Knowledge Multimedia Processes in Technology Enhanced Learning

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ABSTRACT

Success of Technology Enhanced Learning (TEL) depends on the careful engineering of multimedia and the related communication/collaboration features. Particularly, at engineering TEL environments for professionals and scientists in many disciplines, it is crucial to enable the system to reflect the nature of knowledge creating discourses in these domains. For that purpose, it is necessary to fully understand the occurring multimedia operations and knowledge sharing aspects involved in the learning processes. TEL environments therefore need to reflect the nature of the underlying knowledge creation processes and their discourses. This paper describes a media theoretical approach to TEL which is capable of synthesizing multimedia operations and knowledge sharing aspects involved in TEL.

Categories and Subject Descriptors
H.5.1 [**Multimedia Information Systems**], H.5.4 [**Hypertext/Hypermedia**], K.3.1: [**Computers in Education**]

General Terms
Design, Human Factors

Keywords
Technology enhanced learning, knowledge management, media theory, multimedia process model.

1. INTRODUCTION

Independent of its applications, Technology Enhanced Learning (TEL) requires to provide learners with the most suitable contents at any time and in every context regardless of professional cultures [45]. While the design and implementation of TEL environments is a challenging issue, in general, certain application domains are more difficult to handle than others. In some professions TEL as a means of knowledge management and knowledge sharing is quite common and has become an integral part of higher [1] and professional education [51] in recent years.

From a TEL point of view knowledge management and knowledge sharing are special cases of cultural communication. As a result, TEL cannot be 'reduced' to the design and implementation of factual knowledge tests, but requires a consideration of the overall context and the media used that lead to a certain position. Multimedia learning artifacts are predominant many professional learning processes where knowledge cannot be codified easily. Consequently, learning success cannot be simply measured based on the evaluation of simple multiple choice quizzes, but is only understandable as a process of insight and mediation. For that reason, the traceability of the complete discourse linked with any multimedia learning artifact is required at any time as it depends on the context whether a statement can be considered as correctly understood. A naive understanding of TEL – e.g. that multimedia artifacts might stand alone and serve as learning objects – isn't sufficient, as complex interrelations between media and complex cultural interfaces to these media exist [32]. For all the many facets of TEL the hypothesis therefore is: Professional learning is the result of knowledge sharing processes and media settings intertwined in each other. This implies for TEL that it is insufficient to provide efficient learning support without considering the media operations going on.

The research question therefore is: How can we support learners with traceable interactions on the top of multimedia artifacts in TEL environments? This paper presents a media theoretical approach to TEL in order to bridge the gap between the media specific needs inherent in learning processes and research undertaken in the field of knowledge management. The result is a novel approach synthesizing both theories in a media theoretical approach for TEL.

The rest of the paper is organized as follows. In the next section the underlying theories from media and knowledge management studies are introduced and compared. Based on the differences and similarities figured out between those approaches, a synthesis of these approaches is undertaken in Section 3. The next section gives some short notes about related work. The paper closes with conclusions and gives an outlook on further research.

2. MULTIMEDIA AND KNOWLEDGE

Knowledge sharing is primarily a social process [3; 25; 50]. In order to get a deeper insight into the learning processes, both media operations and steps in the knowledge sharing process need to be understood. For that purpose, now a closer look at the

underlying theories will be undertaken. Particularly, it will be pointed out that it is insufficient for TEL it is insufficient to consider them separately, but an intertwined approach is required. Therefore, the Theory of Transcriptivity is introduced at first, which will help to understand the media operations. After that, a refinement of the renowned Nonaka SECI-model will be introduced. By doing so, the model becomes more feasible and easier to transfer into non-technical disciplines.

The German philologist Ludwig Jäger developed the so-called "Theory of Transcriptivity" (ToT) [26]. This theory describes a media practice in creating and further developing a cultural semantic by symbolic means. Thus, transcriptivity describes the underlying basic relation between knowledge organization and communication in the cultural sciences and other non-technical disciplines. It is based on the following three media operations [17; 24]:

- Transcription is a media dependent operation in order to make media collections more readable.
- Localization means an operation that transfers global media into local practices.
- (Re-) addressing describes an operation that stabilizes and optimizes the accessibility in global communication.
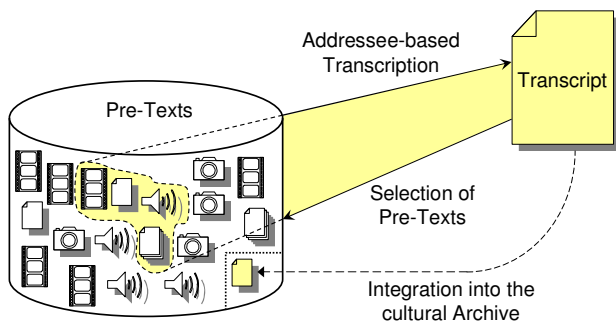

Figure 1 The Theory of Transcriptivity (adopted from [26])

The processes described in the ToT are shown schematically in Fig. 1. While the transcription operation can be identified as a distinct procedure constituting a transcript out of previously existing pre-texts (either real texts or undergone experiences), the media operations of localization and addressing are not visible as separate entities. The reason is that both processes are to some extent specializations of (and consequently dependent on) the transcription and help constituting the feedback loop of "Understanding and Critique" within the overall process. In this aspect, addressing can be seen as technical means in order to improve distributing and presenting contents (and thus the transcripts). Similarly, localization is a procedure that refines the adaptation and presentation of media artifacts (the transcripts), given a dedicated context.

Altogether, the ToT represents a renowned model that describes the process of knowledge sharing in the cultural sciences from a media theoretic perspective. However, the implications of the media operations described here are not considered from a technical point of view. Regarding TEL the ToT does not contain any references to the underlying learning processes within the media operations described. Hence, the ToT is not suitable to serve unescorted as a model for TEL without taking the learning processes into consideration from a knowledge management perspective.

The knowledge creation theory, especially the SECI model by Nonaka and Takeuchi [36] is widely acknowledged in management theory and practice. Also, in CSCL and TEL the most prominent knowledge management theories are founded by Bereiter, Engeström and Nonaka & Takeuchi [37]. The SECI model makes a basic distinction between tacit or procedural and explicit or declarative knowledge [35, 36; 38].

In TEL the learning process according to the SECI model starts with an individual who has some media-specific knowledge. This individual has basically two alternatives to share her expertise. On the one hand, there is an option to present this information to others by human-human interaction (Socialization), which is equivalent to the development of a shared history. On the other hand, individuals may also perform to create new media artifacts (Externalization). These contents may now be further processed within a learning environment (Combination). The cycle is closed when contents are accessed by others (Internalization). The overall process might then be initiated and.

This distinction is quite coarse. Particularly, a plain classification of knowledge into just two categories (tacit and explicit) neglects the fact that the overall context and the media used have to be taken into account in order to understand a certain position in the learning process. Thus, the SECI model needs to be refined at the level of Combination by the concepts of semantic and episodic knowledge introduced by Tulving and Ullmann [48; 49]. The key point is that only through a combination of semantic and episodic knowledge the context of media settings (and thus a certain viewpoint) can be correctly understood (cf. Fig. 2).
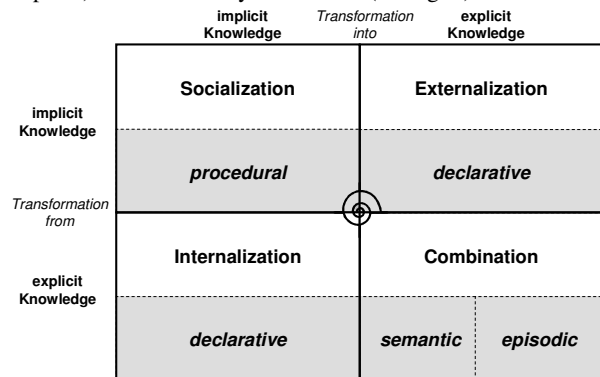

Figure 2 The SECI model of knowledge processing [36] with refinements (in grey) by Ullman [49]

While semantic knowledge is kind of semiotic and conceptual such as documentation in organizational charts, business process definitions and so forth, episodic knowledge makes use of undergone experiences such as episodes and narratives. Thus, documentation is a means of semantic knowledge, which can again be refined as verbal (linguistic data) and non-verbal (e.g. video or visual) contents. However, the situational context leading to a certain document might be lost. Here, episodic knowledge comes into play as it covers the situational context of a certain media setting.

In this aspect, it is important that learning processes require a fine-grained distinction of both in order to ensure the success of a learning process. Particularly, a multimedia artifact (semantic knowledge) has to be considered from various viewpoints and can be interpreted in different ways (episodic knowledge). Thus, it is crucial to consider the situational context as a distinct concept within the overall learning process.

An approach to developing learning histories [41] is story-telling. It intertwines semantic knowledge, i.e. already reified concepts of communities stored as documents, by linking it with the narrative experiences gained from episodic knowledge. Consequently, story-telling is an important aspect for knowledge. Here, the aspects of telling, sharing and experiencing stories are a problem-oriented way to learn from the experiences of others.

However, the extended SECI model still does not help to gain a deeper insight into the media operations involved in the hermeneutical learning. Thus, the next chapter describes a media theoretical approach to TEL that synthesizes the previously introduced theories.

3. AN OPERATIONAL MEDIA THEORY FOR TEL

In order to systematize the learning processes, the media operations taking place need to be linked with a knowledge management theory. Thus, the following section describes the synthesis of the media specific operations extracted from the Theory of Transcription with the extended SECI model. The result is a media theoretical approach to TEL based on the previously introduced media operations [24] and social learning and knowledge creation processes adopted from Nonaka & Takeuchi [36] and Wenger [50].
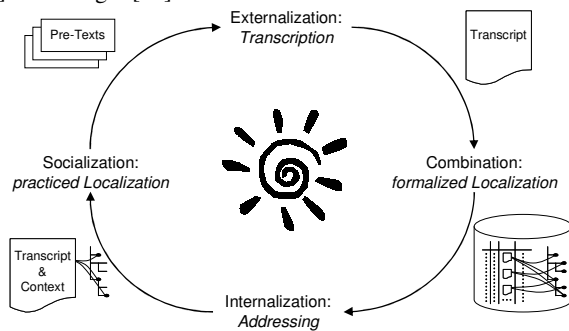
Figure 3 A media theoretical approach to TEL

Fig. 3 brings together both approaches in a media centric theory of learning for TEL. It combines the two types of knowledge (tacit resp. procedural and explicit resp. declarative [35; 36; 38]) as part of a knowledge creation and learning process with the media specific operations introduced in the ToT. On the left side, operations dealing with tacit (procedural) knowledge are visualized. The starting point is that an individual has gained some media-specific knowledge. In TEL the first step of a learner is a transcription by creating a new media artifact as part of an externalization process. This operation leads to the right side of the drawing where the digital learning contents are processed and explicit (declarative) knowledge is visualized. The so-created contents are now further processed within the learning environment. That means, the contents might not only be (re-) combined in an arbitrary fashion, but also a processing of semantic and episodic knowledge happens. From a media theoretical point of view, this operation describes a formalized localization process. Following, addressing of contents occurs. In this procedure the contents are internalized by a learner bringing us again to the left side of Fig. 3. In a final step, the contents might be discussed with others (either within the learning environment or directly among the learners) and so socialized. From a media theoretical point of view, this can be best described

as practiced localization. From then on, the process might be repeated infinitely oscillating between tacit and explicit knowledge on the epistemological axis and between individuals and the learning community on the ontological axis.

Our collaborative approach to creating contents in tries to bridge the gap between folksonomy-style high-level semantic knowledge about multimedia and purely technical low-level content descriptions. Our TEL environment allows knowledge sharing by means of multimedia annotation and story-telling which shows the validity of the media theoretical approach. The services provided intend to support collaboration in learning communities by the exchange of multimedia contents and their low-level and high-level semantic descriptions. Hence; users can externalize their knowledge about a certain issue by transcribing the multimedia artifact. Thus, the content becomes more understandable to others as these data contain additional information about the context of an artifact.

In order to ensure interoperability among the contents description; multimedia metadata standards are being incorporated. In this aspect, the Dublin Core (DC) metadata standard [13] is advantageous, since it is an easy to understand and concise method for media annotations. Nevertheless, DC still has the limitations that it is not suitable for temporal and media specific annotations of multimedia contents. For that reason, we try to surmount these limitations by combining the loose classifications in DC with more sophisticated description elements for time based media in the ISO Multimedia Content Description Interface also known as MPEG-7 [23]. Thus, we make use of an excerpt of the extensive MPEG-7 multimedia metadata standard and provide typed media descriptions according to the standard. Even more, we provide services for a semi-automatic conversion [46] from DC to MPEG-7, while an affiliated FTP server is used for an automated upload and download of multimedia artifacts by the community to the common repository.

The combination of contents is primarily based on non-linear multimedia stories. The reason is simple: Non-linear multimedia stories are an ideal medium to intertwine the semantic and episodic knowledge of a multimedia artifact. For that purpose, the TEL environment provides formal methods that help to focus on the local meaning of multimedia artifact in a globally accessible learning environment.

Hence, the TEL environment provides dedicate features to capture the semantic and episodic knowledge within non-linear multimedia stories. In order to help learning content designers create useful stories (from a structural point of view), the Movement Oriented Design (MOD) paradigm [43] is applied as a theoretical basis. For the sake of brevity, we only briefly discuss the major principles here. Two user interfaces are available for story-telling support, an editor and a player. The editor allows users to create new or to edit already existing non-linear multimedia stories. The player is used by users to subsequently consume and interact with existing non-linear multimedia stories. Besides, the explicit knowledge contained in the multimedia contents and their high-level semantic tags are also accessible here. These multimedia contents can be thereafter temporally arranged in the way that they depend on a certain context. During the story creation authors can define paths covering different problematic aspects along the contents. Thus, the specified problems depend on the path selected and consequently lead to different endings of a story.
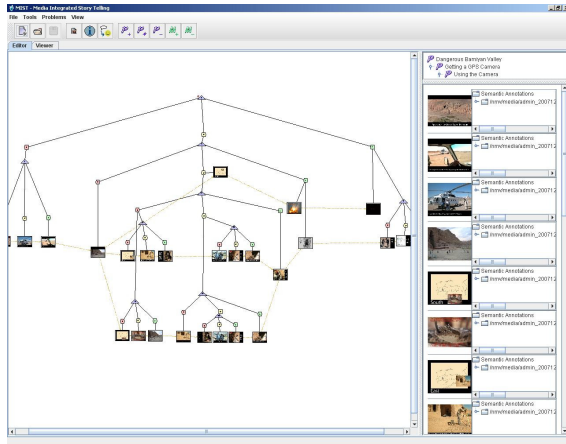
Figure 4 Creation of a non-linear story

Fig. 4 shows the editor consisting of three main elements (from left to right, and top to bottom): storyboard, plot, and semantic annotations. The plot in the upper right represents the declarative knowledge captured in a story. It is rendered by a tree hierarchy, which allows the further decomposition into sub-problems. In addition, problems addressed in a multimedia story can be linked to related multimedia contents. The storyboard on the left panel illustrates a visualization of episodic knowledge as paths between content elements. The story decomposition accords to the MOD paradigm with its designated begin (B), middle (M), and end (E) elements. Finally, in the lower right panel additional semantic annotations can be added to any multimedia element. Thus, users may express verbal-knowledge being associated with non-verbal knowledge.

The internalization of previously encoded knowledge is supported by contextualized multimedia presentations and the consumption of multimedia stories. Here, the addressing of multimedia contents contained in the learning environment takes place. For that purpose, we offer two types of learning content presentations: Contextualized multimedia presentations and the consumption of multimedia stories.

Contextualized multimedia presentations are used in order to help the learner in searching and exploring the contents. Here, plain keyword search and typed semantic retrieval are applied in order to guide the learner to the most relevant contents. Keyword tags enable the learners to search for multimedia artifacts based on a set of plain keywords as it can be done in Flickr (www.flickr.com). Semantic tags search go a step further by allowing users to define semantic entities and to assign semantic entity references to an image or a video. They are more expressive than plain keywords, because they carry additional semantics. For example, in the domain of cultural heritage management, one could not derive from a plaintext keyword Buddha, that it describes an agent, while for semantic tags, Buddha has been modeled as a semantic entity of type agent. All these high-level content descriptions can be cross-walked with any learning standard by fixed mappings or even dynamically by mapping services [8]. Even more, for multimedia retrieval learners can formulate keyword search expressions as propositional logic formulae using keywords as atomic propositions.

Similarly, the presentation of multimedia stories can be applied to internalize the knowledge contained in the learning contents. In our second application scenario the multimedia story player is applied in entrepreneurial education in order to share entrepreneurial knowledge. Here, interviews with venture capitalists and famous entrepreneurs such as Andreas von Bechtoldsheim (Sun Microsystems) or Kai Krause (MetaCreations) about various aspects in founding a company have been captured, an idea coming originally from the area of foreign language training developed at the MIT [16]. These contents are made available to the users via the multimedia player described before; again offering a variety of background information, which allows an authentic, contextualized multimedia presentation (cf. [29] for details). It consists – like the story editor – 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 media artifact in order to navigate through one possible path of a non-linear multimedia story.

The final step in socializing the learning contents is based on direct human-human communication where the practices are discussed locally. Thus, it cannot be supported "naturally" within a learning environment. However, at least we provide additional forum features where learners can discuss about the contents previously consumed.

4. FORMALIZATION

In the second section media and knowledge management theories have been compared in order to get a deeper insight into the hermeneutical learning processes in non-technical disciplines. As a result, we introduced in the previous section a media-theoretical approach to TEL that intertwines both media operations and processes involved in knowledge sharing. In addition, we have pointed out that the process of knowledge sharing is based on the illustration of media artifacts, which requires tracing back the underlying media conditions prevalent at time of artifact creation.

From an engineering point of view, it is therefore required to formalize the media operations taking place in the knowledge sharing process. Hence, we will now introduce the formalization of an operational media theory for TEL. For that purpose, we formally describe the operations transcription, formalized localization, addressing and practiced localization, contained in the operational media-theory for TEL.

4.1 Transcription: Metadata Management in Multimedia Archives

The media operation of *transcription* (cf. Section 3 for details) is from a computer scientific viewpoint a data processing issue that primarily concerns the creation of (multi)-media (meta)-data, e.g. MPEG-7, DC or IEEE LOM. A starting point for a media-centric knowledge sharing process is the so-called pre-texts $p \in P$. The pre-texts do not only contain contents that have been already externalized via a multimedia artifact (e.g. a text document), but might also be an undergone experience. A pre-text p is in the following defined as:

$$P := p(i,m)$$

consisting of an incorporated content $i \in I$ and the media artifact $m \in M \cup \emptyset$. The media artifact might be either an arbitrary multimedia object, but might even be an "empty" artifact, when being associated with a user's undergone experience. In the case of digitally artifacts we distinguish between different multimedia types as follows:

Text documents: $M_{\text{„Text“}}$
Images: $M_{\text{„Image“}}$
Music and spoken contents: $M_{\text{„Audio“}}$
Audio-visual contents: $M_{\text{„Video“}}$

Consequently, the overall (media)-archive is the set M that consists of the previously mentioned media types and pretexts as follows:

$$M \in \{M_{\text{„Text“}}, M_{\text{„Image“}}, M_{\text{„Audio“}}, M_{\text{„Video“}}\}^n \cup \{P\}, n \in \mathbb{N}_0.$$

Obviously, this definition consists of two media types. On the one hand, there are "externalized" media artifacts (such as images). On the other hand, there are "undergone experiences" in terms of pre-texts. With respect to an information system backed support of media operations, it is indispensable that media contents exist as "externalized" media artifacts which can be further processed:

$$M \backslash P$$

The (media)-archive M_z at any given time point z, is subject to a continuous working and extension process. Therefore, at any point in time additional media artifacts can be added to the archive:

$$M_{z+} := M_z \cup m; \text{ having } m \in M$$

z^+ denominates a latter time point where (potentially) additional media artifacts m have been added to the archive. The removal of media artifacts is possible in general from the viewpoint of computer science. However, any information system supporting deletion of media artifacts, too, would not satisfy the requirements of an archive in general. Hence, we do not consider the operation of deleting media artifacts here, but want to point out that some sort of "deletion" (performed via an individual filtering technique) will be described in the scope of the *formalized localization* process (cf. Section 4.2 for details).

The creation of a media artifact is the result of a *transcription* operation. Here, a media artifact comes into existence from any sort of pre-text, either a media artifact or some undergone experiences. In this process, a media artifact together with its (multi)-media (meta)-data is generated. Thus, we define a transcript as follows:

$$t_p := (\tau(p), \mu(p), \iota(p)). \; T := \{t_p\}$$

is the set that contains all transcripts. The operation $\tau(p)$ performed when a *transcription* takes place generates a media artifact m from a pre-text p is defined as follows:

$$\tau : P \rightarrow M \backslash P \text{ having } \tau(p) := m.$$

Additionally, with respect to the creation of manually created

(semantically valuable) metadata in the process of (meta)-*transcription* $\mu(p)$ the following constraints apply:

$$\mu : P \rightarrow M_{\text{„Text“}} \cup \emptyset \text{ having } \mu(p) := m.$$

In parallel, an automatically performed (meta)-*transcription* $\iota(p)$ takes place. Here, semantically inferior metadata data are extracted from the media artifact by the information system (e.g. size, file type, etc.). This is defined as follows:

$$\iota : P \rightarrow M_{\text{„Text“}} \text{ having } \iota(p) := m.$$

The only difference between automatically and manually created metadata is the fact that the automatically extracted metadata always exist (hence, they do not contain empty contents), which does not necessarily hold for manually created metadata.

Consequently, the *transcription* $\tau(p)$ of a pre-text p is comparable to an externalization of a media artifact m in a medium M. Even more, externalizations of incorporated contents are assigned with text-based metadata described by the operations $\mu(p)$ and $\iota(p)$. In the case of manually created metadata $\mu(p)$ the resulting annotations are "high-level". However, these metadata do not necessarily always exist, as the user is required to do so. On the contrary, automatically created metadata $\iota(p)$ always exist, as the information performs the task. However, these annotations are "low-level" only and are mostly limited to technical details.

Another sort of *transcription*s is commenting on media artifacts by so-called media-dependency-graphs. A media-dependency-graph consists of media artifacts m and edges e in order to express the relationships between media artifacts (such as image A is the film poster of movie B). For that purpose, the e is defined as a 3-tuple:

$$e := (m, m_o, \Theta(m, m_o)) \text{ having } m, m' \in M \backslash P \text{ and}$$

$$\Theta(m, m') := m_e \in \{M_{\text{„Text“}}\} \cup \emptyset$$

which can be typed optionally with a text-based description. The set of all edges is:

$$E := \{e\}$$

A media-dependency-graph $g \in G_M$ therefore consists of a set of media artifacts M linked among each other by the set of existing edges E. Two media artifacts are set into relation with each other by typed and directed edges. For the sake of completeness, "empty" (non-existing) descriptions are allowed, too.

4.2 *Formalized localization*: Multimedia Access in Dynamic Archives

In accordance with Section 3 the process of *formalized localization* describes an information system driven process of multimedia artifacts within a digital archive. For that purpose, the previously created transcripts are processed and presented for the background of a specific context. However, this context changes over time and is – even more – different for any user. Hence, the local (individual) context needs to be captured and/or adapted to a certain user's needs. We therefore allow each user to capture his context by an individually modifiable categorization.

At first, we have to ensure that only authorized users are allowed to access and/or modify transcripts stored in the information

system. Thus, transcripts are administrated by so-called access control lists. An ACL is defined as follows:

$$ACL := (T, U^{allowed}, U^{prohibited}, C^{allowed}, C^{prohibited}, R)$$

consisting of the sets

$$T, U^{allowed}, U^{prohibited}, C^{allowed}, C^{prohibited}$$

and the Boolean function R.

The sets $U^{allowed}$ contain $C^{allowed}$ those users respectively members of a community that are allowed to access a specific transcript $t \in T$. On the contrary, the sets $U^{prohibited}$ and $C^{prohibited}$ contain all those users respectively members of a community who are not allowed to access that particular transcript. The Boolean function contains information about global access rights.

Access to a transcript $t \in T$ is evaluated against the function $\zeta ACL(t, n)$ based on the access rights of a user $u_t \in N$, C respectively based on the global access rights $r_t \in R$ as follows:

$$\zeta ACL(t,n) := \begin{cases} 1 \ (n_t \in U^{allowed}) \vee (n_t \in C^{allowed} \wedge n_t \notin U^{prohibited}) \vee (r_t = 1) \\ 0 \ else \end{cases}$$

Since access prohibitions can be declared explicitly and a security first evaluation process (strictly: user access rights first, then community access rights, and finally global access right), an additional protective mechanism is in place: Users who are not allowed to access a transcript may not gain access to it indirectly through membership in a community that is allowed to.
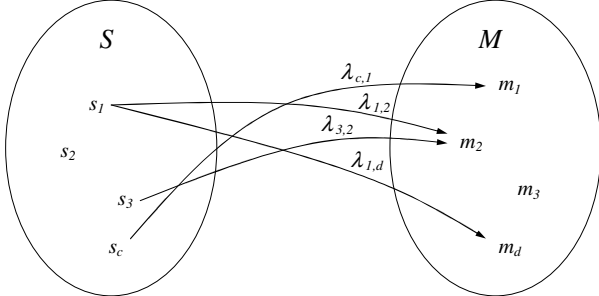
Figure 5 Index-based access to multimedia artifacts

The *formalized localization* process in itself takes place by an adaptation of transcripts for the background of a local context. The starting point is an index based on a set of keywords S:

$$S := \{s\}$$

that consist of non-empty string arrays s. Each string specifies a term which serves a descriptor of a media artifact. Based on the elements contained in a keyword index S through which the media artifacts are made accessible. Therefore, the mapping λ_i is applied to allow an indexed access to media artifacts m as follows:

$$\lambda_i : S \to \mathcal{P}(M) \text{ having } \lambda_i(s) := m$$

and $\mathcal{P}(M)$ being the power set of M. Hence, a single string can be associated with multiple elements in M. Figure 4 illustrates the principle of indexing applied as an access method to media artifacts.
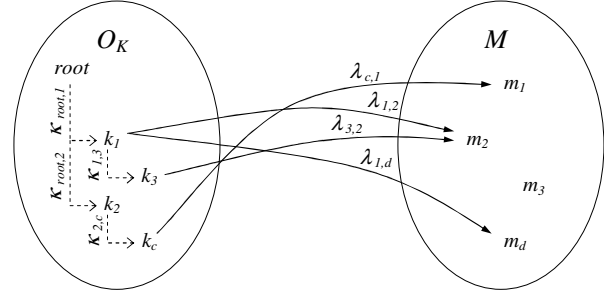
Figure 6 Categorization-based access to multimedia artifacts

However, naming of strings is not necessarily unique (consider, e.g., the term "portrait" as a picture style or a genre of a movie). Hence, the same term might be applied onto completely different media artifacts, depending on their contexts. In order to allow an unambiguous referencing, a taxonomical categorization is applied. From the viewpoint of computer science, this can be achieved within a tree-like structure consisting of nodes and leaves, which represent a structured keyword index on unique identifiers id. Those identifiers id are defined as:

$$id \in \{\texttt{Integer; Character}\}^*. \ ID := \{id\}$$

is the set of all existing (unique) identifiers. On the basis of the previously introduced identifiers a category k is defined as

$$k := (id, s)$$

being a tuple of a unique identifier id and a string s, contained in the categorizations overall set of terms K:

$$K := \{k\}.$$

Categories are then arranged within a tree-structure. The result is an acyclic tree, containing uniquely identifiable nodes/leaves. The ordering o among the tree elements is defined as follows:

$$o := (k, k', \kappa(k_{id}, k'_{id})) \text{ having } k, k' \in K$$

and with its successor relation $\kappa(k_{id}, k'_{id})$.

We denote $O_K := \{o\}$ tree-structure O_K that is associated with the categorization K. In a final step, the categories (k) are concatenated via an empty root node $root$ having $s = \emptyset$. Hence we achieve that even non-connected tree segments can be made accessible via the same root node.

Likewise accessing media artifacts based on a keyword index S the relation λ_k defines the access to media artifacts m in a categorization (cf. Figure 5 for a graphical representation):

$$\lambda_k: ID \to \mathcal{P}(M) \text{ having } \lambda_k(id) := m.$$

Initial point is a global categorization K_{global} including its arrangements among its identifiers (O_{global}). A global categorization stands for an approach to finding a community categorization's "least common denominator". In that sense, the "least common terminology" is to be understood as an approach to finding a set of unambiguous terms used in a community. Again, the mapping λ_{global} specifies interdependencies between categories and media artifacts.
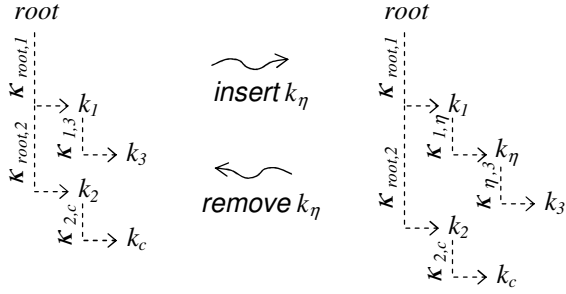
Figure 7 Adding and removing of elements in a categorization

In order to allow a customized access to media artifacts as part of the *formalized localization l* the global categorization K_{global}, its structure O_{global} and its access methods λ_{global} to media artifacts may be adapted to the user's local context. In the process of a *formalized localization*, the following three operations have to be considered:

a) Renaming of categories k of an categorization K:

$(id,s) \rightarrow (id,s')$

b) Adding, deleting or changing of elements in a categorization K and its order O_K (cf. Figures 6 and 7):

$\kappa(k_{id},k'_{id}) \rightarrow \kappa(k_{id},k''_{id}) \wedge \kappa(k''_{id},k'_{id})$ [insertion]

$\kappa(k_{id},k''_{id}) \wedge \kappa(k''_{id},k'_{id}) \rightarrow \kappa(k_{id},k'_{id})$ [removal]

$\kappa(k_{id},k'_{id}) \rightarrow \kappa(k'_{id},k_{id})$ [change]
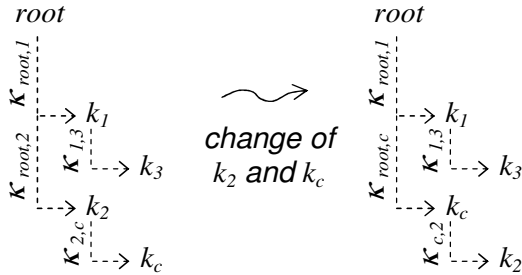

Figure 8 Changing the order of elements in a categorization

c) Customization of the access method $\lambda_k(id)$ to media artifacts by adding or removing of links between categories and media artifacts (cf. Figure 8):

$\lambda_k(id) : m \rightarrow \lambda_k(id) : m,m'$ [add]

$\lambda_k(id) : m,m' \rightarrow \lambda_k(id) : m$ [removal]

Hence, the *formalized localization* is defined as a 3-tuple:
$l := (K_{local}, O_{local}, \lambda_{local})$ that consists of a local categorization (K_{local}), local order of categories (O_{local}) and local access method (λ_{local}). $L := \{l\}$ denotes the set of all *formalized localization*s. Consequently, the context of a media artifact is expressed by the interdependencies defined in the access method $\lambda_k(id)$ that specifies the links between IDs id and artifacts m within the scope of a *formalized localization* l. Additionally, transcripts can be made accessible via different access methods, which is (for

instance) required, if refinements of a categorization need to be undertaken.

4.3 *Addressing & Practiced Localization*: Contextualized Artifact Presentation

Addressing stands for methods of a contextualized artifact presentation (cf. Section 3). Even more, the process of *practiced localization* closes the feedback loop of "Understanding and Critique" introduced in Section 2.1. In accordance with our explanations in Section 3, the process of "Understanding and Critique" cannot be (or at most partially) captured by means of information systems. Hence, the *practiced localization* will be formally introduced as a successfully completed *addressing*.

The *addressing* of transcripts requires recourse on the security mechanisms introduced in Section 4.2 in order to ensure that only authorized users may obtain access to the media artifacts. An elementary sort of *addressing* is a discussion about a transcript t_p defined as:
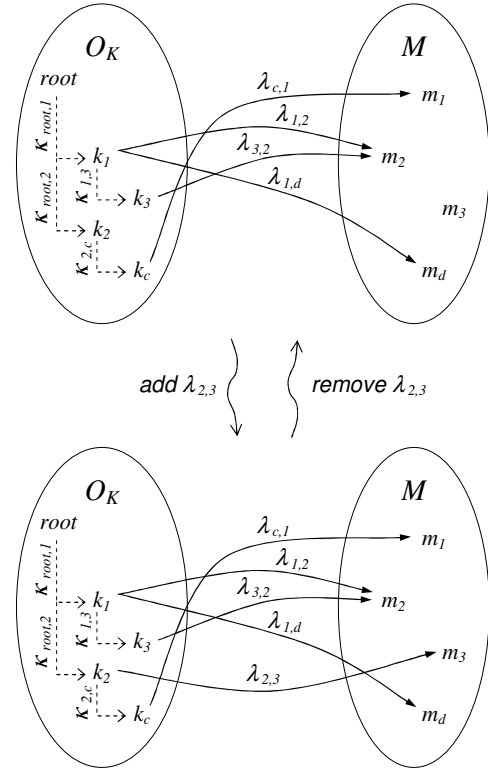

Figure 9 Adaptation of references from categories to media

$d_{t_p} := (t_p,\delta(t_p))$, and the set of discussions having: $D_{t_p} := \{d_{t_p}\}$. The discussion associated with a transcript δ_t is defined as:
$\delta_t: T \rightarrow M_{\text{„Text"}}$

a textual supplement of an externalization process $\delta_t(t_p)$ associated with a transcript tp as follows:

$\delta_t(t_p) := m_{\text{„Text"}}$.

Hence, an additional means of discussing about or commenting on media artifacts emerges, beside manually created metadata $\mu(p)$ of a pre-text p.

A "distinct" medium of collaboration support in the process of

addressing are so-called hypermedia documents. Hypermedia documents are a compound structure, which allows the aggregation of – potentially many – transcripts ($t_p \in T$), media-dependency-graphs ($g \in G_M$), *localization*s ($l \in L$) and discussions about transcripts ($d_{t_p} \in D$) together with a manually created metadata description $\mu(h)$. A hypermedia $h_{t,g,l,d}$ is therefore defined a s follows:

$$h_{t,g,l,d} := (t_p{}^u, g^v, l^w, d_{t_p}{}^x, \mu(h)); \text{having } u,v,w,x \in \mathbb{N}_0.$$
$$H := \{h_{t,g,l,d}\}$$

is the set of all hypermedia documents. In additions, the operations allowed on transcripts may be generalized for hypermedia documents. A discussion about a hypermedia document $d_{h;g;l;d}$ is defined as:

$$d_{h_{t,g,l,d}} := (h_{t,g,l,d}, \delta_h(h_{t,g,l,d})),$$

and the set of discussions given by:

$$D_h := \{d_{h_{t,g,l,d}}\}.$$

Similarly, a discussion δ_h about a hypermedia document is defined as

$$\delta_h \colon H \to M_{\text{„Text"}}$$

a textual supplement of an externalization process $\delta_h(h_{t,g,l,d})$ associated with a hypermedia document $h_{t,g,l,d}$ having:

$$\delta_h(h_{t,g,l,d}) := m_{\text{„Text"}}.$$

The operation of *addressing* in itself concerns the presentation of the incorporated contents i involved in the knowledge sharing process, based on their context of creation. Hence, the *addressing* α_l associates media artifacts m with the l that is required to understand a certain fact:

$$\alpha_l \colon T \to I \text{ having } \alpha_l(t) := i.$$

The last step in a media-centric knowledge sharing process is the socialization σ. However, this operation is not explicitly measurable (e.g. by a "true" or "false") decision. Even more, this operation takes place "outside" of the information, but in the social interaction among its users. For that reason, the socialization of media artifacts m and of hypermedia documents h can be interpreted as a process of understanding and critique. Thereby, the incorporated contents become a new undergone experience of a user n, thus becoming a new pre-text for latter *transcription*s. The social process of a practical *localization* σ_n is defined as:

$$\sigma_n \colon T \times H \to P$$

a perception of a transcript t or of a hypermedia document h by user n as a new pre-text p:

$$\sigma_n(t,h) := p$$

The practical *localization* closes the loop within of the media-centric knowledge sharing process, which – from then on – might be repeated infinitely often. Hence, a continuous discourse about media artifacts within the community is supported. Even more, the operation of *formalized localization* allows knowledge sharing and refinement of the underlying theoretical context in parallel.

In the next section, we will present related work ranging from early ideas of implementing hypertext and hypermedia for technology enhanced learning to semantic web ideas for supporting learning. Still, we are offering an operational media theory to be distinguished from all simple media ontology approaches. A medium can only be understood by comparing its performance for a specific function in another medium.

5. Related Work

Hypermedia support for TEL is traceable till the days of the Second World War with the idea of a technical implementation of hypertext by Vannevar Bush [7]. The idea was renewed by Ted Nelson in the 1960's and implemented in the Xanadu prototype [34]. The most important concepts of hypertext are therefore non-linearity of text, computer supported links and the interactive way of using hypertext. Thus, 20 years later, Jeff Conklin reduced the technical definition of hypertext to "windows on the screen […] associated with objects in a database, and links […] provided between these objects" [9]. Objects can contain any digital data, text or image. These data-filled objects will be referred to as "hypermedia artifacts" below. In the Humanities the Apple Hypercard was a very successful tool which transformed millions of slip boxes into hypertext. In modern hypermedia, so different system issues like adaptability [5], multiculturalism [42] or multimodality [31] are discussed in the frame of an emerging theory of multimedia semiotics [10]. Multimedia discourse support systems for scholarly communications exist for many application domains like scholarly publishing [6] and dancing studies [18]. Learning from discourses in a community was discussed in a more user-centric manner by the concept of cognitive apprenticeship [30] before the community itself came into the focus of research with the seminal book of Etienne Wenger [50]. Several hypermedia systems for computer supported collaborative learning (CSCL) have been built these years, many of them in a constructivist setting [15; 4]. Learning repository support [11; 14] was developed in the last years with a focus on metadata standards such as Dublin Core [13], RDF [52], MPEG-7 [23] and ontology management [2]. In computer science, an ontology is considered as a specification of shared conceptualization [19] within an ongoing discourse. The formal knowledge representation language OWL [44] is used to specify ontologies and inference mechanisms in the semantic web [2].
Experiences with earlier multimedia standards like Dublin Core lead to the insight that the effort of harmonizing relatively small ontologies often appears frightening and generates questions about scalability [12]. Certainly, there is no alternative to merging of ontologies, which raises new scientific challenges. It considers intellectual effort and is a learning process for individuals as well as their communities. Basically, core ontologies are small and give an opportunity to specify a larger amount of specialized concepts [20]. Special importance for discourse analysis has the detection of similarities in the use of a certain vocabulary by different users [33; 39; 40]. Here, studies have figured out that in TEL the basic distinction can be extended to technical and non-technical disciplines in general [27; 28]. That means in concrete, contrary to scholarly education in technical disciplines which aims (more or less) at the processing of factual knowledge, learning processes in the non-technical disciplines tend to be discourse oriented.

6. CONCLUSIONS & OUTLOOK

More than in any technical discipline the success of TEL depends

on a careful engineering of multimedia artifacts and the related communication/collaboration features. Thus, the occurring media operations and knowledge sharing aspects involved in the learning process need to be fully understood. Only in combination it becomes possible to create TEL environments for professionals and scientists reflecting the nature of discourses in these domains. In this paper, we therefore presented a media theoretical approach to TEL. With this approach, we were able to synthesize media operations and knowledge sharing aspects involved in TEL.

The result of the media theoretical considerations has led to a novel learning environments providing custom-tailored services for learning communities. In order to achieve this, a key feature is the traceability of the complete discourse linked with any multimedia artifact. Thus, it is possible at any time to comprehend the context of multimedia artifact and to decide whether a statement can be considered as correctly understood. Thus, scholarly communication heavily depends on the discursive nature of knowledge creation and the versatile media in use.

Elsewhere, we also demonstrated the usefulness of MPEG-7 [23] for the processing of multimedia learning contents by capturing episodic knowledge inherent in multimedia stories and semantic knowledge of multimedia contents. Due to its easy to use user interfaces, users can now collaborate, exchange knowledge and thus learn anytime and anywhere by exchanging multimedia stories via a common repository.

Current research aims at measuring the learning success of multimedia learning contents created with. Therefore, we plan to embed user models based on standards like IMS LIP [22] or IEEE PAPI [21]. By doing so, we can investigate the multimedia reception process and identify success factors. Hence, we intend to use pattern based approaches to detecting frequently occurring learning behaviors. Thus, we will conduct a comprehensive cross-media analysis that might give us a deeper insight to understand media related impacts on learning processes.

7. ACKNOWLEDGMENTS

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