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Virtual Entrepreneurship Lab 2.0: Sharing Entrepreneurial Knowledge by Non-Linear Story-Telling

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Abstract: Digital non-linear story-telling is an ideal approach to share entrepreneurial knowledge in large distributed communities and networks. Story-telling combines semantic knowledge and episodic knowledge by explicit problem solving strategies. In order to facilitate entrepreneurial knowledge sharing authoring environments based on multimedia repositories as well as advanced story players are needed. Interoperability with existing information systems can be enhanced by relying on multimedia description standards like MPEG-7 and the use of W3C standard compliant community hosting engines. We present the Virtual Entrepreneurship Lab 2.0 for sharing entrepreneurial knowledge by collaborative creation and consumption of non-linear stories based on high quality video taped interview sequences from well-known high-tech entrepreneurs.
Key Words: Knowledge management, non-linear story-telling, MPEG-7, web-based learning, entrepreneurship
Category: H.3.0, H.5.1, J.5

1 Capturing Entrepreneurial Knowledge in (Non-)Linear Stories

Innovative and knowledge intensive high-tech start-ups have a positive impact on the economic development of regions by fostering the structural change and the dynamics in employment rates. Having this in mind, knowledge from universities should be deployed more effectively for future entrepreneurial activities of students. By now, only a small amount of students start a new enterprise after having worked 8 - 15 years in industry [Schulte and Klandt, 1996, Albach, 1998, Moog, 2000, Jarke et al., 2003]. So universities should make students more aware of their entrepreneurial potential and qualify them for successful entrepreneurship. Entrepreneurship cannot be stimulated and taught by solely transferring knowledge. Didactical approaches need to be integrated. Entrepreneurial knowledge is extremely hard to formalize and teach. In business schools, entrepreneurial programs and centres try to connect entrepreneurs and academia by especially designed events, shared labs and other concepts. Big companies want to enhance the entrepreneurial spirit of their employees for competitive advantages by more risk taking. The basic idea behind both approaches is that entrepreneurs serve as role models for employees or students and entrepreneurial knowledge is shared by developing a common practice within practical courses. High tech entrepreneurship is an interesting area to investigate learning processes because the actors

have to develop their skills continuously. This is due to the quickly changing nature of the relevant technologies and the dynamically evolving markets. Following this considerations entrepreneurship teaching has been developed rapidly in the US in the last 25 years. Most of the competences needed for founding a company are teachable and can be developed in courses. [Neubauer, 1998, 312]. In the US there are 1500 colleges and universities offering courses in entrepreneurial education. More than 100 active, university affiliated entrepreneurship centers and 270 endowed chairs exist. There are inspiring examples of universities which have developed such a comprehensive approach in entrepreneurship teaching, like the MIT Entrepreneurship Lab [Roberts, 1991]. A major challenge is to create such learning experiences also for students and professionals who have not always or no direct access to world famous entrepreneurs.

Concepts for teaching of future entrepreneurs differ extremely from country to country and from university to university. There are for example the classical business planning games which simplify situations that occur in the reality but guarantee standards in education. The traditional, knowledge transfer based university teaching system was criticized from theoretical and practical point of view [Collins et al., 1989, Jonassen and Mandel, 1990]. Thus, recent scientific approaches favour constructionist and socio-cultural concepts of learning. Based on the work of Vygotsky [Vygotsky, 1962] and Bateson [Bateson, 1973] learning is seen as an active, constructive and social process. Learning means not just transferring knowledge. Learning is rather the permanent construction of knowledge, based on former experiences. Hence learning is linked to real world problems [Lave and Wenger, 1991]. Hypermedia learning environments amalgamate the concepts of working with hypertext and the consequent use of multimedia material. The Virtual Entrepreneurship Lab we present as a proof-of-concept implementation in this paper is not thought to be a replacement for entrepreneurial teaching within universities or entrepreneurial knowledge sharing within companies. It is thought to be a useful technology enhanced learning environment which can be used in entrepreneurial courses and company training. The Virtual Entrepreneurship Lab enables learners in organizations to create multimedia narratives, to share them and to learn from such narratives. The first version of the Virtual Entrepreneurship Lab [Klamma et al., 2001, Klamma et al., 2002b] is based on the learning environment "Berliner sehen" developed by Kurt Fendt and Ellen Crocker at the MIT Germany program [Fendt, 2000]. "Berliner sehen" supports students in learning German language and culture. The basic principle are video taped talks with different actors living in a specific quarter of Berlin. Students explore the material by choosing a character and a category in the user interface. The multimedia material (digital video, images, and text) is presented according to the selection of the student. The student can play individual talks and browse them by following implicit or explicit links. The student can also

change the context of the actual document and gets a new selection of linked documents presenting the new context. Viewing the material and changing perspectives can lead to a different understanding of the material. This is non-linear and flexible. The explorative way of researching the material, the repeated viewing of documents in different contexts, the comparison of results with other students, and the discussion with teachers and other students leads to the learning effects wished by constructivist theory. After collecting experiences with the Virtual Entrepreneurship Lab a couple of years in entrepreneural courses [Klamma et al., 2003, Klamma et al., 2004] one major challenge in the learning environment became very visible to us. In the environment itself it was not possible to design learning tasks for the students. The problems addressed in the digital materials were only implicitly given. The student explored the materials guided or facilitated by the assignments of teachers external to the learning environment. Inspired by the book of John Seely Brown and Paul Duguid [Brown and Duguid, 2000] about the power of story-telling for knowledge sharing we developed the idea to enhance the Virtual Entrepreneurship Lab with a story-telling environment.

Entrepreneurship is one of many domains for which non-linear story-telling is perfectly suited, since the problem of starting an enterprise does not involve one distinct solution. Such a problem has to be considered from various viewpoints and can be solved in many different ways. In figure 1 we depict a hierarchy of different kinds of knowledge that are discussed in the following. The knowledge creation theory, especially the SECI model, by Nonaka [Nonaka and Takeuchi, 1995] has become widely acknowledged in management theory and practice. Also, in the fields of CSCL and professional learning the most prominent knowledge management theories are those of Bereiter, Engeström and Nonaka [Paavola et al., 2002]. We are building environments on the assumption that in organizations informal communities of practice want to share knowledge about their profession. Knowledge sharing in this setting is primarily a social process [Jarke and Klamma, 2002, Wenger, 1998, Brown and Duguid, 2000]. The SECI model makes a basic distinction between **tacit** or **procedural** and **explicit** or **declarative knowledge** [Polanyi, 1966, Nelson and Winter, 1982, Nonaka and Takeuchi, 1995]. While even this distinction is under debate, we add one refinement to the SECI model by introducing a distinction between semantic and episodic knowledge [Tulving, 1972, Ullman, 2004] in a community/organizational context. While **semantic knowledge** represents semiotic and conceptual knowledge such as documentation in organizational charts, business process definitions and so forth, **episodic knowledge** is knowledge about experiences such as episodes and narratives, e.g. war stories. Our claim is that through a combination of semantic and episodic knowledge media in a community/organizational context, explicit knowledge can be used more effectively in organizations. While situational con-

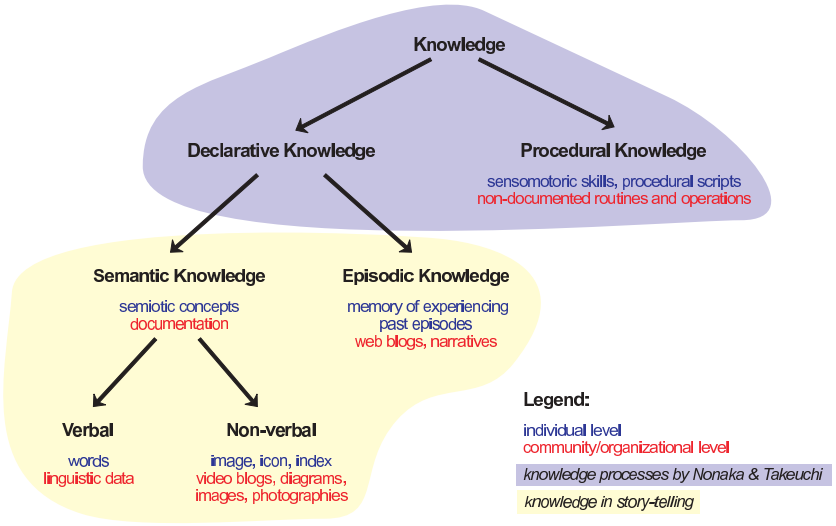

Figure 1: Levels of knowledge processing and sharing

text may be lost by externalizing stories, outreach and impact of stories may be increased by this process. Documentation as a means of **semantic knowledge** can again be refined as **verbal** (linguistic data) and **non-verbal** (e.g. video or visual) contents.

Although story-telling is recognized to be very important in organizational knowledge creation, there are only a limited number of approaches to improve the outreach and impact of story-telling by using organization wide information systems. Story-telling is defined by the Digital Storytelling Association (DSA) as follows: "Digital Story-telling uses digital media to create media-rich stories to tell, share and to preserve. Digital stories derive their power through weaving images, music, narrative and voice together, thereby giving deep dimension and vivid color to characters, situations, and insights" [Digital Storytelling Organization, 2002]. From this it becomes clear what story-telling is all about: Sharing knowledge.

Story-telling intertwines **semantic knowledge**, i.e. already reified concepts of communities stored as documents, by linking it with the narrative experiences gained from **episodic knowledge**. Thus, story-telling can be seen as an approach to develop learning histories [Roth and Kleiner, 1999] by creating knowledge hyper stories [Royrvik and Bygdas, 2002]. Consequently, story-telling is an important aspect for knowledge sharing in communities of practice. Here, the aspects of telling, sharing and experiencing stories are a problem-oriented way to learn from the experiences of others.

In the related work section we shortly explain our theoretical learning back-

ground and give an overview on existing story-telling systems. We explain their underlying theoretical methodologies and discuss their suitability to combine semantic and episodic knowledge. In order to provide an overview of the VEL 2.0 development process, we will point out stepstones and their improvements towards the final system. Subsequently, we introduce the VEL 2.0 as a further development of VEL and demonstrate the novelty of our approach by MPEG-7 based multimedia metadata for semantic knowledge sharing in a multimedia story-telling environment. The paper closes with an outlook on further research.

2 Related work

Our approach combines hypermedia learning environments and story-telling. While plain hypermedia environments transport media and capture semantic knowledge, story-telling support enables users to additionally capture procedural and episodic knowledge. In this section we will provide an overview of current development in hypermedia learning environments and in digital story-telling.

In the last decade constructionist theories of learning played an important role in the development of new computer-based learning designs [Duffy and Jonassen, 1992]. In the following, we will explore the role of socio-cultural theories of learning and link them to newer theories of social capital in economic and social theories. Socio-cultural learning theories take learning as a collective process which is linked to specific contexts of action. Knowledge emerges in communities of practice by discursive assignment of sense. Communities of practice (CoP) [Wenger, 1998] are characterized by common conventions, language, tool usage, values, and standards. The development of a common practice which defines the community integrates the negotiation of meaning among the participating members as well as the mutual engagement in joint enterprises and a shared repertoire of activities, symbols, and artefacts. A community practice is inseparable from issues of (individual and social) identity. Identity is mainly determined by negotiated experience of one's self in terms of participation in a community and the learning process concerning one's membership in a CoP [Wenger, 1998, 145]. The approach combines the "two sides of the medal" of community participation: the social practice of the community as a collective phenomenon and the identity of its members as an individual one. The aggregated resources an actor can gain from these individual learning processes are often labelled with the metaphor of human capital. Recently the concept of human capital has been complemented by the one of social capital. Bourdieu [Bordieu, 1985] defines social capital to be the aggregate of actual or potential resources, which an actor can derive from his permanent network of more or less institutionalized relationships or from his social reputation. Like with human capital, it takes the individual quite some efforts (investments) to build up social capital. Social

capital is assumed to help individuals to make use of their human capital. Often the creation of human and social capital is interrelated. For instance when going to an excellent university, students build up a social network which helps them learning and adapting during their whole professional life. On the other hand given social networks allow for (cooperative) learning opportunities. Coleman [Coleman, 1988], Burt [Burt, 1992], Cohen und Prusak [Cohen and Prusak, 2001] have contributed to the discussion in the Anglo-Saxon literature about social capital and knowledge management. Putnam [Putnam, 1993] defines social capital as a features of a social organisation, as networks, norms, and trust to ease reciprocal actions and cooperation. For this reason it is important to have a closer look at the formation of social capital. We want to investigate how social capital complements individual capital in enabling collective learning processes in building high-tech start ups.

Many approaches to learning environments have been proposed in the last years [Anderson et al., 2001,Henze, 2001,Hiltz and Wellman, 1997,Looi and Ang, 2000, Ligorio, 2001]. In [Anderson et al., 2001] a system for **tutored video instruction** for introductory programming courses is presented. [Looi and Ang, 2000] describes a **multimedia-enhanced collaborative learning environment**. Still, the use of metadata and especially metadata standards is evolving. There are some proposals for learning data standards and projects using metadata [Avaro and Salembier, 2001, Böhm and Rakow, 1994, Bray, 1998, Dublin Core Metadata Initiative, 2005, Dhraief et al., 2001, Hunter, 1998, IEEE Learning Technology Standards Committee WG 12, 2004, Saddik et al., 2001, Schär and Krueger, 2000] especially for technical and organizational aspects. There are different meta data initiatives to come to a unified naming of data worldwide, e.g. Dublin Core [Dublin Core Metadata Initiative, 2005], which is the basis for further developments of metadata standards, Resource Description Framework RDF [World Wide Web Consortium, 1999] for the management of metadata on the world wide web and MPEG-7 [International Organisation for Standardisation (ISO), 2001,Salembier and Smith, 2001], which covers many approaches for describing multimedia metadata.

There are several approaches to story-telling. Most approaches are commercial and aim at the creation of fictive stories. Our overview will focus on systems that are suitable to share semantic and episodic knowledge in communities. **Dramatica** is a comprehensive framework for creating multimedia stories [Phillips and Huntley, 2001b]. However, it does not allow any kind of non-linearity. In Dramatica a story represents a particular model called the "story mind". It is left to the creativity of the authors to express their episodic knowledge as a linear story so that dedicated aspects of the story are filled with contents. Dramatica is also capable to support semantic knowledge. **Adaptive Digital Storytelling** (Adaptive DST) tries to integrate basic principles of narratives

and dramatic art into interactive digital stories [Franz and Nischelwitzer, 2004]. Adaptive DST subdivides episodic knowledge of stories into selected- and must-phases and specifies their interdependencies. Another key concept in Adaptive DST is the option to manipulate the story a-priori. Here, a variation of a story can be generated based on predefined tags used to specify the level of information a user wants. Based on a 4-ary classification scheme stories are adapted from superficial to fine-grained. Thus, non-linearity is only supported to a certain amount: The existing "core story" might not be changed in its outcome, but might be altered. While the concept is applicable for knowledge sharing on scholar level, it is doubtful that such a labor-intensive and mostly unguided creation process might be applicable in a community or at larger scale. **Storylining Suspense** and **Story Engine** are closely related for the creation and consumption of non-linear multimedia stories. While Storylining Suspense is an authoring method for interactive story-telling [Schneider et al., 2003], Story Engine is used to capture episodic knowledge by narrating interactive non-linear stories (e.g. created by Storylining Suspense) [Braukmann, 2001]. The focus in Storylining Suspense is on authoring of non-linear stories based on a set of morphological functions defined by V. Propp [Propp, 1958]. These functions are mapped within the system based on a scene model thus creating variants of a story based on the underlying model and the user's interaction. Additionally, there are options to store semantic knowledge about multimedia contents but it is left open, whether these contents are available only to support the creation process or will be accessible upon consumption, too. Despite their client/server structure, Storylining Suspense and Story Engine are suited only on a limited scale for multi-authoring.

3 Exploration of Multimedia Contents by Semantic Zapping

The Virtual Entrepreneurship Lab (VEL 1.0) is an approach to the exploration of multimedia contents based on a static content classification. The learner takes the role of a researcher, who at first faces an unstructured accumulation of the material. All media that are integrated into the learning environment are assigned to several contexts, which represent certain views on the material. These contexts are described as metadata both visible in the user interface (right sided buttons in Figure 2) and in the material. While working with the VEL the learner can dynamically change these contexts and after that gets presented all assigned media, which can be viewed and analyzed.

VEL 1.0 works with the basic principles of "Berliner sehen" to support the entrepreneurship education. The learning environment was a joint development from computer science (RWTH Aachen, Fraunhofer FIT) and management science (Institut für Mittelstandsforschung, Bonn). Multimedia learning objects are used to create comprehensive context-oriented learning scenarios. This includes

interviews with entrepreneurs, venture capitalists, business angels and other persons who have been involved in the process of founding a company. The video sequences are supplemented with other multimedia objects like pictures and text.

Figure 2: Semantic Zapping in the VEL 1.0

Main aspect of the design and implementation process of the VEL was the openness of the system. The term "open learning environment" means, that it can be adapted to other areas than the entrepreneurship education and that the learning material can easily be extended and administrated in modules. To guarantee this openness all metadata for the different media has to be represented in an open and flexible manner. Therefore the MPEG-7 metadata standard [International Organisation for Standardisation (ISO), 2001] was chosen for storing all necessary information of the different media. MPEG-7 is a base for applications, in order to enable qualitative access to the content of multimedia data. On the one hand this is filtering, searching and retrieval of information, on the other hand it is linking and arranging of media and personalized access to the data. MPEG-7 has the biggest set of descriptors for audio-visual material at all [International Organisation for Standardisation (ISO), 2001]. If you decide to use MPEG-7 in applications, it is not necessary to know the whole standard, as you can use different levels of granularity for the description of the media.

Another functionality of VEL 1.0 is the learners possibility to create own multimedia collections (bottom of Figure 2). Within these collections a learner can store own perspectives of the material, own trails through the media and own textual annotations [Hall, 2000]. He can mark the collections private or public. Public collections can be seen by all users of the VEL. All these metadata (information about the user, the media, annotations, etc.) are also stored in the database as MPEG-7 compliant XML documents. This is another indication for the expressiveness of MPEG-7: You can describe personalized multimedia collections of different media. The usage of the MPEG-7 metadata standard to describe all information necessary to arrange and present media, to navigate in the VEL and to create own collections and annotations is the main reason to realize openness, flexibility and adaptability. You can easily administrate and extend the learning material by editing, adding and deleting the related MPEG-7 documents. If you are familiar with MPEG-7 you will understand the syntax and semantic of the VEL MPEG-7 documents at once. Furthermore it is possible to exchange data between applications that "understand" MPEG-7.

We evaluated the system with learners from entrepreneurial courses [Klamma et al., 2003, Klamma et al., 2004] but also with learners from other domains. While all the evaluators appreciated the idea of exploring the materials and getting an idea of entrepreneurial knowledge to start a company, they were not satisfied with the collaborative features of the environment nor was it possible to assign problem-based learning tasks to the students from within the learning environment. It was possible to organize and annotate materials in a special shared folder of the environment but the order of the material was linear or arbitrary at all. Since there is no one solution to the problem of starting a company, we worked on an extension of these collaborative features to allow students to share knowledge in a story-telling approach. Complex problem areas like entrepreneurship can now be described and decomposed in problem hierarchies which facilitates technology enhanced learning more than just sharing collections of annotated multimedia materials.

Learning from this experience we first put effort into the development of a system more open for extensions. Our aim was to improve VEL in the sense that learners should be able to feed the system with their own multimedia data and MPEG-7 compliant metadata. The following section presents MECCA/MEDINA, which introduced solutions for media uploads, media annotations, dynamic media ontologies, media graphs, etc.

4 Dynamic Adaptation of Contexts Sets based on Multimedia Metadata Standards

MECCA and MEDINA is a combination of community based tools together forming an information system especially designed for a community of media

science students in cooperation with Prof. Wolfgang Beilenhoff, Ruhr Universität Bochum. Media screenings and a constant discourse on media are essential in media science education. The following coarse requirement set for additional features could be identified:

- **Extendable Media Repositories:** Learners should be enabled to share media among community members. MEDINA, an MPEG-7/Dublin Core [Dublin Core Metadata Initiative, 1999] annotation- and upload tool for a set of supported media types realizes this requirement. For each medium a learner can provide a rich set of multimedia metadata, that are stored in an MPEG-7 compliant XML format. Media can be uploaded to a central FTP Server.

- **Media Categorization:** Learners should be enabled to create, edit and share their own categorizations on available multimedia material. In MECCA, this requirement is realized by a GUI component enabling learners to create, edit and share so-called context sets maintaining hierarchically structured multimedia ontologies. With this step we solved the challenge of defining and maintaining own ontologies in contrast to the static singleton read-only ontology used in VEL 1.0.

- **Media Graphs:** Learners should be enabled to combine multimedia material in a way that shows up relationships among the media items. For this purpose MECCA provides a basic grapheditor and -browser component. In contrast to VEL 1.0 it became possible to build relationships between media. A prominent candidate is the predecessor/successor relation that is now used in VEL 2.0 among other relation types in order to create non-linear multimedia stories.

- **User Folders:** Learners should be enabled to maintain and share media collections in a sort of filesystem. MECCA realizes this requirement by providing a GUI component enabling learners to create and maintain such a collection filesystem. A MECCA collection can contain an arbitrary number of subcollections, multimedia items, -graphs and -categorizations. Since VEL 1.0 only maintained one set of plain media collections, this was a step towards a more flexible and well-structured collection management.

- **User Discussions:** Learners should be enabled to start discussions on any item of the system, i.e. media items, -ontologies or -graphs. This requirement is solved by a MECCA component offering basic community support for user discussions.

Figure 3 shows two screenshots of MECCA GUI components responsible for the creation and maintenance of folder systems and context sets.

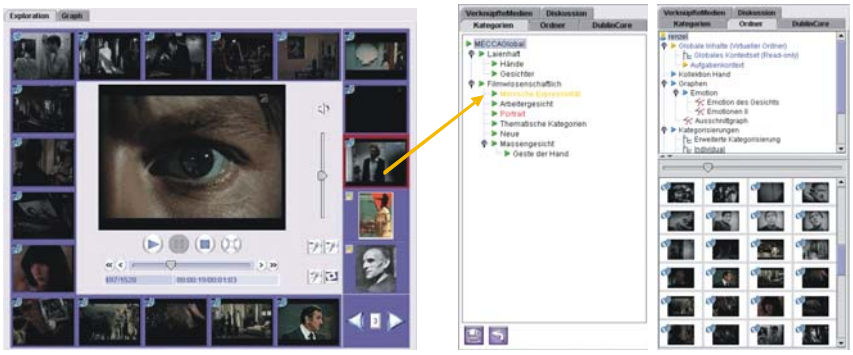

Figure 3: MECCA Categorization (left) and User Folders (right)

However, entrepreneurship is a problem, which can be considered from various viewpoints and solved in many different ways: Starting an enterprise does not involve one distinct solution. Different from the concepts applied for knowledge sharing in the film studies, episodic knowledge is of particular importance. For that purpose, we have integrated abilities to describe non-linear entrepreneurial aspects within a web-based community information system.

5 Re-contextualization of Episodic Knowledge

MIST (Media Integrated Story Telling) is an approach to non-linear multimedia story creation. It is based on the Movement Oriented Design (MOD) [Sharda, 2005] principle, which is a new methodology for the creation of linear and non-linear stories. Its core idea is to bring together different theories, models and tools under one roof. Thus, it integrates features from Dramatica [Phillips and Huntley, 2001a] as well as the Aristotelean Poetic [Aristoteles, 2000]. The result is a novel methodology and a formalism in order to create multimedia stories by combining three facets of stories: Motivation, Exigency and Structure.

- Motivation (Why): The motivation facet directs a project by formulating the project concept as a series of problems or questions. These elements are suitable to capture **verbal** and **non-verbal knowledge** in stories. Beginning with a problem statement (*plot*), which is hierarchically organized in order to specify *media* that solve a particular (sub-)problem.
- Exigency (What): The exigency (need) facet now combines **verbal** and **non-verbal knowledge** as **semantic knowledge**. The ability to create emotional movement in the user is paramount for all multimedia systems. Thus, the aim is to store (meta)information causing emotional movement. However,

the main challenge is to device a story structure that facilitates the creation of this emotional movement by the use of *media*.

- Structure (How): In order to facilitate the organization of **episodic knowledge** a story is an ensemble of *story units*. For that purpose, each story unit has three parts, a *begin*, *middle*, and an *end* which have to be passed subsequentially in any valid story. Thus, a graph builds up the overall story.

Thus, the MOD methodology is a comprehensive framework for the creation of non-linear digital stories. The next section introduces a formal notation of MOD stories created with MIST. Due to the existence of such a formal notation it becomes possible to validate a given story or even let users only create valid stories. However, all MIST stories are stored compliant to the MPEG-7 standard. In the context of the MPEG-7 Schema, MIST stories are modeled as structured collections defining relationships among each other, i.e. hierarchical child/parent relationships or arbitrary user defined relationships. VEL 2.0 is powered by our own lightweight application server (LAS), that supports MPEG-7 services in community engines [Spaniol et al., 2006] and serves as middleware. In section 5.2 we present a more detailed description on LAS and in particular MPEG-7 services.

5.1 Formalization of MOD

Formally, non-linear stories in MOD consist of two structures: Non-linear multimedia stories $\mathcal{S}$ and their problem hierarchies $\mathcal{P}_\mathcal{S}$. All stories $s \epsilon \mathcal{S}$ are compliant to the MOD paradigm. The problem hierarchy defines a problem that is covered by a story. The universes of both structures are based on a common set of identifiers defined as follows:

$$I \subseteq \mathbb{N}, 0 <\mid I \mid < \infty$$

with:

$$I = I_{CSU} \dot{\cup} I_P \dot{\cup} I_M$$

where I_{CSU}, I_P and I_M are identifiers for composed story units (CSU), addresses problems (P) and the media (M) contained in a story.

Given the signature $\sigma = \{CSU, M, Rel_{SUCC}, Rel_B, Rel_M, Rel_E, root\}$ with:

$$CSU, M \in R^1(\sigma) Rel_{SUCC}, Rel_B, Rel_M, Rel_E \in R^2(\sigma) root \in F^0(\sigma)$$

Then, a σ-structure

$$\mathcal{S} = (SU, CSU^\mathcal{S}, M^\mathcal{S}, Rel^\mathcal{S}_{SUCC}, Rel^\mathcal{S}_B, Rel^\mathcal{S}_M, Rel^\mathcal{S}_E, root^\mathcal{S})$$

is a valid story in MIST iff the following interpretations and conditions are fulfilled, cf. table 1. The signature σ and the $\mathcal{S}$ structure carry the following semantics given the previous conditions: The universe of $\mathcal{S}$ is the set of existing story units SU.

Figure 4 provides an overview of various media transitions possible within the MOD methodology. Basically, three different types of transitions exist. First, there are transitions from begin to middle or from middle to end [*(B)* → *(M)*, *(M)* → *(E)*] between two media elements m_i, m_j within a composed story unit c not being decomposed recursively. Next, any transition within a composed story unit c between a medium m_i followed by another medium m_j located in a recursively decomposed succeeding story unit s is being defined [*(B)* → *(B)*, *(M)* → *(B)*]. Similarly, those transitions within a composed story unit c between a medium m_j with a proceeding medium m_i of a recursively decomposed story unit s are defined [*(E)* → *(M)*, *(E)* → *(E)*]. Finally, any media transitions within a composed story unit c between media m_i, m_j located in recursively decomposed story units s_1, s_2 are being defined. Both transitions are of the same "type" [*(E)* → *(B)*] depending on the position between the recursively decomposed story units s_1, s_2 within the composed story units c. They relate a medium m_i located as an end element of a story unit s_1 with a medium m_j located at a begin position in another composed story unit s_2.

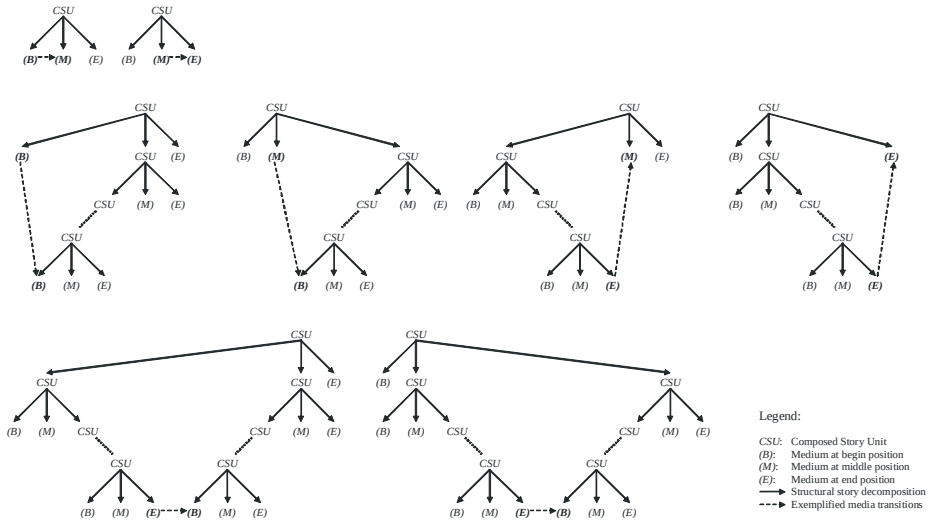

Figure 4: MOD compliant media transitions in MIST

	Interpretation / Condition	Comment
1	$SU = CSU \cup M$ where $CSU = I_{CSU}, M = I_M$	The set of story units *SU* is the disjoint aggregation of the set of non-atomic composed story units *CSU* with the set of atomic media *M*
2	$Rel_B, Rel_M, Rel_E \subseteq CSU \times SU$ with $Rel_B, Rel_M, Rel_E \neq \emptyset$	The dependencies between composed story units *CSU* and their succeeding story units *SU* are defined as binary relations
3	$\forall c \in CSU : \exists b, m, e \in SU$ having $(c,b) \in Rel_B \wedge (c,m) \in Rel_M \wedge (c,e) \in Rel_E \wedge b \neq m \neq e$	Every composed story unit contains at least one begin *(B)*, middle *(M)* and end *(E)* element, that might be either atomic or composed thus allowing a recursive decomposition of multimedia stories
4	$Rel_{BME} := Rel_B \cup Rel_M \cup Rel_E$	The set of all existing dependency relations is the disjoint union of begin, middle and end relations
5	Let $s \in SU, a, b \in CSU$: $(a,s) \in Rel_{BME} \wedge (b,s) \in Rel_{BME} \Rightarrow a = b$	The linking of a story unit *s* with a composed story unit *c* is unique
6	$root : \emptyset \rightarrow CSU$	Dedicated root element
7	$\neg \exists c \in CSU$ with $(c, root) \in Rel_{BME}$	The root element may not be contained within another composed story unit *c*
8	$\forall y \in SU \setminus \{root\} \exists x : (x,y) \in Rel_{BME}$	All story units *s* except the root may not stand alone and thus be inaccessible from the root
9	$Rel_{SUCC} \subseteq M^2$	Binary relation which is used to link two media *m*, which are atomic story units
10	$B(c) := \{x \in SU \mid (c,x) \in Rel_B, c \in CSU\}$	Set of story units *s* succeeding a given composed story unit *c* in the beginning relation
11	$B^*(c) := \bigcup_{n \in \mathbb{N}} B^n(c)$	Finite closure of all beginning relations given a composed story unit *c*
12	$E(c) := \{x \in SU \mid (c,x) \in Rel_E, c \in CSU\}$	The set of story units *s* succeeding a given composed story unit *c* in the end relation
13	$E^*(c) := \bigcup_{n \in \mathbb{N}} E^n(c)$	The finite closure of all end relations given a composed story unit *c*
14	$\forall (m_i, m_j) \in Rel_{SUCC}, i \neq j, \exists c \in CSU$ having $(c,m_i) \in Rel_B \wedge (c,m_j) \in Rel_M \vee (c,m_i) \in Rel_M \wedge (c,m_j) \in Rel_E \vee \exists x \in SU :$ $\left[\begin{array}{l}(c,m_i) \in Rel_B \wedge (c,x) \in Rel_M \wedge m_j \in B^*(x) \vee \\ (c,m_i) \in Rel_M \wedge (c,x) \in Rel_E \wedge m_j \in B^*(x) \vee \\ (c,x) \in Rel_B \wedge m_i \in E^*(x) \wedge (c,m_j) \in Rel_M \vee \\ (c,x) \in Rel_M \wedge m_i \in E^*(x) \wedge (c,m_j) \in Rel_E\end{array}\right]$ $\vee \exists y, z \in SU :$ $\left[\begin{array}{l}(c,y) \in Rel_B \wedge m_i \in E^*(y) \wedge (c,z) \in Rel_M \wedge m_j \in B^*(z) \vee \\ (c,y) \in Rel_M \wedge m_i \in E^*(y) \wedge (c,z) \in Rel_E \wedge m_j \in B^*(z)\end{array}\right]$	A transition between any two media m_i, m_j compliant to the MOD paradigm

Table 1: Interpretation and conditions for stories in MIST

We have now defined the structure of non-linear multimedia stories. In the next step, problem hierarchies within the plot of a story are defined as follows: Given the signature $\pi = \{P, M, L, root, super\}$ with:

$$P, M, L \in R^1(\pi) Rel_{PM} \in R^2(\pi) root \in F^0(\pi) super \in F^1(\pi)$$

	Interpretation / Condition	Comment
1	$PS = P \cup M$ where $P = I_P, M = I_M$	The universe of the problem structure PS is the disjoint union of the problems P and the media M of a story
2	$Rel_{PM} \subseteq P \times M$	The dependencies between the problems $p \in P$ addressed by a medium $m \in M$ are defined as a binary relation
3	$root : \varnothing \rightarrow P$	A dedicated root problem $p \in P$
4	$super : P \rightarrow P$, having : $super(root) := root$	Assignment of a tree structure to the problems addressed
5	$L := \{ p \in P \mid \neg \exists c \in P : super(c) = p \wedge p \neq c \}$	The set of leaves L contained in the tree
6	$\forall l \in L, \exists m \in M : (l,m) \in Rel_{PM}$	Every leaf l is linked with at least one medium

Table 2: Interpretation and conditions for problem hierarchies

Problems addressed by a story $\mathcal{S}$ are defined given the following π-structure $\mathcal{P}_\mathcal{S}$.

$$\mathcal{P}_\mathcal{S} = (PS, P^{\mathcal{P}_\mathcal{S}}, M^{\mathcal{P}_\mathcal{S}}, L^{\mathcal{P}_\mathcal{S}}, root^{\mathcal{P}_\mathcal{S}}, super^{\mathcal{P}_\mathcal{S}})$$

defines a valid story-plot of problems in MIST iff the following conditions are fulfilled, cf. table 2. The signature π and a problem structure $\mathcal{P}_\mathcal{S}$ carry the following semantics given the previous conditions: The universe PS of $\mathcal{P}_\mathcal{S}$ is the union of problems P covered by a story in combination with the media M.

Since MIST stories imply the usage of multimedia, we chose to map the above formal concepts to XML descriptors compliant to the MPEG-7 multimedia metadata description standard [International Organisation for Standardisation (ISO), 2001]. MPEG-7 descriptors have been designed as general as possible, so they are universally appliable in a variety of problem domains and applications. Thus, we chose to create a set of MPEG-7 services available for our own implementation of a lightweight application server LAS, that now provides MPEG-7 functionality not only for MIST, but also for other projects, where media are possibly used in different ways. LAS is used to integrate community based service functionality support to our projects. The following section gives an introduction to LAS putting a focus on MPEG-7 services.

5.2 MPEG-7 Services in a Lightweight Application Server

The MPEG-7 Services provided in LAS are used in order to support collaboration in communities by the exchange of multimedia contents and their low- and high-level semantic descriptions. In their conceptualization, LAS MPEG-7 Services try to bridge the gap between “folksonomy-style” high-level semantic information about multimedia and purely technical low-level content descriptions. In this aspect, the Dublin Core (DC) metadata standard [Dublin Core Metadata Initiative, 1999] has been a step forward, as it is an easy to understand and

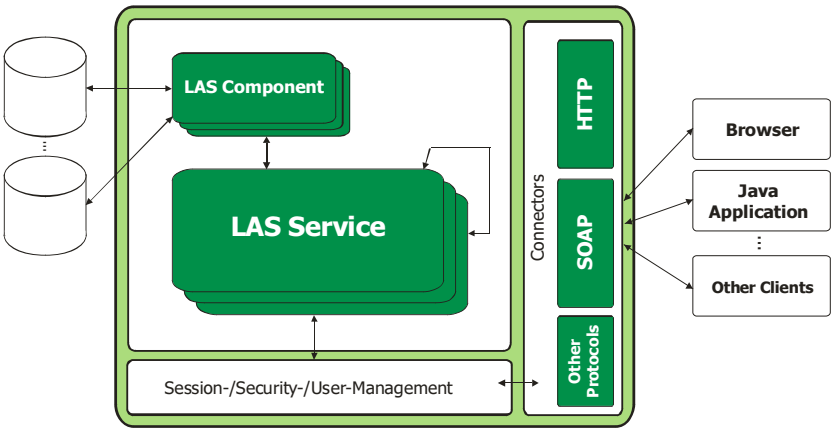

Figure 5: Simplified LAS Architecture

concise method for media annotations. Nevertheless, DC is not suitable for temporal and media specific annotations of multimedia contents. For that reason, we try to overcome these limitations by a combination of the loose classifications in DC with more sophisticated description elements for time based media in MPEG-7. Thus, our MPEG-7 services are based on an excerpt of the extensive MPEG-7 multimedia metadata standard. Even more, we provide services for a semi-automatic conversion from DC to MPEG-7 while an affiliated FTP server is used for an automated up- and download of multimedia artifacts by the community to the common repository. We first describe the basic concepts of LAS. Finally, we introduce the LAS MPEG-7 Services as an extension of LAS.

5.2.1 The LAS Architecture and Main Concepts

LAS is a platform independent Java implementation of a lightweight middleware platform for service oriented architectures (SOA) developed at our chair for the purpose of providing network services which can be shared among various tools supporting the work of communities in practice. The LAS Java API and its concepts are used to build the server's functionality and thus allow arbitrary server extensions by three basic element types: connectors, components and services. Figure 5 shows a simplified diagram of the LAS architecture and the interrelations between the server elements described in the following.

A connector realizes the server side for client-server communication using a particular protocol, e.g. HTTP or SOAP. Components encapsulate functionality for common tasks shared by services or other components. Services define the actual functionality that LAS offers to its clients. Public service methods are

available to clients through one of the connectors inside a session context. Service methods can be invoked by clients using a connector client for any of the available communication protocols (HTTP/SOAP). Access to service methods as well as to arbitrary secured objects is controlled on server side by an internal security management that is based on users, groups and roles. Access rights can be defined on different levels of granularity, i.e. per-service, per-service-method or per-method-signature. The scenario of accessing a service from client side is depicted in figure 6. A client connects to the LAS using one of the available connector clients and invokes LAS service methods remotely, possibly involving secured objects.

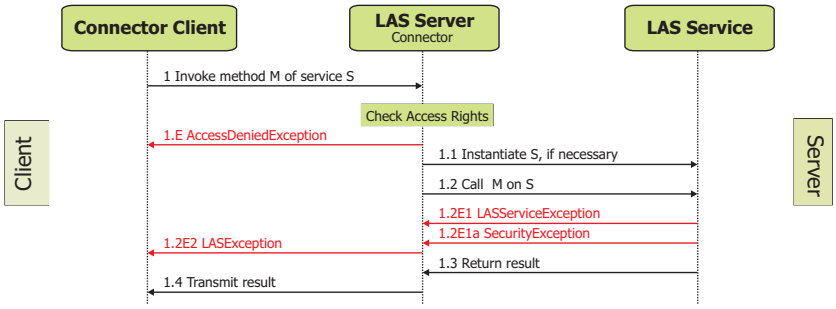

Figure 6: Sequence Diagram "LAS Service Method Invocation"

5.2.2 The LAS MPEG-7 Extension

The LAS MPEG-7 extension has been created as a framework for building services that offer methods to create, retrieve, update and delete persistent MPEG-7 XML [Bray et al., 1998] documents. Retrieval is realized by the execution of XQuery [Boag et al., 2005] resp. XPath [Berglund et al., 2002] expressions on the MPEG-7 database. Updates are realized by executing XUpdate [Laux and Martin, 2000] expressions. MPEG-7 documents are stored in a XML database that can be accessed by an MPEG-7 service via a built-in LAS XML database mediator being capable of combining a set of different XML database instances (e.g Oracle, IBM DB2, eXist) to one virtual XML database context. An MPEG-7 service uses the Apache XMLBeans XML Binding framework [Apache, 2006] for convenient navigation and valid operations on MPEG-7 documents. Figure 7 shows a structural diagram of the MPEG-7 extension. Class `MPEG7Service` is of central importance. Implementations of further higher-level MPEG-7 services are derived from `MPEG7Service`, which itself is an extension of a LAS service. Each service derived from `MPEG7Service` inherits support for accessing the underlying

MPEG-7 database and for using the MPEG-7 binding class library generated from the MPEG-7 XML-Schema [Brown et al., 2001] by the Apache XMLBeans Binding Framework [Apache, 2006].

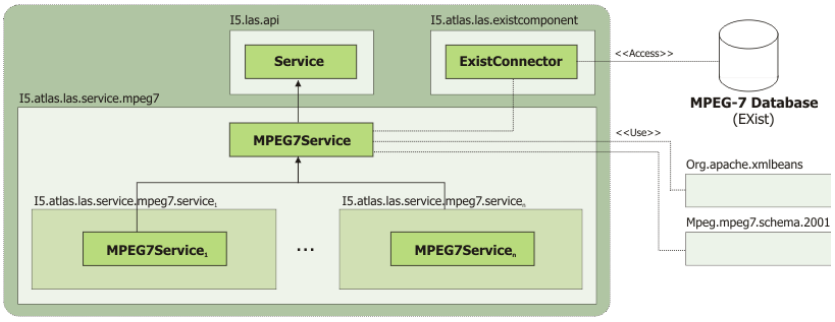

Figure 7: LAS MPEG-7 Extension

6 VEL 2.0: Sharing Entrepreneurial Knowledge by Non-Linear Multimedia Stories

The **Virtual Entrepreneurship Lab 2.0 (VEL 2.0)** is the further development of the VEL [Klamma et al., 2002a] combining the most prominent features of MECCA, MIST and LAS MPEG-7 services. Like MIST it is based on the Movement Oriented Design (MOD) [Sharda, 2005] principle.

For the purpose of authoring and consuming non-linear multimedia stories, the VEL 2.0 GUI provides an editor and a player. The editor allows users to create new or edit already existing multimedia stories. The player is used for the consumption of existing multimedia stories. VEL 2.0 contains media and media metadata of interviews with different entrepreneurial players from high-tech companies like Sun Microsystems, MetaCreations and ByteBurg. Besides the explicit knowledge contained in the interviews, entrepreneurs also serve as role models which make other people more sensitive to the topic itself. All interviews were tagged semantically [Klamma et al., 2002a]. The interviews deal with different aspects of entrepreneurial activities like finding the right team, identifying the right opportunity, looking for start-up money etc. These issues can be temporally arranged as they depend on a distinct stage of a funding and can be associated with problems to be solved. When creating a story the author can now create paths covering different problematic aspects of entrepreneurship from the entrepreneurial interviews. Thus, the problems addressed depend on the path selected and lead consequently to different results in an entrepreneurship.

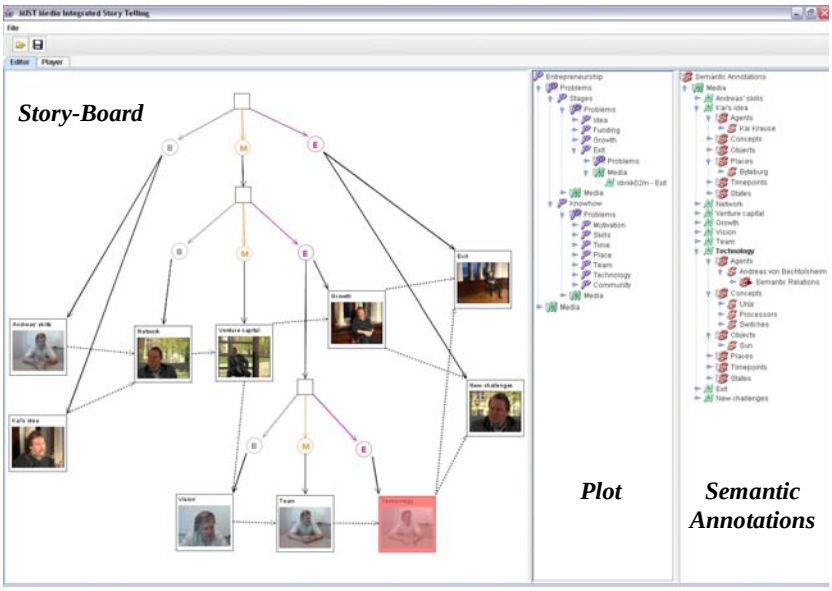

Figure 8: Multimedia Story Editor

Figure 8 shows the editor consisting of three main elements: *Storyboard*, *plot* and *semantic annotations*. The plot in the middle represents the declarative knowledge captured in a story. It is rendered as a tree hierarchy reflecting the stages of an entrepreneurship. Problems addressed in a multimedia story can be linked to related multimedia contents. The *storyboard* on the left hand side shows a visualization of episodic knowledge as paths between content elements. In addition, the decomposition of stories according to MOD paradigm into begin *(B)*, middle *(M)*, and end *(E)* is shown. Finally, on the right hand side, additional semantic annotations can be added to any multimedia element. Thus, users may express **verbal-knowledge** being associated with **non-verbal knowledge** inherent in any multimedia content. Consequently, the editor in VEL 2.0 supports the creation of multimedia stories based on the MOD paradigm, covering the complete spectrum of **declarative knowledge**.

The multimedia story player of VEL 2.0 is shown in figure 9. It also consists of three tabs. The player located in the middle allows rendering of arbitrary multimedia content such as video, audio, text or image. The entrepreneurial problems addressed by the *plot* are presented as multimedia contents. The tab on the right contains additional *semantic annotations* related to the medium. In the tab on the left possibly succeeding media are shown in a thumbnail preview. According to the media transitions defined in the editor's *storyboard* the user can select a medium in order to navigate through one possible path of a non-linear

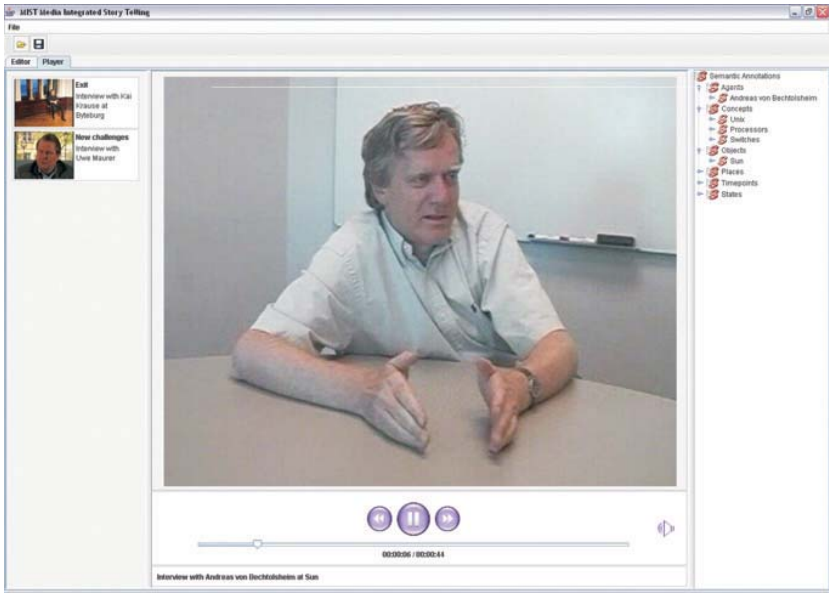

Figure 9: Multimedia Story Player

multimedia story.

With VEL 2.0 we presented a story-telling tool capturing all types of knowledge. The original goal of an advanced support for entrepreneurship lab courses was achieved by extending VEL 1.0 by numerous improvements towards a multimedia centered, community-based, collaborative learning environment. The next section summarizes the current status and provides a brief glance on our future work.

7 Conclusions & Outlook

Knowledge sharing in general and entrepreneurial knowledge sharing in particular benefit from technological innovations like blogs, forums, movies etc. using digital media. Community building speed and expert availability are increased. However, the impact of story-telling in fostering learning by connecting **episodic knowledge** with **declarative knowledge** in large distributed information systems is still marginal. Furthermore, existing story-telling systems are not suitable for a community/organization wide support of non-linear story creation and consumption. While approaches providing learner communities with multimedia technologies are promising, community learning processes supported by multimedia stories are still a desire. One of the reasons might be that story-telling is an extremely challenging task for many people if not guided by a clear and

simple methodology. We researched different approaches and tools for non-linear digital story-telling.

As a result we have to state that most of them are not suitable for sharing entrepreneurial knowledge in communities. We have demonstrated that VEL 2.0 based on the lightweight application server (LAS) is a comprehensive and extensible framework for community learning from non-linear multimedia stories. Our proof-of-concept implementation demonstrated the usefulness of MPEG-7 for non-linear multimedia story-telling by capturing **episodic knowledge** inherent in multimedia stories and **declarative knowledge** of multimedia contents. Due to its platform independence and an easy to use user interface, users can now collaborate, exchange knowledge and thus learn anytime and anywhere by exchanging multimedia stories via a common repository. While the reception of non-linear multimedia stories currently is not being evaluated, we are planning to do so in future.

In the future we want to create new learning experiences on a global scale around multimedia learning object repositories. In this sense, we have to re-contextualize learning objects within communities of practice. Here, we presented the re-contextualization of digital media in non-linear stories. Other services we explore are re-contextualization of learning objects in time and space, e.g. on virtual maps [Klamma et al., 2005] and the re-contextualization in Web 2.0 social tagging environments [Spaniol et al., 2006]. Putting it all together our learning experience is a "Virtual Campfire", a meeting place both real and virtual where people can preserve, share and create knowledge by the ancient power of story-telling.

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