it.

For the better understanding of the meaning of Creativity Support Tools and their usage, we use some examples of relevant research articles that can be found in the existing literature. For the research topic of computational creativity we can find CSTs implemented for domain specific purposes as well as commercial CSTs. Examples of domain specific research CSTs are related to topics such as the interactive music creation, the collaborative media creation and exploration and the creative writing. In particular an interactive music CST is MySong (Simon, 2008). MySong uses a Hidden Markov Model and a music database for the automatic selection of chords in order to produce melodies automatically. RiTa Toolkit (Howe, 2008) is a CST which is used specifically for the examination of the Computational Literature. RiTa is a suite of open source components, tutorials and examples providing support for a range of tasks related to the practice of creative writing and programmable media. A story generating CST, presented by Riedl (2008) uses artificial intelligence to model the story generation as a model. The application views the story generation as problem-solving activity where the problem is to create an artifact that achieves particular desired effects on an audience.

In addition to the above research based CSTs several commercial CSTs can be found too. Examples of such tools are the Comapping (http://

www.comapping.com), Mind Meister (http://www.mindmeister.com), MindManager 8 (http://www.mindjet.com), Thinkature (http://thinkature.com/) and TRIZ (http://en.wikipedia.org/wiki/TRIZ). In contrast to the research based CSTs that we mentioned these tools do not use any AI algorithm during their process neither they have a specific domain of use. In general these tools are used as aiding tools that guide the users to shape a problem during a creativity process. Therefore we can define Creativity Support Tools as the software tools that support users during all stages of a creativity process.

The aim of this work is the design and development of the contextual model for the creativity process within CSTs and the usage of this model for producing recommendations which are most relevant to the user and the particular creativity process. Our main focus is not to compare recommender systems and algorithms to prove that our proposed method excels, but to show that the traditional creativity process supported in CSTs lacks of contextual usage and support and that this can be compensated by using context-aware recommendations. In particular, this chapter includes the following sections: a description of a use case scenario to illustrate the usefulness of the proposed recommender in a creativity process; an overview of the most well known context modelling and reasoning techniques; a description of Topic Maps technology; further elaboration on the topic of creativity and an attempt to identify its contextual elements and finally a description of the proposed model for creativity focusing on its application in the idSpace platform. We describe a preliminary evaluation that has been setup for the extraction of conclusions regarding the usefulness and usability of a context aware recommender system in CSTs. We conclude this work with a discussion of the present work and the future directions it may take.

A USE CASE SCENARIO

We will depict the importance of a context aware recommender system in a CST through a use case scenario.

A large company, specialized in environmental fuel production, is consisted of several branches (in the US, Europe and Asia). The company assigns to the engineering department in Europe a new project regarding the design and production of a new type of fuel that will be environmental friendly for future use on aircrafts. As a first step, the biology engineering team in Paris produces a chart representing all the scientific domain fields related to the task. Next, Tom, the project leader, must organize a team by finding the most suitable experts of each scientific field among all company branches, who will be able to contribute to the project with new ideas. Formulating a team is not an easy task, since hundreds of people work for the company in many different branches in many different countries and in various fields. Tom will need to work with a multidisciplinary expert group, the company's best of the best, to ensure that the outcomes of this project will be the anticipated. Through creativity sessions, he expects to hear different opinions and thoughts, initiate fruitful discussions, collect valuable resources and eventually select the best solution for the task at hand. Tom decides to use a Collaborative Support Tool (CST) to collaborate. The first task is to prepare the project by carefully stating the problem. To help Tom with the problem stating procedure, the tool's context aware recommender system provides him with solutions of past projects that are most relevant to the current project, so that Tom gets informed of the related work in his company and how this work had been accomplished. This will help him clarify what needs to be done further by his current project and consequently assist him in choosing a good, solid problem statement. Then, he needs to formulate the expert group of users to collaborate with during the creativity session.

He thinks that explicitly searching one by one his colleagues' profiles to find those with most expertise in every related to the project domain to collaborate with would be time consuming, so he decides to use the tool's recommender system to get recommendations for users. The system automatically recommends 5 people to Tom, but prior to selecting any one of them he checks out their profiles and decides that the last two recommended users in the list are not so relevant to the subject. He selects only the top three users in the list and uses again the recommender system, but only after inputting additional relevant information to guide the system towards his needs. The recommender system takes into account the context as well as Tom's criteria to recommend more people. This time, Tom selects all 5 recommended experts. After forming the experts group, the collaborative creative session starts. At this point, the recommender system provides recommendations of relevant to the topic ideas, thoughts and recourses formulated and produced in past projects. In this way the group is able to discover more easily and effectively the correct path that leads to a good solution for the problem at hand.

The above scenario depicts the usefulness of a recommender system in a Collaborative Support Tool. In the example described, if Tom wasn't able to use the recommender system he would not be able to easily find people to collaborate with, he would spend time in searching for resources to study and no inspiration stimuli would be offered to him and his team during the ideation process. The scenario described consists of a problem solving creativity process. Problem Solving is a mental process and is part of the larger problem process that includes problem finding and problem shaping. Considered the most complex of all intellectual functions, problem solving has been defined as higher-order cognitive process that requires the modulation and control of more routine or fundamental skills. Problem solving occurs when an organism or an artificial intelligence system needs to move from a given state to a desired goal state. This move makes problem solving part of creativity process where the participants are called to shape a problem and then use the utilities that a CST supports, in order to find the solution approaches through collaboration. The creativity process in idSpace CST includes the process of problem shaping (called "problem definition and problem statement"), which is a part of the more general "problem solving" area. However, the creativity process in idSpace is not just about shaping the problem, it is also about facilitating collaboration between users, enable resource sharing among them, and as the focus of this paper is, provide recommendations that will stimulate even more their creativity".

CONTEXT MODELING AND REASONING TECHNIQUES

The importance of context awareness focuses on the automated services that can be offered from computing systems to users. In a common dictionary such as the one found in http://www.thefreedictionary.com, the word ¨context¨ is defined as the set of facts or circumstances surrounding a situation or event. Being aware of the context means ¨knowing¨ the circumstances or the facts that surround an event, in order to activate that event.

After conducting a comprehensive research in the area of creativity, we note that very little work exists in modeling the context of creativity. None of the most well known and used CSTs supports any context aware recommendation mechanism that takes into account the creativity context attributes (i.e *Comapping*http://www.comapping.com, *Mind Meister*http://www.mindmeister.com and *MindManager 8*http://www.mindjet.com). In (Sielis, Tzanavari, Papadopoulos, 2008) it was argued that the creative process can be enhanced with the use of context awareness within the

CSTs. In this paper we try to take a step further and propose a contextual model for creativity that will be used for the implementation of a context awareness tool, specifically for CSTs. A review of the most important context modeling methods and context reasoning techniques follows.

Methods of Modeling Context

Key-Values Models

Key-value coding is a mechanism for accessing an object's properties indirectly, using strings to identify properties, rather than through invocation of an access method or accessing them directly through instance variables. Key-Values models are the simplest data structure for context modeling and they are frequently used in various service frameworks, where the key-value pairs are used to describe the capabilities of a service. (Schilit, Adams & Want, 1994) used the key values for modeling context. Key-value coding supports properties that are objects and non-object parameters and return types are detected and automatically wrapped, and unwrapped, as required. Key-Values Modeling is simple but not very efficient for more sophisticated data structuring purposes, because it needs exact matching to support retrieval context algorithms and it does not support inheritance. For better understanding, a coding example using key-values is shown in Table 1 that demonstrates the method of modeling the social news in a project described by Reddit (2010).

Table 1. Example of key-values supporting lists

```
   id = incr NextId => 1
   set news_url_<id> "http>//foobar.org"
   set news_title_<id> "My foobar story"
   push myList 1
   id = incr NextId => 2
   set news_url_<id> "http>//antirez.net"
   set news_title_<id> "The blog you reading now"
push myList 2
```

Markup Scheme Models

All mark-up based models use a hierarchical data structure consisting of mark-up tags with attributes and content. The content of the mark-up tags are defined in other mark-up tags. The mark-up schemes are usually used to collect information for profiles. The context information profile building usually uses the SGML which is the Standard Mark-up Language the super class of all the mark-up languages like XML. There are multiple examples of such profiles given by (Strang & Linnhoff-Popien, 2004) like the Composite Capabilities / Preferences Profile (CC/PP) and User Agent Profile (UAProf).

Graphical Models

UML (Unified Modeling Language) is a modeling context language which is structuring the context modeling based on UML diagrams. A Context graphical model is also introduced by (Henricksen, Indulska & Rakotoniriainy, 2003), which is an ORM extension (Object Role Extension) which differs from the classic ORM. In the classic ORM model, an entity describes a domain, and an entity which can be a concept, a fact or a set of facts, can serve as a model for the domain. (Henricksen, Indulska & Rakotoniriainy, 2003) extended the ORM to allow fact types to be categorized, according their persistence and source, either as static or as dynamic. The latter ones are further distinguished depending on the source of the facts as either profiled, sensed or derived types (Strang & Linnhoff-Popien, 2004).

Object Oriented Models

Object oriented context modeling approaches are using the benefits of the object oriented programming possibilities, the encapsulation and reusability. With these characteristics of object oriented programming, problems raised with the dynamic context in ubiquitous environments are covered and the details of context processing are encapsulated on an object level and hence hidden to other components. In OO models the data are modelled as object types. An object represents a class with associated attributes and its meta-data as relationships, constraints, etc. Every object inherits the parent object type. The inheritance of the object types allows the evolution of types easier and increase the application scalability.

Logic-Based Models

Logic-based models have a high degree of formality. Typically, facts, expressions and rules are used to define a context model. A logic based system is then used to manage the aforementioned terms and allows adding, updating or removing new facts. In these systems the context is defined as facts expressions and rules. The contextual information is usually added to, updated in and deleted from a logic based system in terms of facts.

Ontology-Based Models

According to Gruber (1993) an Ontology is a specification of a conceptualization. Hendler & Heflin (2000) defines ontology as a set of knowledge terms, including the vocabulary, the semantic interconnections and some simple rules of inference and logic for some particular topic. In a more general definition, ontology is the representation of the knowledge over a specific domain using the concepts that describe the domain and associations between the concepts with the use of semantics. Ontologies provide a number of useful features for intelligent systems, as well as for knowledge representation in general and for the knowledge engineering process such as *vocabulary, taxonomy, content theory* and *knowledge sharing and reuse. Vocabulary* is the list of terms in a subject area. A vocabulary in ontologies contains a finite list of terms that they are denoted with the same identifier. Hence the terms of a vocabulary can easily be processed by a machine. Part of a vocabulary in ontologies is the *thesauri* which provide additional semantics in the form of synonym relationships between the terms. *Taxonomy* is a hierarchical categorization or classification of entities within a domain based on common ontological characteristics. Ontologies provide taxonomy in a machine readable and machine process-able form (Gaaevic, Djuric, Devedzic & Selic, 2006). *Content theory* is the identification of classes of objects, their relations and concept hierarchies in an elaborative way using ontology representation languages. *Knowledge sharing and Reuse* refers to the ability of the ontologies to be reused in several applications. Every ontology provides a description of the concepts and relationships that can exist in a domain and that can be shared and reused among intelligent agents and applications (Gaaevic, Djuric, Devedzic & Selic, 2006). Therefore, ontologies are a very promising instrument for modeling contextual information due to their high and formal expressiveness and the possibilities for applying ontology reasoning techniques. Due to the evaluation of the context model made by Strang & Linnhoff-Popien (2004), ontologies are characterized as expressive models that fulfill most of their requirements. Some of these requirements are simplicity, flexibility, extensibility, generality, and expressiveness.

Context Reasoning Techniques

When taking a formal approach to context modelling, context can be processed with logical reasoning mechanisms and has two approaches: checking the consistency of context, and deducing high-level, implicit context from low-level, explicit context (Wang, Zhang, Gu & Pung, 2004). Modelling context as an individual ontology offers the possibility to declare and control the reasoning mechanisms. Contextual reasoning refers to the creation of relations and associations that contribute as the reasoning rules for the extraction of the contextual information. Giunchiglia (Giunchiglia, 1993) gives the meaning of contextual reasoning by describing the difference between *context* and *situation*. According to (Giunchiglia, 1993) contexts are not situations. A situation records the state of the world as it is, independently of how it is represented in the mind of the reasoner. On the other hand context is inside the reasoning individual. It is part of the state and it is responsible for the subjective view of the captured information. In computing systems the formal representation of context helps to capture the information, which is characterized by a situation, and then set the reasoning mechanism for the creation of the context.

In order to make the context reasoning tasks achievable, researchers deployed context reasoning techniques such as *Ontological Reasoning, Rule Based Reasoning, Distributed Reasoning, Case Based Reasoning, Offline Reasoning* and *Probabilistic Reasoning*. These techniques are distinguished in *Non-Symbolic* reasoning techniques and *Symbolic* techniques. The classification of these techniques to Symbolic or Non-Symbolic is depended on the methods of representation of the reasoning *events* and *situations*. The methods of representation might be deterministic by using symbols and regular expressions (Symbolic) or non deterministic using probabilistic methods (Non-Symbolic). A third reasoning method is the Hybrid which is a combination of the other two:

- Non-symbolic reasoning techniques use probabilistic methods and machine learning algorithms for the prediction of data to be recommended. The architecture requirements of systems supporting learning algorithms for reasoning are not only determined by algorithms; they are also determined by data sets and the interaction of algorithms within a larger system (Crago et al., 2006).
- Symbolic reasoning techniques are expressed with symbols. A very simple form of symbolic reasoning can be expressed as a single-case based simulation where each variable can only have a single constant value and the association of an expression with each variable at each point of execution (Blank, Eveking, Levihn & Ritter, 2001).
- Hybrid reasoning techniques combine two or more of the presented Symbolic or non-Symbolic Techniques. A very common combination of techniques is the integration of rule based and case based reasoning.

TOPIC MAPS AND CONTEXTUAL REASONING

Topic Maps are used in semantic web applications for finding and exchanging information using topics. Wrightson (2001) in his description of Topic Maps mentions the distinguished differences between topic maps and ontologies. Ontologies are used for the description of shared common understanding aspects, like objects or relations between them. A topic map is used for the representation of an ontology by linking its entities. In other words, a topic map is the collection of topics, associations and scopes (Anonymous, 2001).

We follow an ontological reasoning approach, which belongs to the category of symbolic reasoning techniques. Modeling the context requires the definition of the context elements that constitute the ontology. Thus, the contextual elements can be represented as entities which can be exalted to symbols. By using a context awareness ontology, the context data are collected and managed by certain entities and are expressed by means of references to ontological classes and relations. The classes and the relations-associations within the ontology can be represented using Topic Maps technology for the integration of reasoning. In other words, Topic Maps can depict the ontology that describes the entities as topics, as well as the associations between them. The result is a transformation of the ontology in a topic maps suitable format, such as XTM or LTM. For the retrieval of data contained in the topic map, various query languages and engines can be used such as TOLOG. More information on Topic Maps technology and tools can be found in (Hatzigaidas, Papastergiou, Tryfon & Maritsa, 2004).

CONTEXT AWARENESS ONTOLOGY FOR CREATIVITY: THE CASE OF THE *IDSPACE* PLATFORM

The current work refers to the idSpace platform (Dols, 2009), a web based collaborative creativity support platform that aims to support creativity and facilitate teams effectively to design innovative products. The idSpace platform enhances the creativity process by providing modular guidance and advice scenarios that can be adapted and applied by the users. It also includes tools to articulate, process and store new ideas resulting from the elaboration of ideas from related creativity sessions. The advice that is offered in the form of recommendations, is given by a context awareness tool, whose modelling and reasoning we describe here.

Creativity Overview: Definition of the Creativity Contextual Elements

As already mentioned, creativity has not a standard definition since it can be used in many disciplines. However, many have attempted to allocate a meaning to the creative process and its potential outcomes. Plucker & Beghetto (2004) define creativity as the interplay between ability and process by which an individual or a group produces an outcome or product that is both novel and useful as defined within some social context. (Shneiderman *et al.* 2006) support that creativity is the development of a novel product that has some value to the individual and to a social group. Cougar (1995) perceives creativity at three levels: as discovery method through the idea generation, as invention with the development of ideas, and as innovation with the transformation of ideas into services (Karapidis, Kienle & Schneider, 2005). (Atman, Turns, Cardella & Adams, 2003) and (Shneiderman, 2000) conceptualize creativity as a sequence of steps with variants. Simulating the creativity steps along with applying creativity techniques produce the software tools known as CSTs.

In (Sielis, Tzanavari & Papadopoulos, 2008) creativity process perceived as a two stages process: "preparation" and "ideation". This two-stage process highlights the steps of creativity defined in (Shneiderman, 2000) in a more concrete way. This grouping of the steps into the two stages facilitates the specification of each step's context attributes and therefore their grouping in "primary" and "secondary" entities, following the transformation proposed by (Haya, Montoro & Alaman, 2004). This transformation has actual value for the design of context awareness ontology.

From the existing studies in the area of creativity, it is possible to identify the context of creativity. From the definition given for creativity, the significance of the user (or group of users), social environment and task as contextual elements in formulating a creativity process is transparent. Each one of these elements constitutes information and includes attributes that can be perceived as individual entities. The combination of these entities builds the overall context of the creativity process. We consider those entities as "primary" and a description for each "primary" context entity is given as follows:

User

This may include someone's competences, preferences, etc. This information defines the profile of a user. This profile can for example be used in creating balanced teams or in establishing the qualification to perform a task. User modeling follows an approach of standard based modeling suggested in (Dolog & Schaefer, 2006) based on combination of open specifications for learner profiles such as IEEE PAPI and IMS LIP where the user's learning activities are recorded in her performance and portfolios. User modeling is mainly used to formulate a profile. The profile defines the user's role in the creative process and thereby the context in which someone functions. The context for the user in idspace platform is a combination of the user's actions, attributes as well as their associations with the other context entities that are subsets of the contextual elements. For example a user portfolio in idSpace depends on the performance, since the user's performance is defined based on the ideas generated or elaborated. At the same time the participation of a user in a creative session, collaborative or individual, depends on user's competences, knowledge background or social background

Social Environment

The social background of the users and the social environment in which the learning takes place. This possibly includes information such as group composition, roles played in the group, etc. The generation of an idea is usually an individual process followed by knowledge transfer to other people, or knowledge received by others. The collaborative process is often used as an internal process in team-groups, companies or organizations. Therefore the conceptualization of Social Environment in terms of the idSpace project, demands the formulation of the appropriate associations between other entities in regards to the social background of the user. The social background of a user can be constructed based on her knowledge background, in domain specific subjects/areas, the social role, the expertise and social attributes such as the language and the location. The importance of the Social Environment in idSpace platform as a context element is traced in its necessity for the formulation of social groups and the assignment of social roles to the participants. The social role and the social background of a user constitute important context factors that influence the final recommendation of a user for her participation in a team's creative session.

System

This may include information such as the software or platform used at a given time. The idSpace platform strives not to be a one-size-fits-all model. Instead, mixing tools and automatically tweaking system functions should result in a platform which can be used in various settings. Some settings require a more formalized environment and other settings require an informal environment. In both cases, a creative process will be facilitated. One way to make a difference between the two options is to offer a set of concepts and associations as a starting point and delimiter for the creative session for formalized and restricted sessions and in the case of a more informal session, to offer a blank slate to be filled in by the users. The system context element can be defined by the following discrete attributes:

- **Connection Speed:** the connection speed influences the collaborative procedure, and is important to the proposed resources type. (E.g. multimedia, real time Skype conversations, etc.)
- **Type of device accessing:** The user may access the idSpace platform from a PC, PDA, and Pocket PC. The interface and supported modules of idSpace must be adapted
- **3rd Party applications:** The system must search on the client's PC for the necessary 3rd Party applications which are used in idSpace and if they are not installed, the idSpace must propose Links for Download (e.g. Skype).
- **Operating System Used:** Different plug-ins and 3rd party applications compatible with the OS.

Task (Also Referred to as Ideation)

Information about a task including which project it concerns, the specific activity, the objective, the owner and the stakeholders of a task. Ideation is the most important element of the creative process. The overall model of contextualization of creativity aims to facilitate successful ideation. The task can be defined through the associations of the aforementioned context elements with contextual entities which are influencing the "ideation". With respect to the idSpace project the "ideation" session depends on the selected creativity technique, which supports the creative process and the creative team that includes the participants of a session. The enhancement of the creative process with the use of the context awareness of the creative process converges to the *Task*. The design of an ontology schema constructed by the described context elements aims to the implementation of a context aware recommender tool that will maximize effectiveness of innovation through its recommendations.

Based on the above contextual elements we have specified all possible contextual entities that are most relevant to the process of creativity. More particular, we defined the context within a collaborative creativity support tool, as described in the next section.

Topic Maps Context Awareness Ontology for idSpace

The design and representation of the context awareness ontology schema for creativity was made using the Topic Maps technology. The context elements described earlier, and their subset entities, are represented as topics. These topics are connected through associations. Entities, associations and occurrences are creating a semantic network which is represented as a topic map.

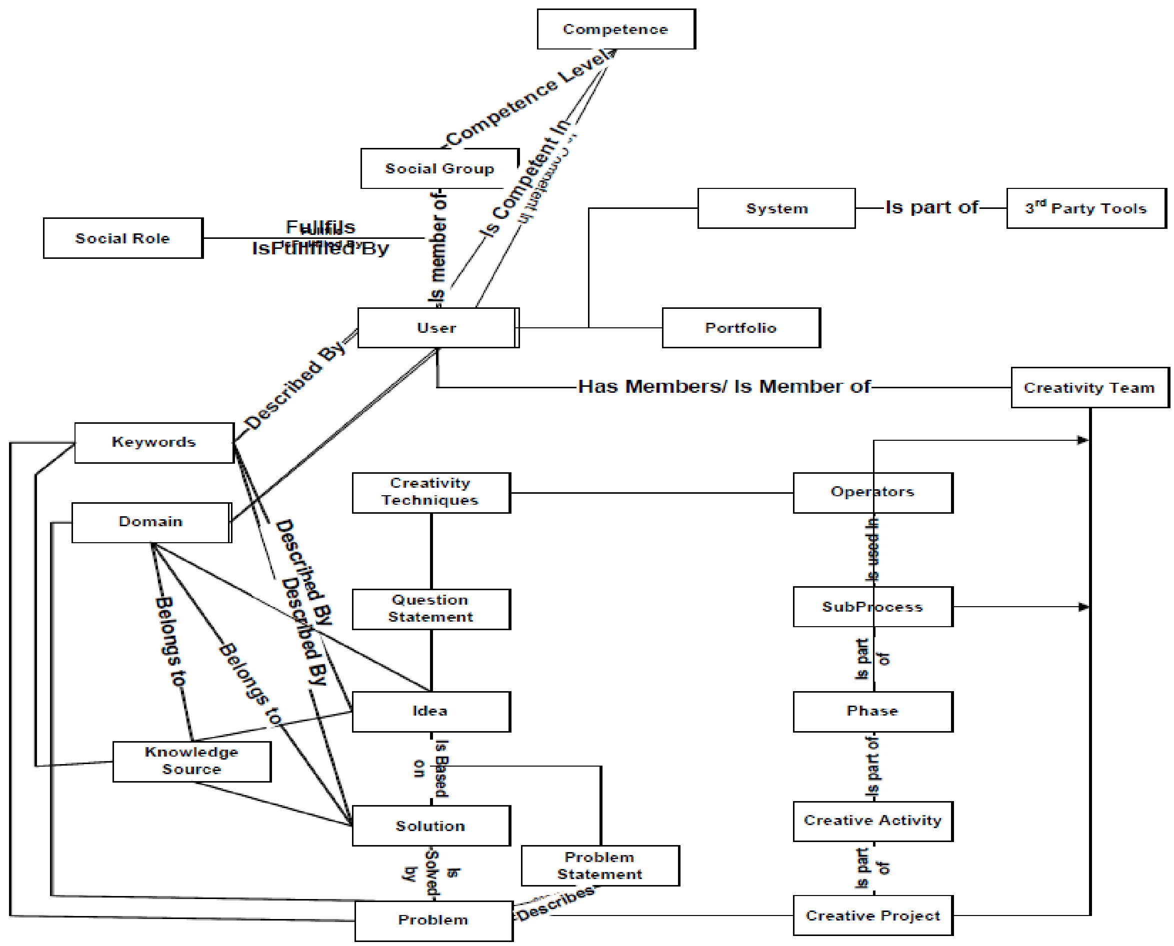
More specifically for the idSpace project the conceptual model of creativity has been represented as a Topic Map (Figure 1). Figure 1 shows all the topic types (called contextual entities) of the context aware creativity ontology. Keywords and domains characterize users, ideas, solutions and problems and can be used as metadata to search for content to be recommended. Depending on the recommendation type, several other entities are used in the recommendation process, e.g. for recommending users, the system uses Social Role, Social Group, Competence etc.

SYSTEM DESCRIPTION AND EVALUATION

Based on the above conceptual model, we have designed, implemented and evaluated a context aware recommender system for the idSpace platform, aiming at recommending: i) people to collaborate with, ii) related solutions of past projects, iii) related ideas conceived in past projects, iv) related recourses used in past projects and v) the best pedagogical pattern to be followed for solving the problem at hand. All these recommendations aim at assisting the user during the creativity session.

Each recommendation type is based on a set of factors. These factors are ontology entity types, for example "keywords", "problems", "domains", etc. Depending on the recommendation type, the recommender examines all instances within the appropriate entity types and measures their relevance to the given problem to be solved, in order to opine which are the most relevant to be recommended. The relevance is being measured by using ontology associations. If an instance of such an entity type is highly associated with the current creativity session at hand, then it is highly recommended by the system. The instance and the creativity session at hand are highly associated if they have common keywords and domains (amongst other things). The more common data they have, the more associated they are considered to be. In the following section the different recommendation types are briefly explained.

Figure 1. Topic map ontology for idSpace

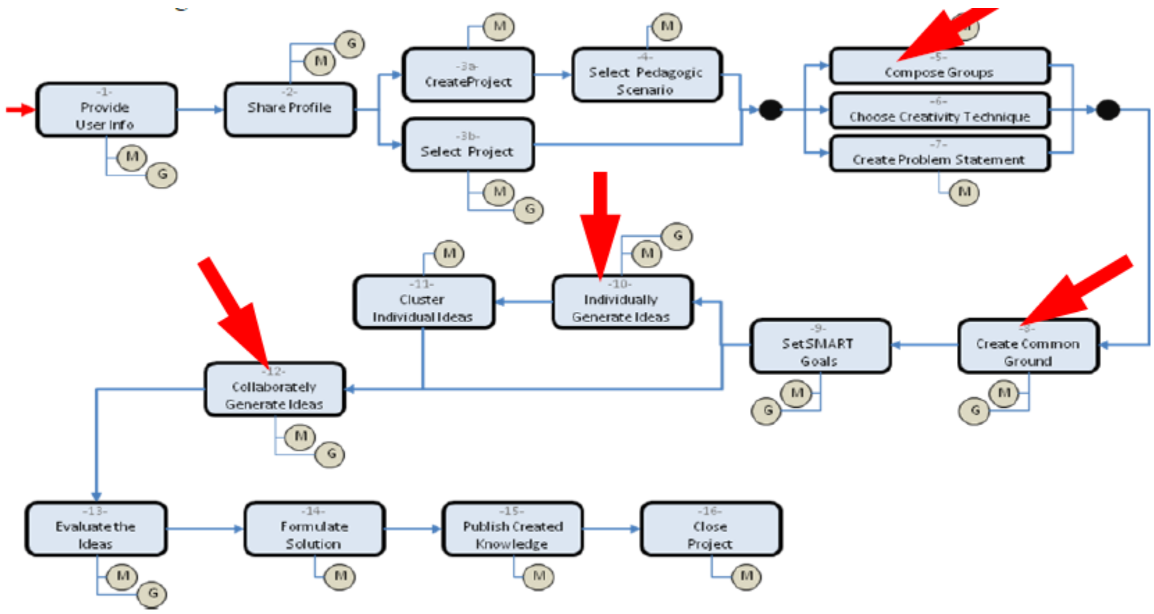


Recommend Users

The recommender system provides recommendations of users that are most relevant to the particular idSpace session (problem solved), in terms of their competence, expertise in various relevant domains, as well as relevance based on the keywords in the user's profile. "User Recommendations" will help the user in forming a proper user group, which will have the best potentials to solve the session's problem. The purpose of user recommendations is to recommend, not only the users who are experts in the project's thematic area, but also users that may have experience in related fields or may have solved relevant problems in the past. Based on the idSpace main process diagram, the recommendation of users will be used in the stages indicated in Figure 2.

User recommendations will initially be needed at the stage of composing a new group of users. At this point, the user wants to add to his/her team the most expert users in certain domains, the most experienced, as well as the most competent ones. The system helps by recommending a list of ranked users, those with higher relevance shown first, according to the previously stated factors.

Figure 2. idSpace main processes diagram. The large arrows indicate where the recommendations of users will be provided (adapted from Sielis, Mettouris, Tzanavari & Papadopoulos (2009)).



Recommendation of users will also be needed in the "create common ground" stage. During this procedure, the user may eventually decide that some of the selected users in his group were not a good choice, so a new set of user recommendations would be very helpful.

Last but not least, user recommendations would be beneficial when a user asks for help or guidance during the ideation procedure. The system should then be able to recommend other users that are experts in a certain field or have experience in a certain technique or procedure.

Figures 3.a, b and c depict the recommender's interface for recommending users. In Figure 3.a the user may specify the parameters he would like to be more significant in the recommendation procedure (keywords in the user's profile, domains in the user's profile, user's previews work and/or user's competence) by specifying a weight for each parameter (high, medium or low). Next, he can choose the role that recommended users should have (the system supports users and moderators – users with more abilities such as creating projects and organizing teams to collaborate). Finally, he is provided with the option to input more keywords and by that to specify particular attributes he prefers the people constituting his collaborative user group to have. The *"tip"* links provide tips as to how to use the weights to receive more effective recommendations (Figure 3.b.). Figure 3.c. depicts a list of ranked recommended users as the result. The link *"Options for more recommendations"* takes the user in the beginning of the recommendation process to re-adjust his input and receive more tailored to his needs recommendations.

Recommend Solutions

The recommender provides recommendations of relevant solutions to the problem being solved. The recommended solutions will indicate to the user how related projects were solved in the past. Based on the main process diagram of idSpace

Figure 3. a. The recommender system's interface for recommending users. b. The "tip" links provide tips as to how to use the interface to receive more effective recommendations. c. Recommended users ranked

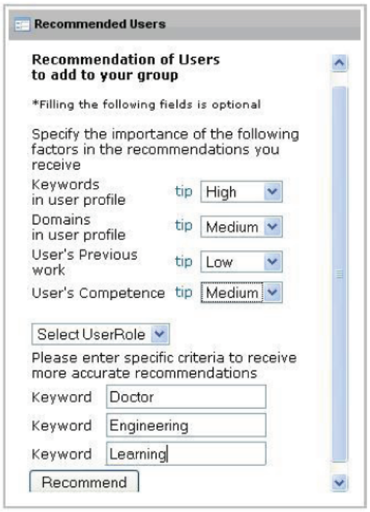


Figure 3.a The recommender system's interface for recommending users

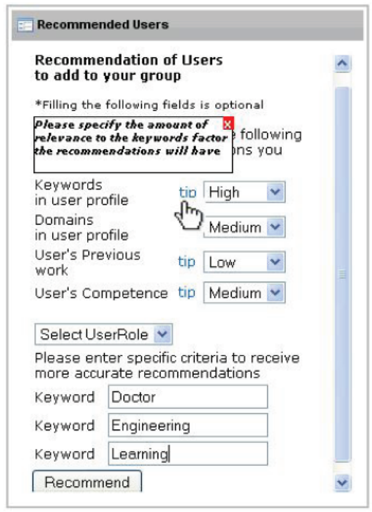


Figure 3.b . The "tip" links provide tips as to how to use the interface to receive more effective recommendations

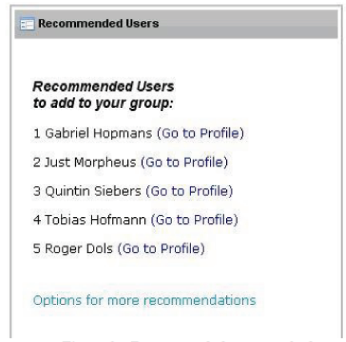
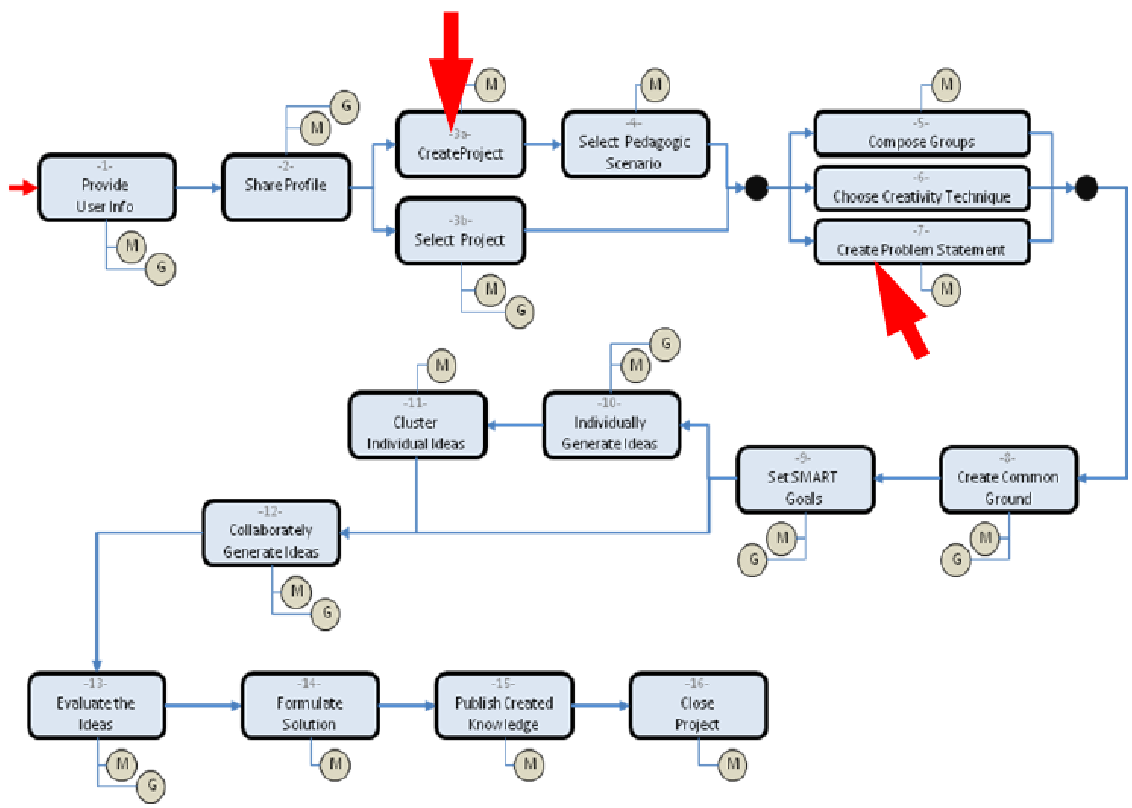


Figure 3.c Recommended users ranked

Figure 4. idSpace main processes diagram. The large arrows indicate where the recommendations of solutions will be provided (adapted from Sielis, Mettouris, Tzanavari & Papadopoulos (2009)).



(Figure 4), the recommendation of solutions will be used in the stages indicated with red arrows in Figure 4. The recommendations of solutions will be provided in the phase of starting a new project. At this point, the user is thinking of how to correctly state a problem in the IdSpace platform, in order to use the platform to find a solution. Thus, in the stages "Create a Project" and "Create a Problem statement", the system will provide relevant solutions.

Recommend Ideas

The recommender provides recommendations regarding relevant ideas. The purpose of these recommendations is to inspire the user during the "ideation session" stage and provide him with motives to become more creative. Based on the idSpace main process diagram, the recommendation of ideas will be used in the stages indicated in Figure 5.

Recommend Resources

The recommender supports the recommendation of relevant resources. These recommendations will guide the user to creating new ideas during the "ideation" stage. A resource might be a web page, a document, a picture etc. that users used to support their ideas. The recommendation of resources is a helpful tool for the user, because it may initiate his thinking towards directions he would not normally explore. Moreover, this kind of recommendations could stimulate one's imagination, thus, making him or her more creative. Based on the idSpace main process diagram, the recommendation of resources will be used in the stages indicated in Figure 6.

Apart from the "Ideation Session" stage, recommendations of resources may be provided at the "Idea Evaluation" stage as well. During this procedure, the user is attempting to evaluate the ideas that resulted from the ideation session. One way of doing so, is by finding tangible evidence that support the idea (e.g. resources that document

Figure 5. idSpace main processes diagram. The large arrows indicate where the recommendations of ideas will be provided (adapted from Sielis, Mettouris, Tzanavari & Papadopoulos (2009)).

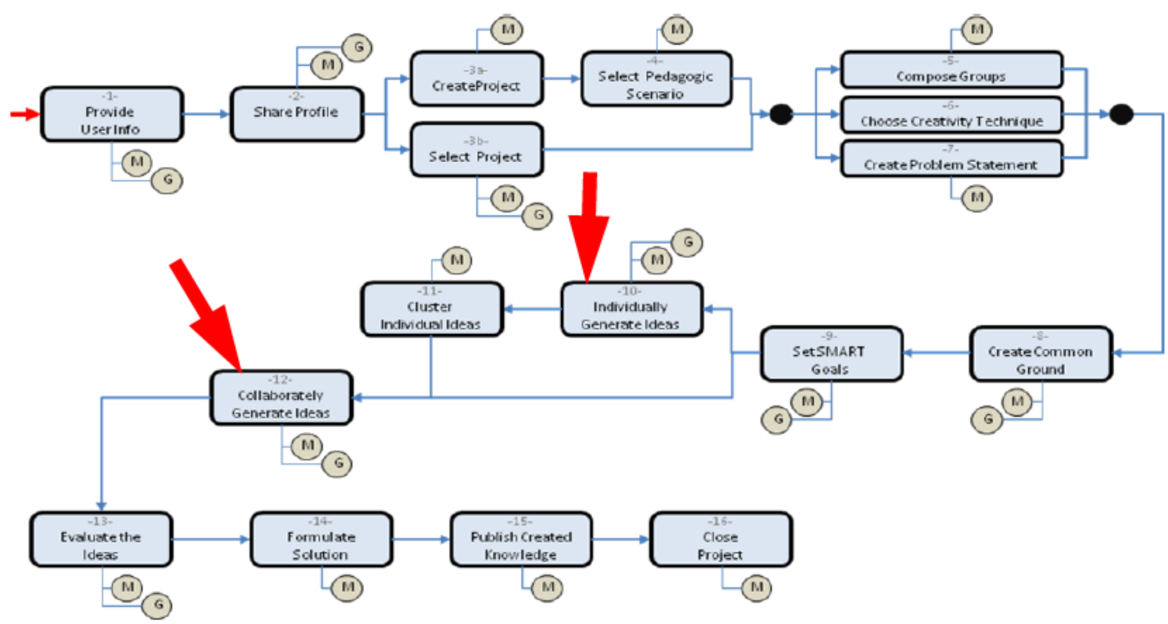
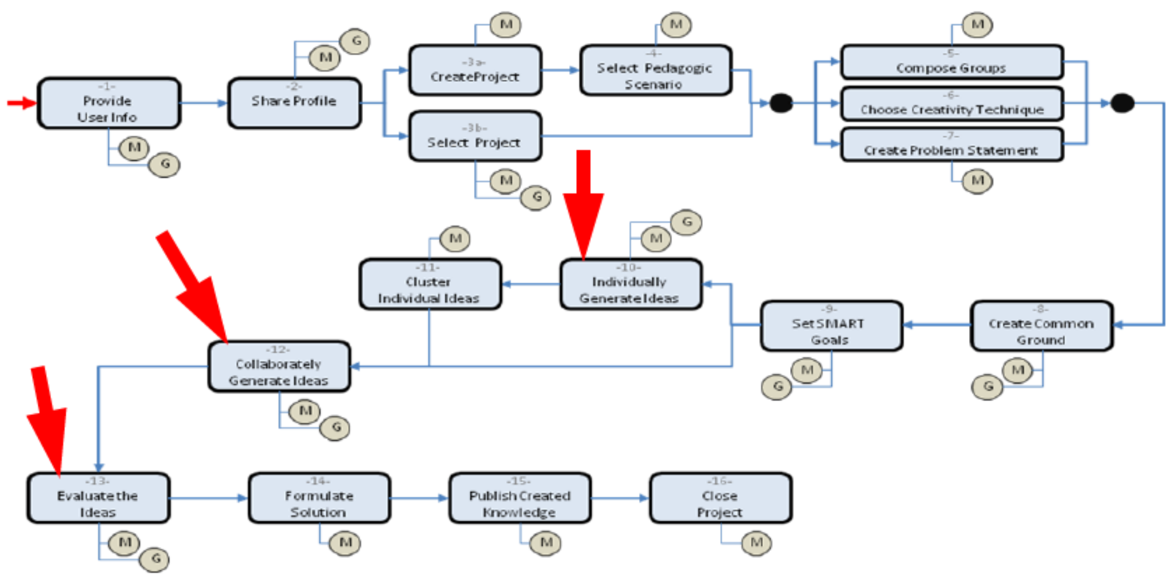


Figure 6. idSpace main processes diagram. The large arrows indicate where the recommendations of resources will be provided (adapted from Sielis, Mettouris, Tzanavari & Papadopoulos (2009)).



it) and/or identify it in previous projects. The recommender system could provide the user with such evidence in the form of resource recommendations.

Recommend Pedagogical Pattern

"A pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice" (Alexander et al., 1977). A pattern language is a set of related patterns (in a patterns' hierarchy) that work together in some context, towards a bigger problem's solution. Design Patterns express the accumulated knowledge with respect to a specific problem and propose how this problem can be solved when someone deals with it. Within Design Patterns the acquired experience from previous circumstances facing the specific problem, is concentrated and the way dealing with it is documented. This is especially useful for problems that occur repeatedly and have been assessed worth been documented, so that everybody dealing with that problem can apply the pattern in order to solve it.

The recommender provides recommendations regarding the best suited pedagogical pattern to be used in the current idSpace session. A pedagogical pattern is a set of steps to be followed in the idSpace platform aiming at solving the specific problem at hand. A pedagogical pattern can be correlated with one or more creativity techniques. The selection of a pedagogical pattern influences the sequence of the steps of the creativity process which can be followed during the process. The selected pedagogical pattern is a result of the consideration of several context parameters that the system must be aware of. The recommended pedagogical pattern aims to aid the users in solving creative problems more efficiently and effectively. Thus, the goal of our system in this case is to recommend the most suitable pattern for the current problem and its context. The recommendation of the pattern is ontology independent and it is based on parameters regarding the specific problem the user is trying to solve (e.g. type of the problem, problem definition, problem complexity, if the problem is divisible, objectives, if expert knowledge required etc.). These parameters are inputted by the user during the preparation of an idSpace session, in order to facilitate the creativity process regarding the usage scenario of the session.

Each pedagogical pattern on the other hand has a combination of characteristics, which differentiate it from the others. The selection of the best pattern to be used is the result of a scoring method based on the values of these characteristics, and on the values of the aforementioned parameters provided by the user that regard the problem at hand.

The recommendation of the Pedagogical Pattern takes place during the "Create Project" stage of the overall creativity process as it is shown in Figure 7.

Considering a usage scenario, the moderator defines the following attributes: problem type, problem definition, problem complexity, divisible problem, employees, moderator, objectives, co-operation and expert knowledge required (Bitter, 2009). For instance, for the attribute values below, the most suitable pattern is in this example the Pyramid pattern, as presented in Table 2.

Attribute 1. Problem type: **open**
Attribute 2. Problem definition: **ill-defined**
Attribute 3. Problem complexity: **medium**
Attribute 4. Divisible problem: **yes**
Attribute 5. Employees: **7**
Attribute 6. Moderator: **yes**
Attribute 7. Objectives: **positive interdependence**
Attribute 8. Co-operation: **yes**
Attribute 9. Expert knowledge required: **yes**

Based on the example above, the CA component processes the moderator's data and results in the pedagogical pattern which is the most ap-

Figure 7. idSpace main processes diagram. The large arrow indicates where the recommendation of the pedagogical pattern will be provided (adapted from Sielis, Mettouris, Tzanavari & Papadopoulos (2009)).

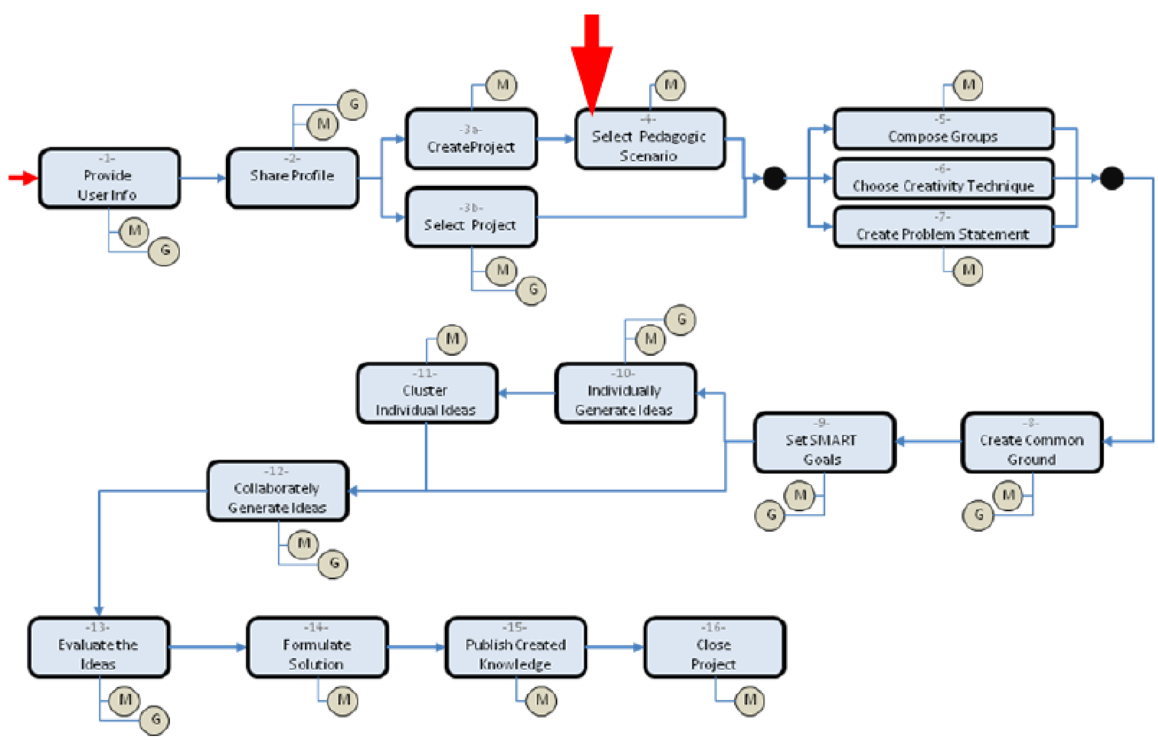


Table 2. Pedagogical pattern scoring example

Patterns / attributes	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Attribute 6	Attribute 7	Attribute 8	Attribute 9	score
Jigsaw			✓	✓		✓	✓	✓	✓	6
Pyramid	✓		✓		✓	✓	✓	✓		7
Think Pair Share	✓		✓		✓	✓	✓	✓		6
Six Hats	✓				✓	✓		✓		5
Progres-sive Inquiry		✓			✓	✓		✓		4
Disney	✓				✓	✓		✓		4

propriate to be used for the current session (seen in Table 2 as the pattern with the highest score).

Evaluation

The context aware recommender system was formally evaluated with respect to its perceived usefulness, as well as its usability. The evaluation method of user testing was chosen as the most appropriate. Two well known questionnaires by Lewis (1995) and Davis (1989), were adapted for our purpose and were used as instruments for our testing. Our users were postgraduate students from the Computer Science Department of the University of Cyprus with work experience in the IT sector. They were asked to voluntarily participate in the evaluation session for the context aware recommender system of the idSpace platform. The aim of this evaluation was currently not to measure the influence of context awareness usage in the creativity process, but only to collect opinions regarding the perception of usefulness and the usability of the context aware recommender system within the specific CST. Measuring or estimating the influence that the use of a context aware recommender may have in the creativity process is far more complicated and it cannot be achieved in a short period of time.

The goal was for the participants to carry out three tasks during the evaluation session and complete a post-task questionnaire after each task. They began by creating a profile, and then were asked to login as moderators (to gain additional user rights) and use the recommender system for completing the following three tasks:

Task 1: "Use the Context Awareness Recommender System to receive recommendations on solutions to related problems. You want to find out whether there existed similar problems and how they were solved, to use that knowledge and perhaps build on that".

Task 2: "Use the Context Awareness Recommender System to receive recommendations on suitable users to add to your team. Suitable users are users who have expertise related to the problem you want to solve".

Task 3: "Use the Context Awareness Recommender System to receive recommendations on ideas that may be useful/relevant for solving the particular problem. Ideas are used to build up a solution".

The post-task questionnaire included 4 7-level Likert items and was based on Lewis (1995):

1. Overall, I am satisfied with the ease of completing this task

2. Overall, I am satisfied with the amount of time it took to complete the task
3. Overall, I am satisfied with the support information (recommender system's explanation guidelines, documentation) when completing the task
4. The presented recommendations were useful

The data was analyzed and the results indicated that the mean for answers for all tasks were close to 5. In particular the mean for Task 1 was 5.14, for Task 2 it was 5.11 and for Task 3 it was 4.86. The average standard deviation was 1.54 for Task 1 answers, 1.86 for Task 2 answers and 1.63 for Task 3 answers. Task 3 had the lowest mean, probably because the recommender system had a small delay in presenting the results and users sometimes had to refresh the page to avoid this.

In general, the satisfaction regarding the recommendation results was high (close to 5). Recommendation of solutions (task 1) received the highest results. A possible reason for this is that the recommender system, by providing recommendation of solutions, helped significantly the users to better understand the current problem they were working on. Moreover, through the recommendation of other existing related projects' solutions, users could more easily understand what the expected outcome of the current project was, and by that, formulate the problem at hand more clearly in their minds.

After completing the tasks and the post-task questionnaire, the participants were asked to fill a *post-test questionnaire*. The questionnaire, retrieved from (Davis, 1989) and adjusted accordingly, included six 7-level Likert items and was designed to test the Perceived Usefulness and the Perceived Ease of Use. From the post-test questionnaire it was noticed that the participants' opinions about how they perceived the usefulness and the ease of use both of the individual tasks, as well as the recommender system as a whole, were generally positive. The highest results received, were about the recommender system's usefulness for effectively solving a problem during the creative process. The lowest results received, were observed in questions related to the interface and the interaction with it. Through this test, the users confirmed the significance of the existence of a recommender system in a CST such as idSpace.

FUTURE RESEARCH DIRECTIONS

The existing creativity support tools are not supported by any context aware mechanism. This is a verification that we concluded from previous work (Sielis et al, 2008). The implementation of context aware systems that will be able to support creativity is a topic that generates several research questions such as, what is the impact of context awareness in the creativity of a user; how context awareness influences the creativity process; which are the proper contextual elements for creativity and how these can be modeled; and finally, issues regarding the evaluation methods that can be used to prove the aforementioned.

A very important and challenging task is the knowledge representation of creativity's context. As it was mentioned before, creativity has a multidimensional perspective. This generates two research challenges that need to be proved. The first is the definition of the contextual elements of creativity. For many years this was a subject of research for many psychologists and theorists. Therefore in the existing literature it is possible to find several approaches in defining which of those elements are the most important, to be taken into account, in order to model creativity. The second challenge is the modeling and representation of creativity using knowledge representation methods. The importance of modeling creativity considering all sub-models that influence it is a step forward from the existing creativity support tools. The existing tools are used to simulate a creativity technique and deliver it to the user as a substitute of a whiteboard, paper or pencil. The enhancement offered by these tools in relation to the whiteboard or the paper is consisted of the memory and the visualization tools included in the tools. However, modeling the context of creativity and implementing creativity support tools aiming at adaptation and personalization can enhance the support of the user during the creative process. Therefore, we identify as the most important and challenging issues the definition of the creativity model, the user model and the domain model and implement a collaborative creativity support tool based on these models. In addition, the evaluation of a collaborative creativity support tool which uses context awareness supportive mechanisms is also necessary. It is important to examine the impact such a tool can have to the user or to the creativity process by using evaluation methods and creativity metrics.

CONCLUSION

After observing that the existing literature lacks a conceptual model for context awareness in creativity, we designed and developed a model that constitutes a first step towards that direction. The implementation of the ontology for creativity using Topic Maps offers the developers the ability to trace the users' actions and monitor the context changes during the creative process. The presented model for creativity is partly used in the architecture of the idSpace platform. The idSpace platform uses Topic Maps and Tolog Query engine in its overall architecture. The described model is already designed and implemented and has been tested using specific queries. The queries provided a successful and accurate retrieval mechanism for the necessary data used by the context reasoning and context adaptation mechanisms for implementing the context aware recommender for the idSpace platform.

The system has been formally evaluated through user testing leading to very optimistic findings. The duration of the project was not sufficient to organize a larger scale evaluation to measure also the real usefulness of the recommendations, in real life creative problem solving scenarios. This however is something highly sought after, because of the inherent complexity of offering meaningful recommendations and because of the lack of other similar recommender systems to compare against. CSTs design is a relatively newly explored area for recommendations. Further evaluation in this sense will also help towards the improvement and calibration of the model itself, which might be demonstrated as corrected or new associations of the topics, or even entirely new topics.

ACKNOWLEDGMENT

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KEY TERMS AND DEFINITIONS

Context (of an Application): Any information relevant to the application, its users and its/their environment.

Context-Awareness: The ability of an entity (e.g. a system) to be aware of its context.

Context Modeling: The process of modeling the context.

Context Reasoning: The process where the context is used in order to obtain meaningful information.

Creativity: The process of creating something new and novel that has value.

CST: Creativity Support Tool is a software tool that supports the user in being creative.

Ontology: A complete organization of a knowledge domain in a hierarchical way. It contains all relevant entities as well as their relations.

Recommender System: A system that recommends items to users according to several criteria such as the user preferences, user history information and the context.

Topic-Maps: XML-like Context Representation Technology.