

XML-based Adaptation Framework for Psychological-driven E-learning Systems

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Abstract

E-learning systems grew to popular knowledge delivery systems until now. Several applications have already been implemented and many project initiatives have been started. Although such systems come with interesting advantages, there are still many unsolved problems. Enriching common learning content by applying multimedia did not meet the general expectation to decrease drop out rates of e-learners using such systems. Additionally, most e-learners complain about a "one-size-fits-all" philosophy, a resulting cognitive overload and consequently the lack of personalization of existing applications.

In this paper a user-centric approach is presented in order to improve the usability and acceptance, thus, making e-learning systems more successful. For this purpose psychological factors are integrated in an adaptable learning system which is based on meta data enriched learning objects specified and described in XML documents. General learning objects are transformed into personalized learning objects depending on the user profile and adaptation rules. Beside learning objects also layout and navigation through the content are adapted and personalized. An adaptation framework is introduced to show the interaction of the discussed concepts to fulfill the request for individualized learning systems.

Keywords

Digital learning environment, Intelligent learning environment, Personalized learning objects, Metadata for education, Learning technologies, Cognitive styles, XML, XSLT.

Introduction

E-learning is one of the most interesting trends in computer science and psychology. As it is meant as any form of learning that utilizes a network for delivery, interaction or facilitation, anytime and anywhere it allows people and organizations to keep up with rapid changes that define the Web and the global business. It is regarded as "a key strategy for maximizing human capital in the knowledge economy" (Hambrecht, 2001).

Despite these promises and although enormous amounts of financial investments have been spent for developing multimedia-rich e-learning courses, current e-learning systems lack in accompanying, guiding and motivating individuals. The question why people are frustrated, de-motivated and finally drop out has already been frequently posed (CHI, 2001). Finally, experts identified the necessity to make learning systems more user-centric. However, a successful answer how to reach this approach has not or only rudimentarily been delivered. The approach introduces individualized learning objects based on psychological factors such as cognitive styles, learning strategies or skills, adapted according to individual user profiles. Personalized learning objects are dynamically generated by applying the possibilities of XML (eXtensible Markup Language) (W3C, 2001) and XSLT (eXtensible stylesheet language transformation) (W3C, 1999) which are used to describe user profiles, general learning objects, adaptation rules and personalized learning objects. In addition, with XML and XSLT beside learning objects also layout and navigation through the content are adapted and personalized.

The paper is organized as follows: chapter 2 illustrates related work in the cognitive field, chapter 3 describes several psychological aspects relevant for learning systems in more detail. Section 4 presents implementation aspects such as how to perform adaptation, how to integrate learning knowledge and finally, introduces an XML-

based framework for improving e-learning systems. Section 5 concludes the paper and describes further research activities.

Related Work

Interactive multimedia provides the stimulation for students to be actively involved in their learning. They can be encouraged to think for themselves to gain a better understanding of the content material. Despite the promises, if such sophisticated systems are not well designed they can create problems in terms of the cognitive demands they place upon the learner and by inadequately supporting changes in individual and group working practices (Preece et al., 1992).

To improve the efficiency of learning, learning systems can be designed in a way to cope with different learning styles and goals of students. Learning systems can offer several features to compensate the differences in learning outcome caused by various learning styles. The differences between good learners and bad learners, or between experts and novices, usually lie in their use of learning strategies.

In the 1960s, Witkin introduced the term “cognitive style” (learning style) to describe the concept that individuals consistently exhibit stylistic preferences for the ways in which they organize stimuli and construct meanings for themselves out of their experiences (Ayersman et al., 1995; W3C, 2001). Cognitive styles include variables within a single dichotomy such as global-holistic versus focus-detailed, field-dependent versus field-independent or right-brained versus left-brained. Learning style is a biologically and developmentally imposed set of personal characteristics that make the same teaching/learning strategy effective for some and ineffective for others. Learning styles refer to an individual's characteristic mode of gaining, processing, and storing information (Kogan, 1971).

In the design of interactive multimedia material, a more enriched learning experience occurs when learners are presented with different styles of learning in both content and teaching style. If learners are able to determine their own pathway in selecting the information available to them, in the manner that best suits to their own learning style, then the whole learning process may be more efficient. Research in instructional design needs to investigate questions about learners and their characteristics in order to determine what type of delivery instruction is best for which type of learner in what type of environment (Orr et al., 1992).

Although considerable research has been conducted on learning strategies and cognitive styles separately, few studies have considered both cognitive styles and learning strategies together. Individual differences of learners may play an important role in the use of learning strategies. It is necessary to consider the impact of cognitive styles on the use of learning strategies (Jonassen, 1988; Liu et al., 1994).

Several existing systems aim to link specific learning strategies with cognitive processes. For this, learning strategies are embedded in some instructional activities, and these instructional activities correspond with learners' cognitive processes. For example, drill and practice is designed to provide a practice environment for learning declarative knowledge. Tutorials are designed to provide guidance and intervention for procedural knowledge.

Research indicated that embedding learning strategies in a computer program was effective (Barba, 1993; Thornburg et al., 1991). Learners in a group which had learning strategies embedded inside the program not only performed better than those without learning strategies embedded, but also retained these strategies after two months (Thornburg et al., 1991). Additionally, e-learning benefits will be heightened when e-learning is dynamically personalized to both groups and individuals. In this case the same courses will be presented with different content variations to different virtual groups. As learners move through the content, the course content and flow will alter. Much of this can be done now by a few systems, but it can be expected that over the next two years, these features will become more robust and will move into the mainstream. All of this personalization will integrate LMS (learning management system) and LCMS (learning content management system) more deeply so that RLOs (reusable learning objects) can be tracked and managed more effectively. An RLO is a discrete reusable collection of content used to present and support a single learning objective (Jacobsen, 2001).

The intelligence of a system also includes the knowledge on the course space translated into learning objectives and on the organization of the didactic resources. The knowledge of these three dimensions (cognitive style, knowledge space and didactic resources) allows the system to provide adapted content fitting to the needs of each individual student (Souto et al., 2002).

The instructional content adaptation to the student’s individual characteristics implies that a learning system has to: (i) recognize the cognitive patterns of each student’s learning and its pedagogical implications, (ii) know the training knowledge space being proposed, (iii) know the instructional material organization, and (iv) be able to dynamically generate the best suited selection and sequence for each student in a particular course stage. These four requirements shape an educational model. The approach presented in this paper refers to these requirements and provides an adaptable learning system based on meta data enriched learning objects.

Psychological Aspects

To keep a common understanding of what is meant here by the terms “psychological aspects” or “psychological factors” the following paragraphs introduce appropriate concepts that affect people’s individual thinking and behaviors. The presented aspects are cognitive styles, learning strategies, skills, learning modalities and sequencing of instructions.

Cognitive Styles

According to Kearsley, cognitive (or learning) styles describe a person’s typical mode of thinking, remembering or problem solving. Research began in the early 1950’s and literature shows that more than nineteen cognitive styles such as holistic/analytical, verbal/imagery or field dependence versus field independence have been identified since then. According to Witkin, field dependence-independence is value-neutral and is characterized as the ability to distinguish key elements from a distracting or confusing background (Witkin et al., 1977). Cognitive styles are considered as bipolar dimensions whereby having a certain cognitive style determines a tendency to behave in a certain manner. It influences attitudes, values, degree of social interaction or shortly the preferred way a person processes information. The following table describes a set of cognitive styles and their impacts on learning as presented in (Dufresne et al., 1997; Hsiao, 1997; Kearsley, 2002).

Table 1. Cognitive Styles – Impacts on learning

Cognitive Style	Description	Impact on learning
Holistic	tend to see a situation as a whole;	prefer to learn in a hierarchical fashion;
Analytical	tend to view a situation as a collection of parts and often stress only one or two aspects at a time;	prefer to learn in a sequential manner;
Verbal (sensory preferences)	tend to be external and stimulating;	
Imagery	tend to be internal and passive;	
Field Independent	tend to approach things analytically; are likely to either analyze a field when it is organized or impose a structure on a field when it lacks organization of its own; are prone to be impersonal; tend to have self-defined goals and reinforcement;	tend to learn more under conditions of intrinsic motivation (self-study); may themselves provide the mediating structural rules as analyzing and structuring;
Field Dependent	tend to approach things in a global way; are interested in interacting with other people; prefer to be guided and to rely on external referents;	tend to be better at learning and remembering social material and learning it in a social way; tend to adopt a passive approach in learning and problem solving;

The presented set of cognitive styles gives an impression of how different people are in absorbing, processing and retaining information. These cognitive differences affect additionally the use of learning strategies as introduced in the chapter Related Work.

Learning Strategies

Learning strategies describe techniques as illustrated in (Kearsley, 2002) that students use to learn, either methods to improve memory for better learning or test-taking strategies. They subsume two aspects: first, cognitive strategies and second, metacognitive strategies (Hsiao, 1997).

Cognitive strategies refer to plans that are used by students to acquire, retain and retrieve different kinds of knowledge. These activities range from acquiring, selecting and organizing information to rehearsing learning material or relating new material to information in memory. Adjunct questions, reflective questions, summarization, note taking, keyword method, pegword method, method of loci, advance organizer or concept mapping have been identified as effective strategies to improve learning.

Methods for “learning to learn” are described as metacognitive strategies. All activities such as checking, planning, encoding, reviewing and evaluating with the aim to monitor the learning process. A set of cognitive strategies i.e. consisting of concept mapping, advance organizer and any method relevant for monitoring activities can be considered useful for meta cognition on learning. The ability to cope with learning processes enables students on the one hand to improve their learning and on the other hand to become more independent learners.

Skills, Learning Modalities

Improving to learn also assumes that individual learning skills have to be identified. Skills can range from skills such as speaking foreign languages to skills like reading, writing or adapting gained information to knowledge. Beside cognitive styles, which describe the way people process information, individual differences in abilities – also considered as modalities – describe students’ peak or high performance in learning. Abilities are unipolar, they range from zero to a maximum value. Consequently, students might prefer one kind of ability that may be beneficial but also have other intelligences to a certain extend. Most well-known is probably Howard Gardner’s theory of Multiple Intelligences. He has identified seven different intelligences illustrated in (Conner et al., 1996) that should be considered for each individual student to improve their learning: verbal-linguistic (sensitive to the meaning and order of words), musical (sensitive to pitch, melody, rhythm, tone), logical-mathematical (able to handle chains of reasoning and recognize patterns and order), spatial (perceive the world accurately and try to re-create or transform aspects of that world), bodily-kinesthetic (able to use the body skillfully and handle objects adroitly), interpersonal (understand people and relationships), intrapersonal (possess access to one’s emotional life as a means to understand oneself and others).

Sequencing

There are a number of theories that describe the order and organization of learning activities or sequencing of instruction. As sequencing of instruction influences the way information is processed and retained as mentioned in (Kearsley, 2002) the kind of building up sequences may be strongly affected by an individual cognitive style. The theories suggest simple-to-complex sequences, goal-directed sequences, linear sequences, letting students form their own learning sequences or adapting instructions to the experience or interest of learners.

Implementation Aspects

The previous chapters described research and theory behind psychological aspects. This chapter will present the impacts of combining cognitive styles, learning strategies, skills and sequencing on developing learning systems. To provide successfully psychological aspects in learning systems their common modules should be firstly identified. Parts in a learning system are the knowledge base providing necessary content such as learning lessons and courses, student administration for accompanying and monitoring success or failure, authoring tools for managing new content provided by teachers or trainers and the pedagogical module that currently can be primarily regarded as a way for instructors to build up learning sequences or courses.

As most available systems are not able to give a strategic answer to the current call for more user-centric systems, it seems appropriate to identify a possible way to overcome this barrier. The next three chapters introduce a methodology that bases on the integration of psychological factors and learning objects to propose new implementation aspects for an adaptation framework.

Adaptation – What and How?

Adaptation in learning systems is two-fold: on the one hand, there is the question of what can be adapted in such environments and on the other hand, there should be given an answer to the question of how the presented psychological factors influence the proposed adaptation. According to Brusilovsky, there are three kinds of adaptation in hypermedia systems: first, content, second, layout and third, navigation (Brusilovsky, 2001). In case of learning system, a specialization of hypermedia systems, the proposed adaptation mechanisms request further investigations. Figure 1 shows considerable psychological aspects and impacts on an adaptable learning system.

Additionally to hypermedia systems, content adaptation in learning systems not only depends on a student's preferences, what he would like, but also on his personal skills what he can achieve. Lessons and courses, particularly the severity of learning material needs to be adapted according to the student's abilities and current learning progress. Individual skill gaps should be identified by the system and content delivery has to be adapted to overcome these gaps step by step without losing the student. Lessons able to teach writing and reading skills should for instance be firstly presented to students who are weak in these cultural skills before they are confronted with a mass of complicated and difficult courses.

The decision for layout has primarily been the task of computer scientists implementing information systems or in the Web era the success of Web designers producing creative applications. Unfortunately, this cognitive overload interrupts people having different intelligences, abilities and ways to process information. It seems obvious to provide students who are visually strong with images, graphs and tables additionally to common text. The visualization and animation of content, combination of text, sound, video and images is heavily influenced by the kind of students' learning modalities.

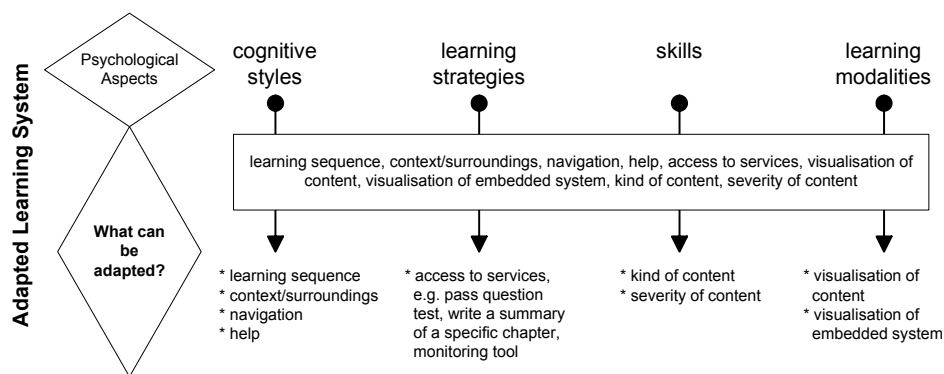


Figure 1. Impacts of psychological factors in a learning system

Navigation adaptation in learning systems is strongly effected by learning sequences, which describe the order and organization of learning activities. As sequencing of instruction affects the way information is processed and retained, cognitive styles seem to be responsible for determining an individual's request for the kind of sequence. Analytical people for instance prefer to learn in a sequential manner and may be supported by a linear sequence of instruction. In contrast to holistic persons who prefer to learn in a top-down manner to keep a global picture which could be encouraged through a simple-to-complex sequence. Furthermore, field independent individuals who are more self-motivated and less interested in a structure to the subject might be supported from time to time through content-different lessons to keep their attraction and motivation.

Field dependent or holistic people favor to learn in a global way, field independent persons however tend to learn more analytically being interested in single factors at one time. The support of detailed chunk of information without connection to a learning domain, chapter or lesson will probably unsettle field dependent or holistic persons. Therefore, the surrounding of an adaptable learning system should at least provide a possibility to gain access to context data either through hyperlinks or more sophisticated through illustrating students' current position, learning progress and available actions that may be taken.

As field dependent persons prefer social contacts and tend to learn in social ways services such as mailing lists, chat rooms or forums seem to be desirable for those learners. These services may in contrast be disturbing for field independent people who are prone to be impersonal. Learning systems should therefore be competent

enough to enable or disable access to these services according to individual requirements. Further services to support individual learning strategies may also be adapted with respect to student's cognitive styles.

Respecting individuals' cognitive styles are without any doubt capable of improving their learning performance and making them happier in passing learning lessons. However, there remains the desire to go beyond one's individual learning horizon, to strengthen one's weaknesses and to broaden one's cognitive styles. This will be achieved by conflicting students from time to time with lessons, surroundings or navigation abilities, which are not meeting their individual styles. Nevertheless, one could argue about the necessity of psychological aspects in learning systems, why considering individual differences at all? The answer to this objection is easily offset because the identification of individual cognitive differences enables at all to distinguish between matching styles for better learning as well as communication and putting place for conflict for challenging or unsettling experiences (Bostock, 1998).

Learning Objects

Learning objects describe any chunk of learning information, digital or non-digital, such as an image, text, video, educational game or sound files. The aim of those entities is to provide a tremendous set of learning knowledge that once developed can be exchanged among organizations, and be used to build up several individual lessons and courses (McGreal et al., 2001). The key factor for this flexibility is not performed by the physical learning object itself but by its standardized description or more precise its metadata specification. As cited in IEEE (IEEE, 2002) Learning Object Metadata (LOM) specification:

A metadata instance for a learning object describes relevant characteristics of the learning object to which it applies. Such characteristics can be regrouped in general, life cycle, meta-metadata, educational, technical, rights, relation, annotation, and classification categories.

During the development of a learning system, especially because single organizations call for individual approaches without loosing access to available knowledge resources, this standard simplifies the integration of learning objects. The simplification is supported because each learning system can emphasize this metadata information that seems to be most important in certain circumstances, e.g. the diversity of cultural and lingual contexts, and however may make extensive use of all available learning objects.



Figure 2. Proposed extension of the Learning Object Metadata specification

The current version of the learning object metadata specification supports educational description such as if an object requires active (pass a question, enter some text) or passive (read a text) student interaction. Nevertheless, it lacks in providing psychological factors as described here although its extensibility would give enough room for such an integration. The advantage of specifying these aspects in the LOM standard enables to select suitable objects for any individual student for any kind of learning system being built on the metadata specification. Figure 2 illustrates the current LOM version and its proposed extension.

After ensured that single learning objects are aware of their psychological strengths a convenient framework being capable of processing this kind of information for cognitive adaptation will be introduced in the following chapter.

Adaptation Framework

The approach presented in this paper primarily focuses on the methodology of adapting learning material and the learning environment with respect to cognitive individualities of single students. The system has therefore to provide two different kinds of data: first, the learning knowledge in form of learning objects equipped with psychological information (as presented in chapter 4.2) and second, a set of adaptation rules to determine the mapping between a student's individualities and the impacts on the kind of response delivered to this person (as introduced in chapter 4.1). To meet this challenge, Figure 3 illustrates an overall picture of the proposed workflow and adaptation mechanisms.

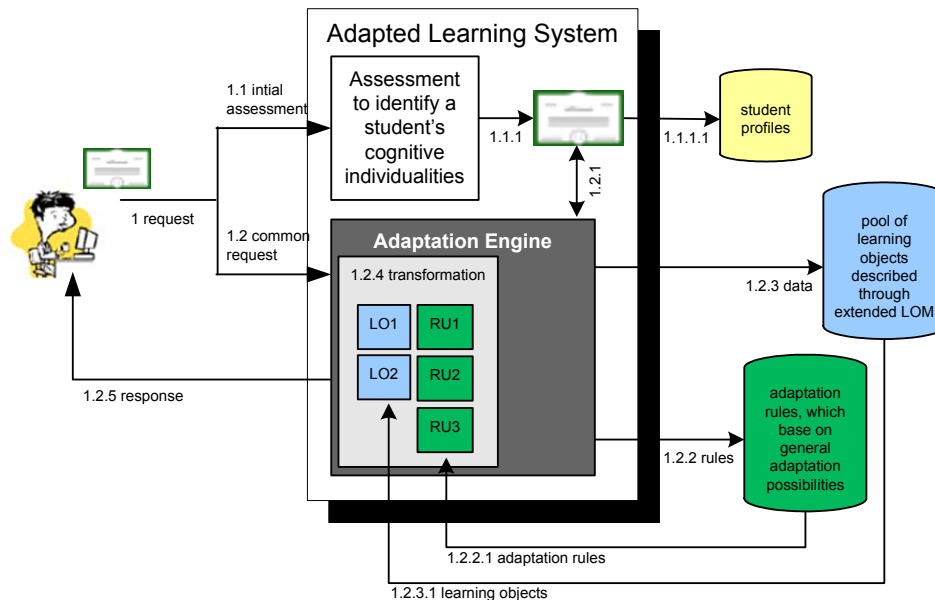


Figure 3. Framework for adapted learning systems

Adaptation Methodology

In an initial phase (1.1 initial assessment), the student is asked for passing an assessment center to identify his individual psychological factors such as cognitive style, learning modalities or skills, shortly defined as student profile. The complexity of this center can range from simply questioning to more sophisticated cognitive tests. In the context of this paper however, we assume that the identification of students' profiles is in any form existent. The system keeps the profile in the local memory (1.1.1) and additionally, stores it in the profile database (1.1.1.1) for further interactions.

After the identification of a student's cognitive profile, any requirements requested by the student will be channeled directly (1.2 common request) to the system. More precisely, the invoked component is named Adaptation Engine. The engine requests the current student profile necessary for performing adaptation from the system's local memory (1.2.1). The awareness of the current profile enables to select on the one hand, an appropriate set of adaptation rules from the database (1.2.2 rules) and on the other hand, a matching set of learning objects from the knowledge database (1.2.3 data). Both databases retrieve the results to the adaptation engine (1.2.2.1 adaptation rules, 1.2.3.1 learning objects) in a convenient format such as XML. The adaptation rules may specify the type of the selected learning objects and how the learning system has to be adapted, illustrated in the following example:

It is assumed that the current student's profile defines a field dependent person who prefers visual learning modality. The delivered adaptation rules, for instance, determine that proposed learning objects have to support either field dependent style or visual representation capabilities (LO1, LO2). The rule (RO1) may therefore have an influence on the selection of learning objects, which have to be proper enough to support in this case these two psychological aspects. An additional rule (RO2) may define that field dependent persons have to be supported with access to a chat room tool, mailing lists and to be provided with a convenient context description.

There might be another rule (RO3) that specifies the visual representation of the interface to the learning system explicitly adapted to field dependent, visual persons.

The combination of learning objects and adaptation rules can then be handled by the engine through techniques such as common programming logic or XSLT (1.2.4 transformation). XSLT is an effective way to produce adapted output in form of HTML (hypertext markup language), WML (wireless markup language) or XML, which can be directly responded to the student asking for a specific learning lesson, which is finally embedded in a learning system optimized for individual cognitive requirements (1.2.5 response).

XSLT Adaptation Process - from a user profile to individualized output

The power of XSLT enables to solve similar problems by following one kind of XSLT employment. During the last years common best-practices according to the implementation of XSLT have been developed and design patterns came into existence. Design patterns are a powerful reuse mechanism to provide a standard solution, and a common language about a recurrent problem. One of those patterns in XSLT are rule-based stylesheets. Rule-based stylesheets consist primarily of rules describing how different features of the source document should be processed. They form the essence of the XSLT language and therefore build an optimal basis for the introduced adaptation mechanism. As specified in (Kay, 2001) they are "at their most useful when processing source documents whose structure is flexible or unpredictable and are very useful when the same repertoire of elements can appear in many different document structures".

```

<userprofile>
  <username>donald</username>
  <cognitivestyle>
    <theory><expert>Witkin</expert><title>Field
Dependence/Independence</title></theory>
    <characteristics>
      <name>field-
independent</name><occurrence><fact>>false</fact></occurrence>
      <name>field-dependent</name>
    <occurrence><fact>true</fact></occurrence>
    </characteristics>
  </cognitivestyle>
  <learningmodality>
    <theory><expert>Howard Gardner</expert><title>Multiple
Intelligences</title></theory>
    <characteristics>
      <name>spatial</name><occurrence><percentage>80</percentage></occurrence>
    </characteristics>
  </learningmodality>
</userprofile>

```

Figure 4. User profile in XML

In this context, single XSLT documents represent the desired result for a certain part of the requested Web page. The outcome is therefore governed through XML documents hosting user profiles, adaptation rules, learning objects, and adaptation possibilities such as access to services or description of the learning context. Figure 4 introduces exemplarily a user profile as XML document.

Adaptation rules are selected according to a single user profile. As illustrated in Figure 1 proposed single psychological factors influence the outcome of the learning system in different ways. Consequently, the selection of those adaptation rules, learning objects or learning environment necessities has to be based on the implementation of filter strategies or dependence rules.

Dependence rules can either follow more simple approaches such as rule-based techniques or more intelligent solutions like case-based reasoning. Additionally, to keep high flexibility in extending adaptation possibilities each psychological aspect and its impacts are clustered and encapsulated in single components.

Following our previous example, selected adaptation rules are filtered from the existing pool with respect to user profile data such as cognitivestyle/fielddependent/true, learningmodality/spatial/80% or learningmodality/linguistic/20% (means that the user "donald" strengthens his visual intelligence, and favours

linguistic abilities only to a certain extend). A single rule determines thereby one single instruction. Remembering and employing Brusilovsky's thesis, a rule may influence: (i) content, (ii) layout and (iii) navigation. Figure 5 shows some rules influencing layout and navigation in XML (no. 1 and no. 2) and introduces learning objects represented according to LOM specification (no. 3 and no. 4). All rules are interpreted by the XSLT adaptation mechanism. Figure 6 introduces XSLT exemplarily for available XML input. According to the rule-based approach there may be a single XSLT for any available XML element. This fragmentary pool allows to define the outcome for a specific element without explicit knowledge of how to pull them together to form different output and vice versa.

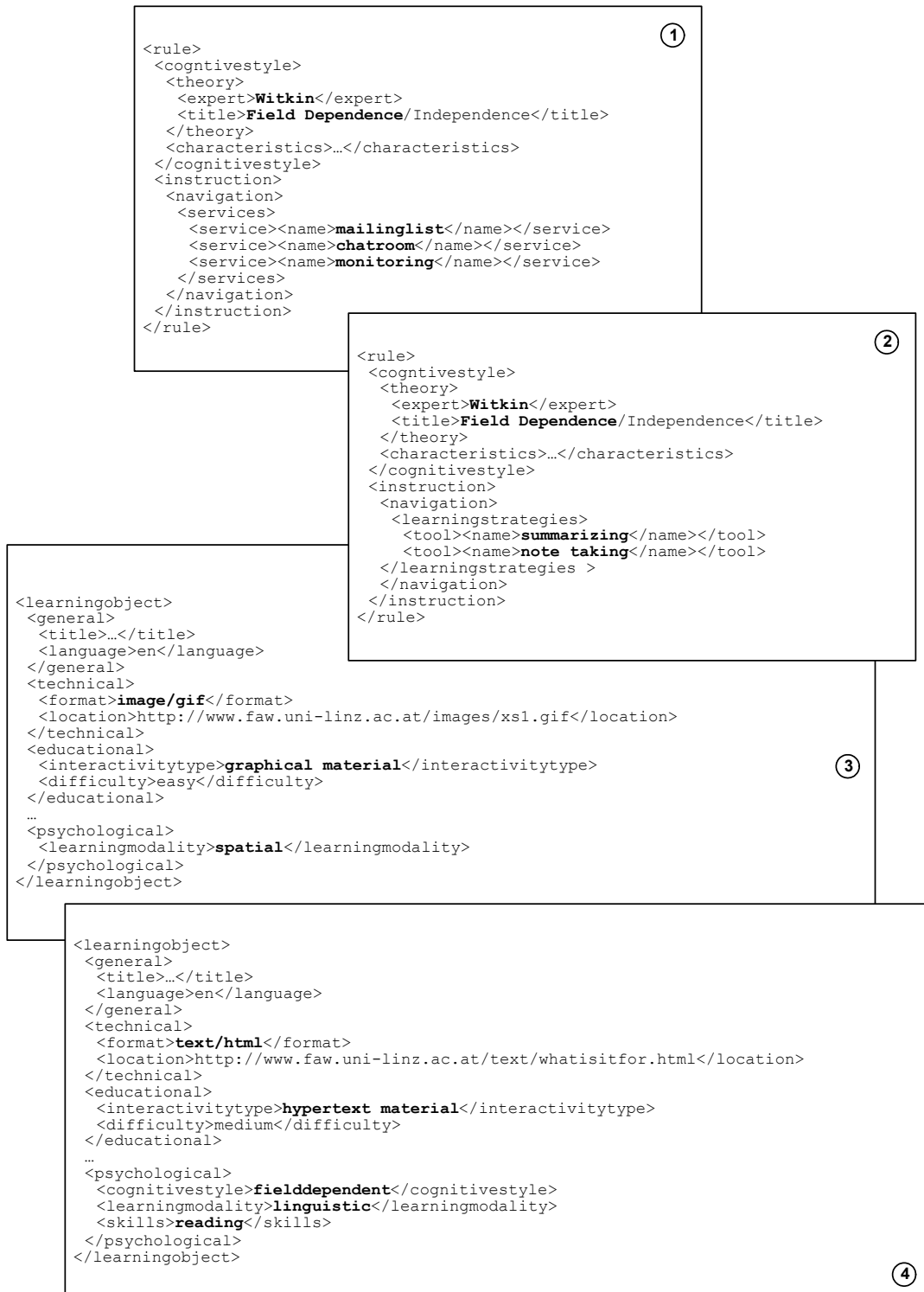


Figure 5. Adaptation rules, learning objects in XML

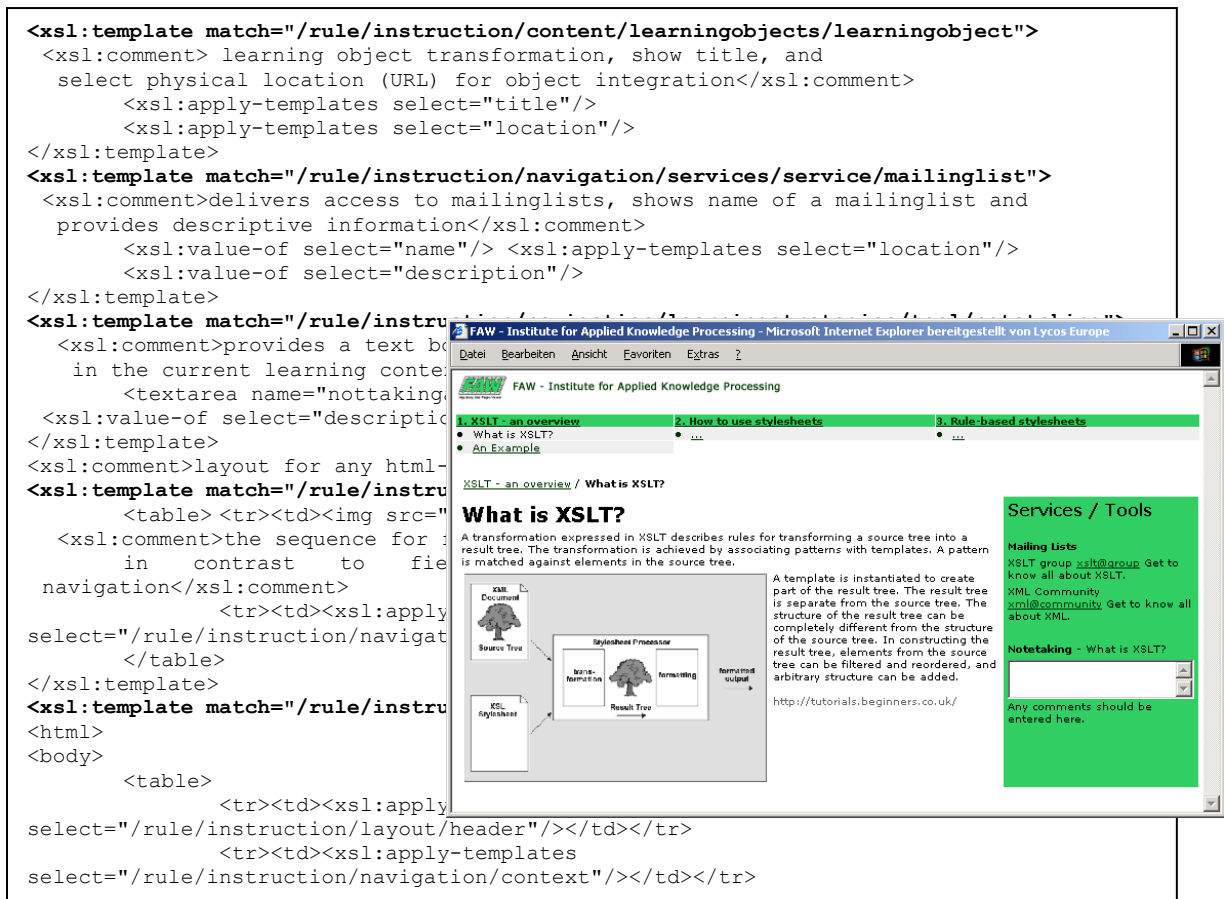


Figure 6. XSLT transformations by example

All filtered rules and learning objects are then interpreted through XSLT stylesheets following the rule-based design pattern approach. As result of the transformation each single user will gain his individual, personalized learning environment dependent on his cognitive style, learning modalities, skills or learning strategies, according to his current user. Figure 7 presents the specific outcome for the proposed example. Limitations of common learning systems currently present in the Web namely, offering learning modules in standard fits-for-all-interfaces can be avoided with the introduced approach. Additionally, users will benefit because at any moment the system is capable of treating single persons as individuals having a specific way of information processing and certain abilities.

Conclusion and further research

In this paper an approach for adapting e-learning systems to psychological factors has been presented, whereby the primary aim was to enable more user-centric opportunities. The method is based on research in the field of cognitive science, the learning object metadata specification provided as IEEE standard and the introduction of adaptation rules combining cognitive aspects with services available in e-learning systems. Personalized learning objects are dynamically generated by applying the possibilities of XML and XSLT which are used first, to describe user profiles, general learning objects, adaptation rules, and personalized learning objects and second, to adapted and personalize layout and navigation through the content. Finally, an adaptation framework has been introduced to show how all the illustrated concepts might work together to fulfill the request for individualized e-learning systems.

Further research in this field will be investigated to detail the semi-structure of adaptation rules, to extend the LOM standard with psychological aspects and to integrate assessment center methodologies for identifying individual student profiles.

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    <td class="main"><a href="url">
    <span class="sequence">2. How to use stylesheets</span></a></td>
    <td class="main"><a href="url">
    <span class="sequence">3. Rule-based stylesheets</span></a></td>
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<td class="submenu"><a href="url"><li/>...</a></td>
<td class="submenu"><a href="url"><li/>...</a></td>
<tr><td class="submenu"><a href="url"><li/>An Example</a></td>
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</table>
</td>

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Figure 7. A single transformation result in HTML

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