University of Hradec Králové

Faculty of Informatics and Management

# DISSERTATION

2016 Ing. Aneta Bartůšková

**University of Hradec Králové**

**Faculty of Informatics and Management**

**Center for Basic and Applied Research**

# Smart Web User Interfaces for Course-based and Repository-based Systems

Dissertation

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Hradec Králové 2016

Acknowledgement:

I would like to thank my supervisor doc. Ing. Ondřej Krejcar, Ph.D. for valuable insights and recommendations for this dissertation and doctoral studies in general.

Declaration:

I declare that I worked on this dissertation independently, with the use of cited literature and other sources.

In Hradec Králové  2016 Ing. Aneta Bartůšková

**Annotation**

**Title: Smart Web User Interfaces for Course-based and Repository-based Systems**

This dissertation thesis is focused on smart solutions in the context of web-based user interfaces. By "smart" is meant better interaction between the user and the system, both more pleasant and efficient. The success of any interaction on web is influenced mostly by design of the website. Therefore better usability - as one of the two principal dimensions of design - is the main goal of the proposed interfaces. The research in this dissertation is based on educational systems, which were divided into the course-based systems and repository-based systems. This dissertation thesis presents new interfaces for both these types and includes also the hybrid approach.

**Anotace**

**Název: Chytrá webová uživatelská rozhraní pro systémy strukturované jako kurz a jako úložiště**

Tato disertační práce se zabývá chytrými řešeními v kontextu webových uživatelských rozhraní. Výrazem "chytrý" je vyjádřena lepší interakce mezi uživatelem a systémem, a to jak pro uživatele příjemnější, tak i více efektivní. Úspěch jakékoli interakce na webu je ovlivněn především designem webu. Tudíž lepší použitelnost - jako jedna ze dvou primárních dimenzí designu - je hlavním cílem navrhovaných rozhraní. Výzkum v této disertační práci je založen na výukových systémech, které byly rozděleny na strukturované jako kurz a strukturované jako úložiště. Tato práce představuje nová rozhraní pro oba tyto typy a zahrnuje také hybridní přístup.

## The list of abbreviations

| | |
|---|---|
| ADL | Advanced Distributed Learning |
| AEH | Adaptive Educational Hypermedia |
| AICC | Aviation Industry CBT Committee |
| AJAX | Asynchronous JavaScript and XML |
| API | Application Programming Interface |
| CMF | Content Management Framework |
| CMS | Course Management System |
| | Content Management System |
| CRUD | Create, Read, Update and Delete |
| CSS | Cascading Style Sheets |
| GPS | Global Positioning System |
| HCI | Human-Computer Interaction |
| HTML | Hyper Text Markup Language |
| IEEE | Institute of Electrical and Electronics Engineers |
| IMS | Instructional Management System project |
| ISO | International Organization for Standardization |
| LATCH | Location, Alphabet, Time, Category and Hierarchy |
| LCMS | Learning Content Management System |
| LMS | Learning Management System |
| LO | Learning Object |
| LOM | Learning Object Metadata |
| LOR | Learning Object Repository |
| MOOC | Massive Open Online Course |
| OER | Open Educational Resources |
| PHP | Hypertext Preprocessor |
| PDF | Portable Document Format |
| PPT(X) | PowerPoint Presentation |
| SCORM | Shareable Content Object Reference Model |
| SLO | Sharable Learning Object |
| SQL | Structured Query Language |
| SWBE | Semantic Web-Based Education |
| UX | User Experience |
| VLE | Virtual Learning Environment |

# Contents

# 1 Introduction

The title of this dissertation is "Smart Web User Interfaces for Course-based and Repository-based Systems". The web user interface presents a layer between a user and a web-based system. Characteristics of this layer, such as its graphics or structure, depend on design decisions. Consequently, web design has a great impact on user´s interaction with the website, his experience and behaviour. Usability and aesthetics are considered as two principal dimensions in design (Tractinsky et al., 2000; Hartmann et al., 2008). Furthermore, usability is considered a critical issue on the web that determines either the success or the failure of a company (Tezza, 2011).

The adjective "smart" in this dissertation means those solutions, which are not just usable, which is the basic presumption of successfully using any system. Smart solutions, in the context of web-based user interfaces, mean generally better interaction between the user and the system, both more pleasant (subjective measure) and more efficient (objective measure). The presumptions for this interaction are based on design principles and a range of user-related concepts such as user experience, user-centered design, user preference and evaluations of usability, aesthetics and content. As stated by Hassenzahl and Tractinsky (2006), focus of user experience is on how to create outstanding quality experiences rather than merely preventing usability problems.

Research in this dissertation is focused on smart design of web-based user interfaces, especially their organization and navigation. Proposed approaches are applied specifically on educational systems; however most of the presented solutions can be used in various other web-based systems. Course-based and repository-based systems are regarded as two major types of educational web-based systems. Course-based systems are represented by LMSs and MOOCs, while repository-based systems inlude LORs / LCMSs or digital libraries. The differences between these two identified types are especially in the architecture, content management and information retrieval. Course-based educational systems guide the user through the content; usually they offer recommended sequence of actions. Systems based on repositories usually contain a collection of resources which can be browsed, filtered or searched, often in a form of standardized learning objects.

# 2 Objectives and structure

The objective of the dissertation was originally defined as "an improvement of design of web-based educational systems". This goal was however too broad and abstract to accomplish in this work, therefore delimitation was needed first to specify the objective. This was achieved by thorough literature review, followed by identifying limitations of existing educational systems and organizing existing knowledge about design. Design-related concepts were consequently structured into the framework of design requirements for web-based interfaces. This framework was used to identify major research areas, which are dealt with in this work, however it is also considered as one of the contributions of the dissertation. The framework presents usability and aesthetics attributes, logically sorted into five main groups of design requirements.

The main goal was then specified to "the enhancement of web-based interfaces regarding their organization and navigation". The proposed approaches are demonstrated on educational systems; however they are applicable also for other web-based systems, which share some of the characteristics with identified types of systems, e.g. knowledge management systems. Based on the analysis of existing solutions for web-based education, two directions were considered - interfaces for course-based systems and interfaces for repository-based systems. Finally, the hybrid solution is also considered.

The structure of this dissertation is as follows. Chapter 3 "State of the Art" presents literature review and research in relevant fields of study. Individual goals of the dissertation are formed by chapter 4 "Problem definition". Limitations and shortcomings of commonly used systems and design approaches are identified in this chapter. These limitations are used as a motivation for new proposals. Chapter 5 "Theoretical proposals" is regarded mainly as the author´s contribution in theory and includes also already mentioned framework of design requirements. Chapter 6 "Proposals of interfaces" contains designs based on the author´s research. Three main proposals emerged from the conducted research; smart interface for course-based systems, smart interface for repository-based systems; and smart interface for hybrid systems with personalization support. The first two proposals are discussed in Chapter 6 in relevant subchapters. The final proposal combines the previous two and presents ideas not only about the interface but also the underlying system. It was therefore placed into the standalone Chapter 7 "Proposal of web-based educational system".

# 3 State of the art

## 3.1 Design of web user interfaces

Design can be understood in several meanings, differentiating in scope and application area. In this treatise, design is regarded as a way of presenting content in web-based user interfaces. This part of design is often named as a visual design (e.g. Vai & Sosulski, 2011), visual display (e.g. Horton, 2012b) or use of visuals (e.g. Clark & Lyons, 2011). However design in this meaning is not all about graphics; it includes organization, navigation, consistency and other concepts. This section presents an introduction to web design attributes (usability, aesthetics and content) and other concepts (user experience, user preference, user evaluation) in human-computer interactions.

### 3.1.1 User-related concepts

User experience (UX) is becoming increasingly popular in the field of human-computer interaction (HCI). User experience can be perceived as a broader concept, which includes traditional usability, beauty, overall quality and hedonic, affective and experiential aspects of the use of technology (Hassenzahl and Tractinsky, 2006; van Schaik & Ling, 2008). The process of improving user experience integrates established web design guidelines and experiential knowledge related to user behaviour, abilities and emotions.

HCI research originally focused almost exclusively on the achievement of behavioural goals in work settings (Hassenzahl and Tractinsky, 2006). This task-oriented narrow focus was apparent also in related user preference research. User preference reflects a user´s choice from alternative websites and a user´s decision about his behaviour on a chosen website (Lee & Koubek, 2010a). Earlier studies suggested that this influence is dependent mostly on usability of the website (e.g. Keinonen, 1997; Nielsen, 1993). More and more of the later studies however put a greater value on website´s aesthetics or hedonic value (e.g. Schenkman, & Jönsson, 2000; Lavie & Tractinsky, 2004; Robins & Holmes, 2008; van Schaik & Ling, 2009; Tuch et al., 2010; Wu et al., 2011). This fact is in accordance with UX expansion. User experience is about technology that fulfils more than just instrumental needs in a way that acknowledges its use as a subjective, situated, complex and dynamic encounter (Hassenzahl and Tractinsky, 2006). In contrast to previous approaches, UX would focus on how to create outstanding quality experiences rather than merely preventing usability problems (Hassenzahl and Tractinsky, 2006). However it is important to keep in mind that usability problems need to be dealt with first. Unsolved usability issues would hinder the efforts placed in improving user experience.

Usability and aesthetics are widely researched aspects of design in HCI (e.g. Tuch et al., 2012; Lee & Koubek, 2010b; Hassenzahl, 2004). These concepts are considered as two principal dimensions in design (Tractinsky et al., 2000; Hartmann et al., 2008). Some studies consider also content or information quality as another dimension (e.g. de Angeli et al., 2006; Bartuskova & Krejcar, 2013). It is however apparent, that aesthetics, usability and content can be taken separately only to a certain degree. They are all present in the website, they have an influence on each other and they are all incorporated in overall user preference (Bartuskova & Krejcar, 2014b). There is no established theory, which would specify what exactly on websites is presented by usability, aesthetics and their intersection.

There are however many studies, which investigate a connection between usability and aesthetics on websites or generally in human-computer interactions (e.g. Lee & Koubek, 2010b; Hartmann et al., 2008; Tuch et al., 2012; Hassenzahl, 2004; Ben-Bassat et al., 2006). There is certainly a connection between these two aspects. Previous studies have shown that subjective evaluations of usability and aesthetics are correlated (e.g. Tractinsky et al., 2000; Lavie & Tractinsky, 2004; Hassenzahl, 2004; van Schaik & Ling, 2009). It is interesting, that quite often objective usability metrics are not in accordance with user preferences. Lidwell et al. (2010) stated that the designs that help people perform optimally are often not the same as the designs that people find most desirable. The question is, which designs should be preferred - those which perform better or those who are liked more by their users. The answer certainly greatly depends on the type of particular website (or web-based system) and its purpose.

Lee and Koubek (2010b) were comparing an influence of the mode and context on perceived usability and aesthetics and consequently on user preference in their research. Their results show, that before use of the website, user preference was mainly influenced by aesthetics (or visual appeal), after use was the preference influenced by usability as well as aesthetics. Recent research of Tuch et. al. (2012) showed that aesthetics has no influence on perceived usability of the website, but on the contrary, the usability has an influence on perceived aesthetics after use of the website. Our own research, based on the evaluation framework for user preference research, confirmed that changes in usability and content quality reflected significantly on aesthetics evaluation (Bartuskova & Krejcar, 2013).

### 3.1.2 Usability

Usability can be taken as an objective construct (precise measurements of user performance) or subjective (perceived usability). Subjective measure can be understood as a user evaluation of system´s usability - how easy was working with the system, if they would use it again, if they feel that the system was easy to use etc. Objective measurements are for example the task time, number of errors or severity of the errors during fulfilling tasks on the website. This division is similar to another two concepts: pre-use usability, which is perceived usability of the interface before use, and user performance as a result of user´s activities on the site (Lee & Koubek, 2010).

The standard ISO 9241-11 defined usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” (ISO, 1998). Most widely used method for measuring usability is user testing, also an inspection and an inquiry (Fernandez et al., 2011). Impact of usability is being researched in various ways, e.g. by manipulating information architecture (e.g. Tuch et al., 2012) or disorganizing items and use of confusing labels (e.g. Lee & Koubek, 2010b).

As was already indicated, there is not conformity among various studies, which aspects are included in usability. One study presents as usability criteria: ease of use, readability, productivity, content quality, completeness or relevance (Spool et al., 1998). Other extensive research includes consistency, navigability, supportability, learnability, simplicity, interactivity, telepresence, credibility, content relevance and readability (Lee & Kozar, 2012). According to the author´s opinion, content should create a separate category, along with its attributes such as content quality, content relevance or completeness. Usability aspect of websites should be limited to ease of use according to layout, navigation, affordances, readability and similar concepts. Usability is also a very important quality criterion for e-learning systems (Gasparini et al., 2010).

### 3.1.3 Aesthetics

Aesthetics of user interfaces is undoubtedly one of the most influential factors of their success with users. Aesthetic designs look easier to use and have a higher probability of being used, whether or not they actually are easier to use (Lidwell et al., 2010). General concept of aesthetics comprises several similar constructs such as visual appeal, beauty or goodness. Both aesthetics and usability form an impression about the website and subsequent user behaviour. Aesthetic qualities are however revealed much faster than usability facets and remain relatively stable, in conformity with first impression (Lindgaard et al., 2006). Aesthetics of user interfaces was originally quite neglected in human-computer interaction research; it is however widely researched in various contexts today. Aesthetics can use only subjective measurements, because evaluation of aesthetics cannot be generalized and most of all measured precisely. Perception of aesthetics is also a subject to individual characteristics, feelings and experience of the particular user (Hartmann et al., 2008; Lavie & Tractinsky, 2004; Hall & Hanna 2004), also his needs and preferences. Still, subjective evaluation of aesthetics helps us understand general guidelines and general user opinions about visual appearance of the website.

Lavie and Tractinsky (2004) in the extensive study stated, that users´ perceptions of a webpage consist of two main dimensions, namely classical and expressive aesthetics. Classical design means orderly traditional design, which is directed by rules and standards in web design. Expressive design is on the other hand created creatively, ofthen with a goal to break these rules and standards. Van Schaik and Ling (2009) were inspired by research about influence of the context on aesthetics by Ben-Bassat et al. (2006) and their own research proves that the existence of the particular goal has an impact on more stable evaluation of aesthetics, which is caused by user´s focus on usage of the website. Classical design was rated as more attractive than expressive, according to the author because of the informative character of the website used in the experiment.

Impact of aesthetics or similar concepts is widely researched with relation to websites. A research of Robins and Holmes (2008) showed an influence of aesthetics on credibility and trust, dependent mainly on first aesthetics impression of the website. Weinschenk (2011) summarized that people use look and feel as their first indicator of trust. That supports previous experiment of Lindgaard et. al. (2006), which specifies time needed for assessing a visual appeal of a website. Van Schaik and Ling examined an impact of a context on perception of aesthetics (2009) and relation of similar constructs - beauty and goodness (2008). Schenkman and Jönsson (2000) uncovered that beauty is the best predictor for an overall user judgement. Van der Heijden (2003) introduced a new construct named “perceived visual attractiveness of the website”, which influences also usefulness and ease-of-use (i.e. usability). Most of the recent research examines aesthetics facets in relation with actual or perceived usability (e.g. Lee & Koubek, 2010b; Hartmann et al., 2008; Tuch et al., 2012; Hassenzahl, 2004; Ben-Bassat et al., 2006).

According to Schenkman and Jönsson (2000), perceived aesthetics can be divided to several categories of subjective evaluation: complexity, readability, organization, beauty, understandability and overall impression. Some of these categories are however more commonly being classified as usability aspects; especially readability, organization and understandability. Hassenzahl (2004) used other measurement scale with attributes: pragmatic quality (in other words perceived usability), hedonic quality (stimulation) and beauty. Evaluation of aesthetics usually reflects visually distinctive elements and their arrangement on the user interface. Éthier et al. (2008) included to the evaluation of visual aspects these criteria: colours, pictures, background and layout.

Aesthetics of websites is usually manipulated through design features such as background or quality of pictures and decorative graphics. Manipulating aesthetics is difficult without affecting usability. As a result, aesthetics manipulation is limited, allowing only minimal decorative changes or change of background (Tuch et al., 2012; Ben-Bassat et al., 2006).

### 3.1.4 Content

Content or information quality is one of the key aspects in a website´s success (Lynch & Horton, 2001), but it is not researched to an extent such as usability and aesthetics. Content´s characteristics can be defined as a quality and a quantity of provided information (de Angeli et al., 2006). Content can be also taken as a subjective measure in form of perceived quality of content (Bartuskova & Krejcar, 2013). Content is often taken as part of usability aspect. Content´s criteria relevant to textual form can be divided into quantity measures (e.g. completeness) and quality measures (e.g. relevance, accuracy or understandability) (Bartuskova & Krejcar, 2014b). Kang and Kim (2006) researched an influence of information quality and quantity of web site content on users' attitudes. The confirmed that the more informative or practically useful the web site content is perceived to be, the more positive will be the post-visit attitude (Kang & Kim, 2006).

Fang and Holsapple (2007) defined content as one class of the system features that may influence usability. Content in this approach included utility (clarity, relevance, importance), validity (confidence, consistency), scope (broad, specialized), currency (up-to-date, archival), navigation structure syntax (hierarchy, network, linear) and navigation structure semantics (subject-oriented, usage-oriented). Content for websites, especially commercial ones, is usually being adjusted in order to attract user and keep his attention. This marketing-related process is known as copywriting. Content is also being structured according to design guidelines to facilitate easy reading and improve usability.

## 3.2 Organization structures

Organization structures present different ways of structuring and visually organizing the information. According to Morville and Rosenfeld (2006), an organization structure defines the types of relationships between content items and groups. Lidwell et al. (2010) used a term "layering technique". This is defined as the process of organizing information into related groupings in order to manage complexity and reinforce relationships in the information (Lidwell et al., 2010).

The first proposal of organization structures by Novick et al. (1999) is connected to spatial diagrams. It was confirmed that spatial diagram representations are important tools for thinking (Larkin & Simon,1987, Novick et al., 1999). According to Tversky (2001), externalizing a representation reduces demand on memory and facilitates information processing. Spatially organized information can be accessed, integrated and operated on quickly and easily, especially when the spatial organization reflects conceptual organization (Tversky, 2001). This is applicable for displaying content of websites as well as for organization of educational resources in any learning environment. Novick et al. specified three types of spatial diagrams:

a) a hierarchy or branching structure
b) a matrix with rows and columns
c) a network or system of paths

(Novick et al., 1999).

These three basic types differ in global structure, building block, number of sets, item/link constraints, item distinguishability, link type, absence of a relation, linking relations, path, and traversal (Novick & Hurley 2001). Similar organization structures were later proposed by Morville and Rosenfeld (2006) for website information architecture. They specified these types:

a) a hierarchy as a top-down approach
b) a database model as a bottom-up approach
c) hypertext as a nonlinear way of structuring information

(Morville & Rosenfeld, 2006).

The similarity with organization structures by Novick et al. (1999) is very clear. A hierarchy is the same concept in both cases, a database model consists of matrices (called more commonly tables, but the structure is the same), and hypertext system is in fact network or system of paths. Pure hierarchies can be limiting from a navigation perspective, however the web´s hypertextual abilities removed these limitations, because hypertext supports both lateral and vertical navigation, so a hypertextual web can completely bypass the hierarchy (Morville & Rosenfeld, 2006).

Pilgrim´s (2007) taxonomy of sitemap designs for website navigation also consists of three types of structure: network, hierarchical and categorical (Pilgrim, 2007). It closely corresponds with the previously discussed organization structures. The term "categorical structure" is new, however it is easily comparable to matrix (alternatively parallel, table or database model) structure. Later, Lidwell et al. (2010) proposed two basic types; linear organization (without relationships within the information) and non-linear organization, where the latter is further divided into:

a) hierarchical, with superordinate and subordinate relationships
b) parallel, when information is based on the organization of other information
c) web, when information has many different kinds of relationships

(Lidwell et al., 2010).

Similarly Tidwell (2011) presented several organizational models for information visualization. The first four models are consistent with the previous typology, namely: linear, tabular (i.e. parallel), hierarchical and network (i.e. web). The remaining presented models in this typology were geographic (or spatial), textual and others (Tidwell, 2011).

All of the proposed classifications closely correspond with each other, as is shown in [Table 1]. All of them deal primarily with two-dimensional organization. Lidwell et al. (2010) further suggested three-dimensional layering for viewing additional information without switching contexts, i.e. in a form of overlays like e.g. highlighting technique.

**Table 1. Mapping organization structures by different authors**

| Novick et al., 1999 | Morville & Rosenfeld, 2006 | Pilgrim, 2007 | Lidwell et al., 2010 | Tidwell, 2011 |
|---|---|---|---|---|
| hierarchy | hierarchy | hierarchical | hierarchical | hierarchical |
| matrix | database model | categorical | parallel | tabular |
| network | hypertext | network | web | network |

The following sections are dedicated to each of the three identified types of structures.

### 3.2.1 Table / matrix

Most of the databases in active use are built upon the relational database model, where data is stored within a set of relations or tables (Morville & Rosenfeld, 2006). Tables are however widely used not only in automated data processing but also in graphical user interfaces and commonly in various digital and printed materials whenever there is a need for two-dimensional data representation. Table is a basic representation device known to be easy to use and adopted by teachers in standard practice, they e.g. often use tables to edit and prepare their sessions (Sobreira & Tchounikine, 2015). The main building block of a matrix (table) is a cell denoting the intersection or combination of value i on one variable and value j on the other variable (Novick & Hurley 2001). According to Sobreira and Tchounikine (2015), the table representation has two intrinsic limitations - first, it only supports simple associations, and second, a table introduces a sequential representation, which means branching constructions or parallelism can only be defined implicitly.

Both table and hierarchy are common solutions for representing relationships between items. One of the main differences between a table and a hierarchy is that all of the rows and columns in the table have identical status, while in contrast hierarchy consists of levels with distinguished status (Novick & Hurley, 2001). Usually the higher level means the bigger importance, scope, more general term etc. In contrast to these structures, the representation of network (hypertext / web) can be interpreted more loosely.

Tversky presented "a list" as a spatial device for delineating a category, where organization into a column indicates that the items share a property (categorical relation). A table is then an elaboration of a list, using the same spatial device to organize both rows and columns, cross-classifying items by several categories simultaneously (Tversky, 2001). Horton (2012b) claimed that some subjects are best organized chronologically, for which he proposed a timeline map, which is in fact a matrix. He recommended including the time scale and making sure that the items and scale are familiar to learners (Horton, 2012b).

### 3.2.2 Hierarchy / tree structure

Hierarchical organization is the simplest structure for visualizing and understanding complexity (Lidwell et al., 2010). The foundation of almost all good information architectures is a well-designed hierarchy or taxonomy (Morville & Rosenfeld, 2006). A hierarchical knowledge structure is an effective means of presenting knowledge (Chiu & Pan, 2014). Items (e.g. categories) in hierarchies are usually present only once in the hierarchy - they should be mutually exclusive. The opposite are polyhierarchical taxonomies, which allow cross-listing, but if too many items are cross-listed, the hierarchy loses its value (Morville & Rosenfeld, 2006). Tversky associated hierarchical displays such as trees to ordinal relations (Tversky, 2001).

Primary website navigation is often multi-level menu, which is in fact a hierarchy. Same as any other hierarchy structure, menu can be deep and narrow or broad and shallow. Depth refers to the number of choices required to descend the menu from the top to the specific topic and breadth refers to the number of choices on each menu level (Horton, 2012b). More generally, breadth refers to the number of options at each level of the hierarchy and depth refers to the number of levels in the hierarchy (Morville & Rosenfeld, 2006).

Perception of hierarchical relationships among elements is primarily a function of their relative left-right and top-down positions, but is also influenced by their proximity, size, and the presence of connecting lines (Lidwell et al., 2010). According to Lidwell et al. (2010), there are three basic ways to visually represent hierarchy: trees, nests, and stairs. Most commonly used for visualization of smaller hierarchies is probably the tree structure, where the child elements are placed below the parent elements and usually connected with lines. When the hierarchy is getting more complex, structure of stairs is more effective as it displays only the part of hierarchy which is e.g. currently browsed and some of its parent or neighbouring elements. This system is implemented e.g. in file systems.

The choice of visualizing hierarchy also relates to already mentioned depth and breadth of a hierarchy. When considering breadth, Morville and Rosenfeld (2006) suggested that we should be sensitive to people’s visual scanning abilities and to the cognitive limits of the human mind, in other words there is a danger of overloading users with too many options. On the other hand, if the hierarchy is too deep, users have to click through an inordinate number of levels to find what they are looking for (Morville & Rosenfeld, 2006). Research on menus suggests that wide menus are better than deep ones, because it is easier to re-read a long menu than to have to click back and forth between levels of a menu system and it is easier to find entries by moving the eyes than by moving the mouse (Horton, 2012b).

### 3.2.3 Hypertext / network

This way of organizing information is the most flexible and nonlinear from the presented types. The representation of network does not have any predefined formal structure, and it does not necessarily have a unique starting or ending node (Novick & Hurley 2001). Information are then revealed through any number of associative linkages (Lidwell et al., 2010). Horton (2012b) presented flexible free-form structure, basically a network, which imposes no restrictions on the organization beyond those implied by the subject matter. Though this organization is very flexible, when used for primary organization, Morville and Rosenfeld (2006) alerted that this organization structure presents potential for complexity and user confusion from several reasons, most importantly users can not create a mental model of the site organization without context and hypertext links reflect highly personal associations. Similarly Chapnick and Meloy (2005) mentioned that for e-learning purposes can be nonlinear / hyperlinked type of navigation confusing.

Horton (2012b) proposed maps as one of the navigation mechanisms. He defined a map in the e-learning context as a visual menu that shows how e-learning or its subject is organized and so it displays the logical or navigational organization of e-learning (Horton, 2012b). He defined several types of maps, one of them - a logical map - can be classified as a network. These maps can show logical relationships but also processes, workflow or dependency. This corresponds with the description of network: links between nodes may be associative (i.e. nondirectional), unidirectional or bidirectional (Novick & Hurley 2001).

## 3.3 Organization schemes

While organization structures are ways of structuring and visually organizing the information, organization schemes can be described as constructs by which the information is organized. According to Morville and Rosenfeld (2006), an organization scheme defines the shared characteristics of content items and affects the logical grouping of content items.

Morville and Rosenfeld (2006) and later Kalbach (2007) proposed primary division of organization schemes into exact (objective) schemes, which divide information into well-defined and mutually exclusive sections, and ambiguous (subjective) schemes, which divide information into categories that defy exact definition. Other authors suggested there are generally five ways to organize information. This approach is known as the LATCH, where LATCH stands for Location, Alphabet, Time, Category and Hierarchy (Wurman, 2000; Chapnick & Meloy, 2005; Lidwell et al., 2010). Wurman (2000) originally published Continuum as the fifth title, but changed it later to Hierarchy to create the acronym LATCH. Lidwell et al. (2010) however presented Continuum as a more accurate description of this organization scheme.

Proposed schemes from both approaches can be mapped to each other, as they present the same or similar concepts. The following table [Table 2] summarizes these schemes.

**Table 2. Comparison of two sets of organization schemes [14]**

| **Wurman, 2000; Chapnick & Meloy, 2005; Lidwell et al., 2010** | **Morville & Rosenfeld, 2006; Kalbach, 2007** | |
|---|---|---|
| time (by chronological sequence) | chronological | exact |
| location (by geographical or spatial reference) | geographical | |
| alphabet (by alphabetical sequence) | alphabetical | |
| continuum or hierarchy (by magnitude) | - | - |
| category (by similarity or relatedness) | topic | ambiguous |
| | task | |
| | audience | |

Organization by time has the same meaning as organization by chronological sequence, organization by location is interchangeable with organization by geographical or spatial reference, and alphabet is the same as by alphabetical sequence. These three organization schemes are regarded as exact or objective. Continuum (or hierarchy) refers to organization by magnitude, e.g., highest to lowest, best to worst etc. (Lidwell et al., 2010). There is no counterpart to continuum in the approach of Morville and Rosenfeld (2006). We can organize information by category either when clusters of similarity exist within the information or when people will naturally seek out information by category (Lidwell et al., 2010). On the other hand Morville and Rosenfeld (2006) proposed several ambiguous schemes including topic, task, audience or metaphor. As both of these concepts present organization by similarity or relatedness, we can regard them as counterparts. Colborne (2011) also suggested several approaches to organization of the interface, including organization by categories, alphabet, time, space, size and location. In comparison with previous suggestions, continuum or hierarchy is replaced by space and size. Size is in fact a continuum, as it presents organization by magnitude. Space is more related to organization structures and similar concepts such as layout or items´ placement.

## 3.4 Systems for web-based education

Web-based education can act as an alternative or complement to traditional learning. It was proven that student and faculty engagement and satisfaction are the same in face-to-face classes as they are in e-learning courses (Liebowitz & Frank, 2010). Web-based learning has become an important way to enhance learning and teaching, offering many learning opportunities (Hwang et al., 2007). Today the most important and commonly used delivery platform for distance education systems are web based systems (Somyürek, 2015). Educational organizations can choose from many web-based solutions, both free and commercial ones, for managing a complex educational experience or just providing students with access to learning resources. Learning management systems (LMSs) and learning object repositories (LORs) or interchangeably learning content management systems (LCMSs) belong to the most common web-based educational solutions. The typical scenario is where an organization stores learning materials locally in an LCMS and deliver them through a LMS to the learner's device (Redondo et al., 2010). LMSs usually include a wide variety of features that can be utilized to support both distance and traditional teaching (Islam, 2013).

There are continuous efforts to invent better platforms for online education or to improve the existing ones. These efforts are directed e.g. towards personalization, adaptation, collaboration or improved search. New forms of higher education have also emerged, where individuals can access learning courses and repositories on their own via without the institution. In addition learners face unbounded increases in available educational resources on the internet as well as in digital repositories (Šimko et al., 2010). The development of educational systems is subjected to technological advances and trends. E.g. mobile learning is a new direction of education, following the growth of mobile devices. Mobile learning brings many opportunities for learning (Bartuskova & Krejcar, 2014c). The following sub-sections present an overview of the common existing solutions, which are being used for web-based education; both systems used by traditional educational institutions and newer stand-alone learning environments accessible for individuals.

### 3.4.1 Learning management systems

Learning management system (LMS) is a popular choice for online education. LMS is a large space of educational information sources and interaction items, which include not only the educational contents, but also contributions produced and shared by members in the course (Santos et al., 2014). LMSs are used with increasing frequency to support the basic needs of administration and higher-education teaching (Álvarez et al., 2013). Islam (2013) confirms that most universities now use LMSs to support and improve learning and teaching processes. The term "learning management system" can be interchanged for a "course management system" (CMS) or "virtual learning environment" (VLE) (e.g. Al-Ajlan, 2012; Zhao & Forouraghi, 2013). Learning content management systems (LCMSs) or learning object repositories (LORs) are another types of educational systems focused on efficient content management. LCMS can be part of the LMS for managing course content or it can be a separate product that has been integrated with the LMS (iNACOL, 2010).

Moodle, distributed as an open source, is the leading LMS. Moodle is a robust open-source learning platform that helps to create an effective online teaching and learning experiences in a collaborative, private environment (Moodle, 2014). This system facilitates several groups of activities in a form of modules. Among the main activities belong: creation (provided by module database), organization (lessons), delivery (assignments, workshops), communication (chats, forums, news), collaboration (glossary, wikis), assessment (choice, quiz, survey, feedback) and reusability (SCORM, external tools) (Costa, Alvelos & Teixeira, 2012). Al-Ajlan (2012) strongly recommended Moodle as the best choice for higher education, based on e-learning features and capabilities. Other popular learning platforms are Edmodo, Blackboard or SumTotal Systems (Capterra, 2014).

Customization and personalization are often discussed in relation to LMSs. Customization refers to the structure or style of the webpage (or system), while user personalization usually refers to the content itself (Bouras & Poulopoulos, 2012). Customization in LMSs is possible by limited choices e.g. of colour scheme or composition of widgets, which shows new posts in discussion forum, active assignments, calendar, announcements etc. Means of personalization are frequently discussed because educational systems are used by a wide variety of students with different skills, background, preferences and learning styles (Brusilovsky, 2001). Ideally, LMS can be designed to interact with the learners and provide personalized tutoring and guidance based on the learner's performance (Zhao & Forouraghi, 2013). Efficient personalization is however very difficult to achieve, as it requires extensive metadata of both learner and learning resources.

Personalization is achieved by using adaptive (learned by the system) or adaptable (configured by the learner) filtering of information (Devedzic, 2006). Both forms are used commonly on the internet, however adaptive systems are more desired these days, as they put lesser demands on user and as such seem to be more user-friendly. Adaptive learning is defined as a style of learning that uses student successes as the basis for developing future learning directions while a student is participating in the e-learning course (Mason & Ellis, 2009). Adaptive learning is substantially connected with personalisation, recommendation-based learning, and inquire-based learning (Kurilovas et al., 2014). Gasparini et al. (2010) concluded that adaptive techniques are examples of user-centred techniques for approaching a range of serious usability problems found in conventional non-adaptive web-based e-learning systems, usually related to present homogeneous content and navigation for all students. The adaptations in AEH (Adaptive Educational Hypermedia) systems may include both the content of the hypermedia pages (adaptive presentation), and the links included in each page (adaptive navigation support) (Kurilovas et al., 2014).

Cristea and Ghali (2011) defined as a desired feature of e-learning systems, that the student should be able to select if the adaptation is triggered by the system or by himself, thus selecting between adaptivity and adaptability. This approach again belongs to user-centered development. While adaptive systems require little or no effort from the user, adaptable systems allow the user to be in control (Cristea & Ghali, 2011). We could say more accurately, that adaptive systems usually require some data from users before an adaptation can occur, while adaptable systems require some input while working with the system. Further adaptation in adaptive systems can be also based on user activity which is logged and used for personalization. The knowledge representation is internal in adaptive systems and external in adaptable systems, which requires different mechanisms, more complex in the case of the adaptive systems (Fischer, 2001).

### 3.4.2 Learning object repositories

Learning object repositories (LORs) represent another approach to management of educational resources. Learning content management system (LCMS) is sometimes used instead of LOR. LCMS provides the flexibility to have an online content organized in ways other than a traditional online course (iNACOL, 2011). LOR or LCMS allows users to search and retrieve learning objects from the repository; it typically supports simple and advanced queries, as well as browsing through the material by subject or discipline (Neven & Duval, 2002). These systems are highly heterogeneous; each one with a different storage system, query methods, etc. (López et al., 2012).

Learning objects (LOs) are basic elements placed in these systems. LO is a reusable, media-independent collection of information used as a modular building block for e-learning content (Gonzalez-Barbone & Anido-Rifon, 2008). Reusability is one of the main concerns in today´s education. In order to reuse LOs, metadata must describe the LO content making the LO accessible (Devedzic, 2006). Metadata are data about data. As defined by Yigit et al. (2014), it is complementary and descriptive component to any data. Metadata have a fundamental role in organizing and managing digital resources, especially when there is a great quantity of information that must be indexed to facilitate search and retrieval of information (Pani et al., 2012).

With appropriate metadata descriptions, LOs can be modular units that can be assembled together to form lessons and courses (McGreal, 2004). Such a learning object can be then called a Sharable Learning Object (SLO). SLO is a piece of learning material with a single learning objective as purpose, independent from other learning materials, which can be used in different settings and combined as appropriate (Gonzalez-Barbone & Anido-Rifon, 2008). LOs are widely used to overcome difficulties in terms of economic costs and loss of time while preparing e-content (Yigit et al., 2014). Their usage depends on approach of the particular educational institution. Internationally accepted specifications and standards make LOs interoperable and reusable by different applications and in diverse learning environments (McGreal, 2004). The standards should enable such high-level requirements as: accessibility, interoperability, durability and reusability (Totkov et al., 2004).

The IEEE Standard for Learning Object Metadata (LOM) is an open standard for learning objects, which are in this specification described as being any entity, digital or non-digital, that may be used for learning, education or training (IEEE-LTSC, 2002). LOM enables creation of structured descriptions (metadata) of learning resources (LOs). These descriptions should help facilitate the discovery, location, evaluation and acquisition of learning resources by students, teachers or automated software processes (Barker, 2005). LOM can be represented as a hierarchy of elements, which are used for description of the learning object. IEEE standard identifies 76 different aspects by which a learning object can be annotated and is supported in some way by all major LORs and e-learning platforms (Brooks & McCalla, 2006). First division of elements is into nine categories: general, life cycle, meta-metadata, technical, educational, rights, relations, annotation and classification (IEEE-LTSC, 2002). The extent of available metadata is however not very usable. Many vendors expressed little or no interest in developing products that were required to support a set of meta-data with over 80 elements (Brooks & McCalla, 2006).

Shareable Content Object Reference Model (SCORM) is a collection of standards and specifications for the packaging and sequencing of learning and assessment material in the form of shareable, reusable content objects (Gonzalez-Barbone & Anido-Rifon, 2008). This learning object packaging standard, that was developed by Advanced Distributed Learning (ADL), recommends using the IEEE 2002 LOM standard as the internal metadata standard (Mason & Ellis, 2009). ADL SCORM has become the de facto standard to allow content developed within one learning system to be exported and used in all other systems (Redondo et al., 2010).

LCMS has advanced capabilities of managing content in comparison with a LMS and can be integrated into a LMS for this advanced functionality. If content is managed by a LMS alone, the content is placed within a specific course and if another course needs to use this content, it must be copied and these two instances are not synchronized among themselves in a case of the update. When content is managed by a LCMS, it is located in the digital content repository (database of learning objects) and then the content in an online course is made up of individual learning objects from the LCMS (iNACOL, 2011).

Online learning is also being associated with Web 3.0 or the Semantic Web movement. According to Morris (2011), online students will benefit from learning personalization and knowledge construction powered by the Semantic Web. Semantic Web-Based Education (SWBE) assumes that web-based educational content is represented by LOs (Devedzic, 2006), which already contain structures metadata for personalization. However despite the wide efforts and investments, most of the existing LORs are being designed mainly as digital libraries rather than knowledge management systems (Zervas et al., 2014).

### 3.4.3 Open educational resources

Although LMSs or LCMS are popular choices for educational institutions, the learner is no longer limited to these institutions. There is a vast amount of learning content available on the internet and learner can easily find online even thousands of instructional texts, tutorials and electronic text-books (Guerra, Sosnovsky & Brusilovsky, 2013). This content is however scattered throughout the Internet and it is difficult to evaluate its information quality and usefulness. New forms of education have emerged to offer well-organized credible educational sources and/or courses online, such as digital libraries and MOOCs. Openness of these learning resources is very actual topic. Openness broadens access to learning and can influence new forms of learning (McAndrew et al., 2010).

Open Educational Resources (OER) are any type of educational materials that are in the public domain or released with an open license that allows users to legally and freely use, copy, adapt and re-share (UNESCO, 2012). OERs constitute a significant part of "Opening up education", which is a global movement dedicated to facilitating open and flexible learning (Zervas et al., 2014). The main aim of initiatives from this movement is to support the process of organizing, classifying, storing and sharing OERs in the form of LOs and their associated metadata in LORs (Zervas et al., 2014). OERs include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge (Atkins et al., 2007). OERs are offered freely and openly for educators, students and self-learners to use and reuse for teaching, learning and research (Organisation for Economic Co-operation and Development, 2007). Universities are collaborating in offering various types of OER in many different projects (DeVries, 2013), such as MOOCs.

### 3.4.4 Massive open online courses

Massive open online courses (MOOCs) are classes delivered in an online environment that are free and open to all, which attract substantially larger audiences than traditional online education, however completion rates are less than in traditional courses (Alraimi et al., 2015). We can classify MOOCs into two categories: xMOOCs (courses structured similarly to traditional courses with all content predefined by the instructor) and cMOOCs (course materials and content is derived from students during the course) (Hew & Cheung, 2014). cMOOCs represent connectivist approach to learning, they have a decentralised, network-based, non-linear structure focused on exploration and conversation rather than emphasising instructor-provided content (Margaryan et al., 2015). More popular today are xMOOCs like Udacity (http://www.udacity.com/) or Coursera (http://www.coursera.org).

The most popular MOOC platforms are associated with a combination of some highly-regarded universities, companies or foundations (Holdaway & Hawtin, 2014). There are however many other online providers of learning courses, they usually offer some learning resources for free for demonstration purposes. Others are accessible either for price per course or on monthly-payment basis. E.g. for learning web programming and design, there are specialized MOOCs like Code School (http://www.codeschool.com/courses), Treehouse (http://teamtreehouse.com/) or Lynda (http://www.lynda.com/). According to Lucas (2013), the emergent popularity of MOOCs can be perceived as a great promise for distance education but also a disruptive technology and a serious threat to institutions of higher education. The internet generally transfers many learning activies from traditional classrooms to online environment and also creates entirely new possibilities. Open education is a key feature of MOOCs and entails increased access, greater choice, and flexibility (Iiyoshi & Kumar, 2008).

### 3.4.5 Digital libraries

The digital library is a collection of information that has associated services delivered to user communities using a variety of technologies (Heradio et al., 2012). Digital libraries are often focused on digitizing existing non-digital resources. They also offer integrated environments with collections, information services, and academic activities for preserving knowledge and effectively supporting learning (Chen & Lin, 2014). The main advantage of a digital library should be creating a rich and diverse knowledge thanks to a large number of users and real-time communication. However it faces similar problems as other collaborative applications, such as low and intermittent participation rates or difficulty of establishing trust relations (Pérez, 2014).

### 3.4.6 Web 2.0 applications

Web 2.0 enabled user-based authoring of content (by utilizing blogs and wikis), facilitated organization and sharing of knowledge (by annotating and tagging content, discussing content) and simplified collaboration and interaction between users (Bieliková et al., 2014). We can categorize Web 2.0 applications into several groups according to their functions: online reflection (blog), online collaboration (wiki), social network, repository, social bookmarking and virtual worlds (Hew & Cheung, 2013). Most of the typical Web 2.0 applications are founded on sharing or collaboration. Web 2.0 represented a paradigm shift in how people use the internet, especially that everyone can actively contribute content online (Pérez, 2014). Web 2.0 applications are being incorporated into education either for management of learning resources or just for temporary project-based purposes. The use of Web 2.0 technologies appears to have a general positive impact on student learning (Hew & Cheung, 2013). Wikis are probably the most applicable in education.

Wiki is one of the online tools for developing collaborative activities (West & West, 2009). There are also studies claiming that Wikis have great potential for computer-supported collaborative knowledge building and learning (Reinhold, 2006). Biasutti and EL-Deghaidy (2012) deal with use of Wiki as an online didactic tool to develop knowledge management processes in higher education. Wiki software is very easily accessible through many open-source platforms. Systems based on Web 2.0 such as wikis also offer advantages for developing and implementing lightweight knowledge repositories (García et al., 2011). They support the processes of traditional knowledge management such as creation, transfer and storage/retrieval (Scherp et al., 2009). Websites based on wiki engine are therefore popular choice for presenting information on various topics on the Internet.

Bookmarking websites are another example of Web 2.0 applications, which can be used for collaborative learning. Social bookmarking tools can foster the recall, identification and exchange of factual information on specific topic of interests (Bower et al., 2010). Applications of this kind are very useful for managing references of websites. Important part of bookmarking systems is tagging. Tags can be organized to provide meaningful navigation structures and can be viewed as an external representation of what users learned from a page and of how they chose to organize that knowledge (Hong et al., 2008).

One of the most popular is Diigo (http://www.diigo.com), which describes its service as a multi-tool for personal knowledge management (Diigo Inc., 2014). Diigo offers in addition to bookmarking also additional functionalities such as highlighting, making notes or screenshots. It also facilitates organizing structures such as lists, sections and tags. Regarding learning, Diigo supports collaborative research and contains a social aspect in sharing entries with other people or groups. Other examples of social tagging are Delicious (https://delicious.com/) or Stumbleupon (http://www.stumbleupon.com).

Other collaborative Web 2.0 applications used for learning purposes are e.g. discussion forums or question and answer sites such as Stackoverflow (http://stackoverflow.com/).

These systems usually target particular problems and their solutions and are not suitable for organized, constructive or long-term education, only for a quick solution.

### 3.4.7 Summarization and usage analysis

All of the presented web-based solutions have their role in various types of learning. To further specify which role it is, the following table [Table 3] resumes the basic usage of presented web-based systems in learning.

**Table 3. Usage of web-based systems in learning**

| **Web-based system** | **Use for education** | |
|---|---|---|
| | **For students** | **For teachers** |
| LMSs | access to learning courses with support of various activities, e.g. communication and evaluation | management of learning courses with advanced possibilities for communication and evaluation |
| LCMSs / LORs | access to repository of learning materials with advanced browsing and searching | delivery and better management of reusable learning materials (use of learning objects) |
| Digital libraries | access to additional learning content like in the library | creating (also by digitizing) and accumulating learning content |
| MOOCs | access to purely online classes | delivering purely online classes |
| Wikis | A) access to learning content, similarly as regular websites<br>B) collaborative knowledge building and learning | A) delivery of learning content, similarly as regular websites<br>B) implementing collaborative learning in the course |
| Bookmarking sites | A) access to reference links<br>B) collaborative building of collection of reference links | A) delivery of reference links<br>B) implementing collaborative learning in the course |

As we can see from the table, there are several systems which perform similar role and several systems which are more distinguishable from others in their objectives. However all of them are primarily used for accessing learning content (from a student role) and managing this content (from a teacher role).

We can identify two distinguished types of web-based educational systems based on their architecture and learning approach. Course-based learning systems (e.g. LMSs or MOOCs) guide the student through the learning process, usually offering recommended sequence of actions and additional functions and activities. On the other hand, systems based on repositories contain a collection of resources which can be browsed, filtered or searched. These learning materials can be offered in a form of standardized learning objects (e.g. LORs / LCMSs or digital libraries) or in a form of individual webpages (e.g. wikis).

## 3.5 Specific approaches in web-based education

The previous chapter presented common means of web-based education. This section presents some specific approaches and principles, most of them not yet widely incorporated into commonly used systems. Various innovative systems are still being proposed to replace the current systems, enhance them or complement them. Some of the discussed limitations of web-based educational systems (see chapters 4.2 and 4.3) were already investigated by these approaches.

Most of all, we can see that there is a great effort to make learning systems more adaptive, flexible and personalized for learners. Many of the novel solutions are focused on automated adaptation and personalization, i.e. the systems algorithms should deliver more relevant content on the basis of metadata and data from users. Some of the novel solutions are based more on human factor instead of automated processes. They emphasize the need to deliver quality content through evaluations, recommendations and collaboration.

Somyürek (2015) reviewed new adaptive educational hypermedia systems and revealed these technological trends and approaches: standardization, semantic web, modular frameworks, data mining, machine learning techniques, social web, and device adaptation. The general problem with novel solutions is that the majority of these projects did not expand beyond the authors´ institution and traditional LMSs are still in common use. Bieliková et al. (2014) concluded that modern adaptive learning systems are usually experimental prototypes designed and developed from scratch and not used beyond the university departments of their authors. Somyürek (2015) offered four challenges as an explanation why adaptive systems are still not used on a large scale; inter-operability, open corpus knowledge, usage across a variety of delivery devices, and the design of meta-adaptive systems. Šimko et al. (2010) emphasized the complexity of metadata used for the personalization as a major drawback of adaptive course authoring, which negatively affects the spread of adaptive learning systems.

This section will present some of the interesting systems along with a brief assessment of their long-term sustainability.

### 3.5.1 Personalization and adaptation

Peng et al. (2013) presented a knowledge management system which would support web-based learning in higher education. The main idea was to integrate different course resources and let students select the part of resources helpful for them and organize them in their own way (Peng et al. 2013). Implemented system KMS-THU manages knowledge organization by different form (tree structure and tags) and different scope (individual, group and public knowledge). This proposed system dealt mostly with learning resources as digital files and focused on a technical solution. In system proposed by Peng et al. (2013), students showed their will to use the system to select useful course resources for themselves because it is easy to integrate the course resources to their own resources. The study of Su et al. (2010) focused on how to store, manage, and retrieve annotation metadata by exploiting the latest Web 2.0 technology. The results indicated a positive correlation between learning achievements and quantity of annotation (Su et al., 2010). Similarly Chen et al. (2012) built up a Web 2.0-based online annotation system and evaluated its effectiveness from a usability perspective.

Gasparini et al. (2010) proposed e-learning system AdaptWeb - an adaptive hypermedia system aiming to adapt the content, the presentation and the navigation in web-based courses, according to the student model. The AdaptWeb's educational contents were modeled through a hierarchical structure of concepts stored in XML format. This system's evaluation however identified some weaknesses, system is not being updated lately and also demo site does not exist anymore. Finally Šimko et al. (2010) and later Bieliková et al. (2014) introduced ALEF, which is a schema of adaptive web-based learning for future LMSs, with these three key principles: 3) domain modeling, 2) extensible personalization and course adaptation and 3) student active participation in a learning process. Adaptive and intelligent web-based educational systems are based upon domain and user models (Bieliková et al., 2014). Domain model of ALEF contains two main parts - metadata (concepts, tags, comments) and educational content (learning objects) (Šimko et al., 2010).

However because we don't have time to teach our systems, or because we prefer to maintain our privacy, we often don't share enough information to drive effective personalization (Morville & Rosenfeld, 2006). Human motivation for tagging knowledge and security concerns are also obstacles to semantic web that will need to be resolved (Morris, 2011). Still even if we would provide enough information, our needs and interests change in time. In other words, past performance is no guarantee of future results (Morville & Rosenfeld, 2006). Badly performed personalization can even hide useful information from users because of incomplete or outdated metadata or badly constructed algorithms.

Personalized search is another research area of personalization. In adaptive systems are needed both metadata that defines each learning object and that describes each learner's aspects (Somyürek, 2015). IMS (2001) issued Learner Information Package (LIP), the specification for learner, which includes these categories of metadata: identification, goal, qcl (qualifications, certifications, licenses), activity, transcript, interest, competency, affiliation, accessibility, security key and relationship. Biletskiy et al. (2009) presented criteria for estimation of conformity of LOM attributes to the learner's personal profile attributes in order to enable personalized search of LOs. This approach is well-justified, however it requires that LOM of every learning object will contain attributes such as interactivity level, typical learning time, intended end user role etc., which do not belong to the common set of metadata. Additionally there is again a major drawback - the complexity of metadata needed for personalization, in both definition of such metadata as well as their further maintenance (Šimko et al., 2010). Yigit et al. (2014) developed SDUNESA LOR to improve search of LOs by using Analytical Hierarchy Process (AHP). However better search does not solve the problem of missing or incorrect metadata.

### 3.5.2 Collective intelligence and tags

Online social interactions facilitated by Web 2.0 technologies, such as tagging, rating or commenting, create collective intelligence. Collective intelligence can be described as the knowledge derived from the collaboration of many individuals (Gruber, 2008). Gathered data can be used to implement web navigation aids such as e.g. sorting articles by number of comments. This approach can be used also in adaptive e-learning systems. We can distinguish two types of social navigation: 1) general recommendations (e.g. the best rated articles, the most popular etc.) or 2) more personalized recommendations (e.g. proposals of articles based on what you read or products similar to what you ordered). Examples of social navigation include Amazon's collaborative filtering (Customers who bought ... also bought ...), recommendation systems or Flickr's tag clouds (Morville & Rosenfeld, 2006).

Social navigation belongs to the set of techniques called adaptive navigation. Brusilovsky (2007) defined adaptive navigation support as a specific group of technologies that support user navigation in hyperspace, by adapting to the goals, preferences and knowledge of the individual user. One of social mechanisms is the collaborative (social) filtering; a technique for providing recommendation based on earlier expressed preferences or the interests of similar users (Brusilovsky, 2007). Kalbach (2007) presented an adaptive navigation as a special type of contextual navigation. Kalbach´s (2007) definition is in fact definition of social navigation, as the links of adaptive contextual navigation are generated from a collaborative (social) filtering.

A newer alternative to the classical hierarchical navigation are tags, which are also considered as a social (and adaptive) navigation. Tagging systems provide means for users to generate labelled links (tags) to content that, at a later time, can be browsed and searched (Hong et al., 2008). Bookmarking systems usually include tagging function and sometimes are interchanged for tagging systems. Usually we can encounter traditional Web 2.0 tag cloud systems, so called folksonomies, but also novel systems were proposed with formal tags based on ontologies (Zhang et al., 2014). Tagging systems provide a means for users to generate labeled links (tags) to content that, at a later time, can be browsed and searched (Hong et al., 2008). Websites which implement organization of web documents or images by tags usually join them in a "tag cloud". The tag cloud is a visual representation of keywords in the form of a cloud (Walhout et al., 2015). Font sizes in the tag cloud reflect the number of matching instances for each tag (Zhang et al., 2014).

Collective intelligence associated with social navigation, adaptive navigation and tags, has also application in education. Redondo et al. (2010) claimed that tags given by prosumers allow creating and dynamic updating a folksonomy which support a mechanism to classify and search educative units. Users look for pedagogical content according to keywords and their decision of choosing one or another will be likely based on the rates each unit has received (Redondo et al., 2010). Walhout et al. (2015) researched that learning outcomes can benefit from using a novel tag cloud as navigational support as compared to more traditional navigation structures.

### 3.5.3 Collaboration and integration

Rego et al. (2010) proposed an evaluation collaborative system in which experts and teachers analyze LOs and give them an individual evaluation. After this evaluation, all the persons that evaluated the LO gather in a sort of forum to reach to its final evaluation (Rego et al., 2010). Similarly, Redondo et al. (2010) designed a learning platform called Educateca, where learners as “prosumers” are supposed to tag and rate learning objects as they use the platform and like teachers they can also create or modify content to contribute to the learning distributed repository. This concept would be however in practice very time-demanding for all participants, not mentioning problems with insufficient knowledge, experience and most of all motivation towards quality evaluation or organizing learning content. Educateca platform however presents an interesting concept; it joins together formal SCORM metadata (provided by expert users, mainly teachers) and informal free-tags (given by less expert users, mainly students) (Redondo et al., 2010). Collaboration is becoming increasingly widespread in online environments including e-learning. According to Redondo et al. (2010), recommendation is essential to avoid overwhelming users with too much educative content that they are not able to filter, asses and/or consume.

MAGADI (Multi Agent Adaptive Instruction) web environment is a system intended for blended learning with real integration of on-line and off-line activities (Álvarez et al., 2009). The motivation behind its development was that teachers and students need on-line tools that are wholly integrated in the learning-teaching cycle in order to promote synergies among all the learning styles in use (Álvarez et al., 2013)

### 3.5.4 Learning as an online service

Several suggestions on novel learning systems were made with the use of cloud computing (e.g. Zhao & Forouraghi, 2013; Redondo et al., 2010) Redondo et al. suggested that learning organizations should publish and even share their material in the cloud so that learners can access them directly. The LMS is then becoming another SaaS (Software as a Service) in the cloud so that the student can select a LMS according to the LMS's features and his/her preferences (Redondo et al., 2010).

This approach however requires that every learner has knowledge and capabilities needed for distinguishing the right learning materials for his/her purposes, as well as already explored and clarified preferences for choosing the right LMS. Redondo et al. (2010) also mentioned that e-learning in the cloud should give the illusion of infinite resources available on demand. This concept however threatens to overwhelm student with a large amount of resources and at the same time fail in delivering the right materials.

### 3.5.5 Knowledge representation

One of the alternative approaches to e-learning is the use of knowledge maps, which function as a visualization tool. Knowledge structures are diagrams showing the important components of knowledge in study; knowledge maps identify the locations of objects and illustrate the relationship among objects (Chiu & Pan, 2014). Maps such as concept maps, knowledge maps or topic maps are often used for knowledge representation, also in learning environments. These maps have nodes and links, nodes as key concepts and links as relationships between key concepts (Lee & Segev, 2012). From a map, the user can recognize the important concepts and the relationships between them (Lee & Segev, 2012).

Ontologies present another approach, closely connected to metadata. Knowledge representation, reuse and sharing in computer and information science are facilitated by the explicit use of ontologies (Gaeta et al., 2009). Ontology is an abstract model, which provides a controlled vocabulary for concepts description with an explicitly defined semantics in machine-readable language. Ontologies capture knowledge by a group of people and may be reused across different applications (Corcho et al., 2003). Regarding learning, ontologies can be used to model educational domains and to build, organize and update specific learning resources (i.e. learning objects, profiles, paths) (Gaeta et al., 2009).

# 4 Problem definition

Limitations of commonly used approaches are discussed in this section. It brings a closer look at the motivation behind solutions, which we propose in the respective chapters.

## 4.1 Organization and navigation issues

Many authors alerted that we are facing information abundance or even severe information overload (e.g. Morville & Rosenfeld, 2006; Liebowitz & Frank, 2010). Organization of information or knowledge is therefore a common concern in almost every web-based system. With the expansion of Web 2.0, the role of publishers transferred from specialists to broader audience. Morville and Rosenfeld (2006) noted that as the Internet provides users with the freedom to publish information, it burdens them with the responsibility to organize that information. Also e-learning needs an adequate management of educational resources in order to promote quality learning (Rego et al., 2010). Where simple content management is not enough, we can enhance it towards complex knowledge management. E-learning and knowledge management can then function as complements and components critical to learning (Ungaretti & Tillberg-Webb, 2010). Both disciplines deal with knowledge capture, sharing, application, generation, and both of them ultimately contribute to the building of the continuous learning culture (Liebowitz & Frank, 2010).

In order to ensure an efficient retrieval of information, it has to be organized in some way. The way we organize, label, and relate information influences the way people comprehend that information (Morville & Rosenfeld, 2006). Consequently it is very important to use appropriate organization system for particular purposes. An organization system includes organization scheme and organization structure (Chen & Lin, 2014), discussed in the previous sections. Organization of content and navigation among this content is essential for effective learning. Navigation is also an important part of website usability (Bartuskova & Krejcar, 2014a). Several issues related to web navigation are discussed in this section. These issues form motivation towards our proposed solution and will be referenced later.

### 4.1.1 Disorientation and site maps

Web users commonly experience disorientation while browsing, which has a negative effect on their performance (McDonald & Stevenson, 1998). This issue of disorientation is often called “lost in hyperspace” (e.g. Park and Kim, 2000; Aksac, 2012). Park and Kim (2000) asserted that users have to perform many tasks simultaneously, such as remembering tasks, searching items, browsing topics, comparing between items, moving between them and so on, which causes them to experience cognitive overload, which may consequently lead to get lost in hyperspace. According to Amadieu et al. (2009), disorientation may be structural (related to the physical space of hypertexts) or conceptual (related to the conceptual space of hypertexts). Structural disorientation reflects a cognitive load linked to the processing of physical space (such as location of the position in the physical space or representation of the previous path) and conceptual disorientation concerns the users’ difficulties to meaningfully link the different concepts conveyed by a hypertext (Amadieu et al., 2009). One of the main contributors to this problem can be confusing and disorganized navigation structure (Fang & Holsapple, 2007).

Danielson (2002) studied effects of constantly visible site maps used as web navigation. Users with this navigation aid abandoned fewer information-seeking tasks, made less use of the Back button, dug deeper into the site hierarchy, made navigational movements of great hierarchical distances etc. (Danielson, 2002). A typical sitemap presents the top few levels of the information hierarchy (Morville & Rosenfeld, 2006). While it is known that a common solution to the disorientation of web users is the presentation of a site map or other overview of the site structure, websites usually contain only limited subset of the standard navigation aids (Danielson, 2002). Similarly Pilgrim (2007) stated that the standard navigation tools provided by Web browsers are inadequate as they do not provide the facilities to visualise the inter-relationships between pages.

Fowler and Stanwick (2004) suggested that it is easier to scan a large list of organized possibilities than to pick one option that leads to another set of options and so on. Leuthold et al. (2011) agreed with their recommendation to show as much navigation links as possible on the screen. This is in accordance with the statement of Shneiderman and Plaisant (2004), that breadth should be preferred over depth in web navigation. A broad, shallow navigation structure with many visible links is generally more usable than a narrow, deep structure with just a few (Fowler & Stanwick, 2004). Leuthold et al. (2011) confirmed in their experiment, that vertical menus (which reveal all navigation items at once) outperform dynamic menus (which display only one level of navigation and reveal lower levels upon interaction with the mouse). Vertical menus are in this regard similar to constantly visible site maps, as both techniques display all navigation items during browsing. Vertical menus were also subjectively preferred by users (Leuthold et al., 2011). On the contrary, with dynamic menu (e.g. dropdown menu) users can't see navigation items on lower levels without mouse hovering or clicking and they never see all navigation items at once (Fowler & Stanwick, 2004).

### 4.1.2 Subjectivity in creating navigation

One of the issues with navigation of websites is the overall subjectivity. Subjective organization schemes divide information into categories that defy exact definition, they are difficult to design and maintain and they can be difficult to use (Morville & Rosenfeld, 2006). Problems with creating useful navigation according to subjective organization scheme include: broad vague categories, poor organization of menu options and poor grouping of categories (Kalbach, 2007).

In an subjective organization scheme, someone other than the user has made an intellectual decision to group items together (Morville & Rosenfeld, 2006). The subjectivity is however not only about dividing items into categories but about the whole process. The decision about how are the items sorted, how are they labelled, in which navigation area are they placed and if they are included in the navigation at all, depends solely on consideration of people involved in the process. These can be information architects, designers or users with administration rights. Usually it is the job of information designers to build the organization structure, deciding on the number of top-level categories of the site, their subcategories, and so on, including linguistic and design decisions (Danielson, 2002). Their decision can be supported by analytics, similar cases and previous experiences, however it is still very subjective process. Ultimately, there is no standard in model-based user interface development environment and graphical user interface is still being created in an ad hoc manner (Mustakerov & Borissova, 2011).

In contrast to subjective organization, objective (exact) organization schemes divide information into well-defined and mutually exclusive sections, which are easy to design, maintain and use (Morville & Rosenfeld, 2006). However website navigation works primarily with subjective schemes (Kalbach, 2007). Subjective organizations are often more important and useful than exact organization schemes (Morville & Rosenfeld, 2006).

### 4.1.3 Descriptive potential of navigation

Website navigation has a descriptive potential, which can be carried out e.g. by spatial arrangement and visual cues. How the brain perceives individual objects can be influenced by applying Gestalt Laws. The four most applicable Gestalt Laws in design are proximity, similarity, continuity and closure (Golombisky & Hagen, 2013). The concept of similarity is frequently used to visually connect related items. Similar elements are perceived as a single group and are interpreted as being related (Lidwell et al., 2010). Different visual cues like colour, size or font can be used to signify items organized into groups (Tversky, 2001; Fowler & Stanwick, 2004). Similarity of colour results in the strongest grouping effect (Lidwell et al., 2010).

However design of navigation is mostly subjected to overall website appearance and related graphic design decisions and as such bears only limited information value. Design decisions influence also usability of the navigation, e.g. contrast, which is a key element for legibility, or perceived free space (Bartuskova & Krejcar, 2013). The most significant value of every navigation item is its text label, from which we can identify names of individual sections or pages, subjectively organized. If it is a multi-level navigation, we can distinguish hierarchy levels from the items´ arrangement. If there are more navigation areas on the page, we can recognize (or sometimes merely guess) meaning of each group by its position on the page, caption or by its content. That is usually all the available information present in traditional navigation.

Overall the visual design and spatial organization of navigation is subjected to the desired appearance of the website and does not contain any useful additional information. Low information density can be characterized by minimal information at first sight, requiring the user to click before seeing more information (Reinecke & Bernstein, 2011). It was however researched that the descriptive characteristics of tag clouds were appreciated (Walhout et al., 2015). Similarly visualization of article descriptors in the form of semantic networks was well accepted and positively evaluated (Pajić, 2014). Consequently, we assume that higher information density of navigation could be highly appreciated by users.

Tag clouds were already mentioned as a new alternative way to navigate on websites. The important characteristics of tags is their higher information density in comparison to regular navigation. Tags provide both one-click access to information and a snapshot of the "aboutness" of a tagged collection (Trattner et al., 2012). A higher information density of tag clouds along with fewer page revisits (researched in comparison with hierarchical menus) indicate that the use of tag clouds may lead to more focused page selection and better processing of the navigational support compared to a hierarchical menu (Walhout et al., 2015). However tags are rarely being used as a primary navigation, rather as an additional secondary function. The hierarchical navigation remains a standard in web environment also for its structural quality. Limitations of tags are discussed further in the section "Organization by categories vs. tags".

### 4.1.4 Cost in human-computer interactions

Hong et al. (2008) identified two types of cost: interaction cost (mouse clicks, button presses, typing) and attention-switching cost (moving attention from one window to another). Activating navigation link contains both costs - interaction cost of mouse click and attention-switching cost of window reload. The return to previous state (e.g. by Back button) or moving to other page includes again both costs. Users use Back button to return to a landmark page or hub, which indicates that the user has either extracted all he wanted from the page, or that the page does not contain desired information (Danielson, 2002).

If the navigation area contained more information about the links themselves, users could make a more elaborate choice without clicking forth and back without desired success. They would have a better idea about what is hidden behind the navigation link, before actually activating the link. When site map was used as a web navigation (which means higher information density on the visible screen area), users made less use of the Back button (Danielson, 2002). Similarly Walhout et al. (2015) confirmed fewer page revisits with use of tag clouds, which have higher information density.

Much information is hidden in sorting and filtering systems. Many websites offer sorting articles e.g. by alphabet or date, e-commerce sites in addition offer sorting products by price etc. This gain of information however requires an additional click as the interaction cost. Kalbach (2007) reviewed tagging system Blinklist, which offered at that time four arrangements of personal tags - a favourites list, a popularity-based list, a chronological list, and a tag cloud. Each of these arrangements was available after clicking on respective tab. In this case, the navigation area was descriptive, however its information value was divided into several individual pages (tabs), so it cannot be seen simultaneously.

Ware (2008) presented an idea of cognitive cost, which originates from moving through space. He reviewed the basic costs of some common modes of information access, where internal pattern comparison is much more efficient than mouse hovering, selecting or clicking (Ware, 2008). Leuthold et al. (2011) confirmed the hypothesis that opening the dynamic menu needs an additional mouse movement and is thus more costly than just scanning the navigation items. Leavitt and Shneiderman (2006) also stated that content should be formatted to facilitate scanning, and to enable quick understanding. Similarly in e-learning, it is hypothesized that contiguous placement will lead students to read more of the course materials and navigate the course more easily, thus reducing frustration and increasing cognitive presence (Rubin et al., 2010).

Finally the success of social and collaborative systems is dependent on the architecture of interaction, as well as on the costs and benefits of interaction to the individual user (Pirolli, 2007). Generally, as the costs of interaction are driven down, more users participate in the production and use of knowledge (Hong et al., 2008).

### 4.1.5 Organization by categories vs. tags

Items placed in hierarchies should be present only once in the hierarchy. There are also polyhierarchical taxonomies, which allow cross-listing, but if too many items are cross-listed, the hierarchy loses its value (Morville & Rosenfeld, 2006). There is however an increasing trend in classifying content by tags (Hong et al., 2008; Trattner et al., 2012; Walhout et al., 2015). For one item are usually used several tags at once, while traditional category (and hierarchy) remains mutually exclusive without cross-listing. Consequently people can organize information items by placing them into folders or by tagging them with labels (Civan et al., 2009). There is an analogy between hierarchies and folder structures, and between tags and labels. Tagging permits a many-to-many mapping (many tags to many documents), whereas folders (which represent hierarchy of categories) permit only a one-to-many mapping (one folder can contain more documents) (Civan et al., 2009). Alternative concept of exclusivity is the main difference between categories and tags.

We can make further connections between categories and tags and organization structures. Organization by categories offers a complete overview of content, and as such resembles a hierarchical organization structure. Tags can be compared to network / hypertext structure as they also do not have any predefined formal structure. Network according to Morville and Rosenfeld (2006) presents potential for complexity and user confusion. It is probable that tags suffer from the similar problem. Tags do not facilitate relationships between web pages, they do not create a structure or hierarchy. The result is a group of web pages on the same level, with few topics assigned to them, through which they can be accessed. This approach is suitable only for limited types of websites, e.g. for blog or news sites.

Tags face also other limitations. López (2012) argued that folksonomies such as tag clouds have noise from the perspective of knowledge representation. The set of tags then lack of consistency and accuracy (López, 2012). Villela Dantas and Muniz Farias (2010) stated that a problem with the use of tags is that they form an uncontrolled vocabulary, which causes ambiguity. It is difficult to maintain united expressions throughout the website, plus the issues such as synonyms, plural and singular or spelling errors. It is also difficult to describe each webpage only by several tags. Morville and Rosenfeld (2006) asserted that there is no evidence that tagging outperforms traditional approaches to organization.

## 4.2 Limitations of course-based systems

This section presents identified limitations of the existing solutions for web-based education, which were classified as the course-based systems. It is especially devoted to LMSs, which are the most common choice for course-based education.

### 4.2.1 Fixed structure and content

LMS presents learning materials and other course-related information with no significant means to adapt the content and its structure to one´s needs. Resources in course-based learning generally are organized by teachers in fixed course scope, which is not sufficient for higher education today (Peng et al. 2013). Peng et al. (2013) concluded that web-based learning systems used by colleges aim only to display course resources and often neglect users' knowledge management requirement. The possibility to adapt structure of the course could be however very useful for students in many scenarios. They may have different levels of prior domain knowledge, they can be learning under time pressure or they can find it difficult to recognize the important concepts and relationships among them (Lee & Segev, 2012). Somyürek (2015) claims that one of the main criticisms concerning web-based learning environments is the inability to meet different users' needs and preferences. The issue of providing all students with the same content is being solved by adaptive learning, which is discussed in section 3.5 " New approaches in web-based education ".

The personalization should be also extended towards external learning resources. Online learners always search supplemental information and resources out of the LMS (Chen et al., 2012). They should have a possibility to include these materials in their learning environment. At the same time, students should be allowed to modify the structure of the course to their needs. In the opposite case, students may end up downloading materials from LMS and learn from their personal offline folders, individually organized and supplemented by additional materials. The same scenario can arise from unsufficient support of annotation mechanisms, which is discussed in the next paragraph.

Educational materials in commonly used LMSs cannot be organized or filtered by students, not even can they add personal comments. As Hwang et al. (2007) pointed out, limitation of traditional web-based learning is the restricted ability of students to personalize and annotate materials. It is however well-known, that students often annotate printed learning materials, which has usually a positive effect on both knowledge acquisition and retention. Annotation, which is the behavior of making marks on reading materials, is important in traditional learning activities (Hwang et al., 2007). According to Chen et al. (2012), taking notes is a common learning behavior. Marshall and Brush (2004) recognized the need for various forms of highlighting particularly for personal use and re-reading. In many studies of annotation was confirmed that students have positive attitudes toward the application of the annotation system to learning (e.g. Hwang et al., 2007; Su et al., 2010). LMSs belong to the most widespread learning systems; but the support for annotation is unsufficient. LMS should provide students with means for their active contribution to the presented content (in the form of tagging, commenting and other annotating mechanisms), its sharing and organization (Šimko et al., 2010). Peng et al. (2013) suggested that students need to select the useful content from a course, consume it and re-organize it by themselves.

Need for personalization of course structure and resources is not limited only to the needs of students. In the study Sobreira and Tchounikine (2015), teachers expressed their appreciation of possibility to adapt the representation to their practices and perspectives. The workload for online instructors is often more than expected, because technology does not reduce an instructor's workload, it just changes its nature (Devedzic, 2006).

As the main issue related to fixed structure and content of course-based learning systems such as LMSs was consequently identified, for both teachers and students:

- an insufficient personalization support for:
    - organization of learning courses
    - organization of learning resources inside courses
    - annotation mechanisms (tags, notes, comments,..)

### 4.2.2 Content management and user interface

LMSs, as well as wikis and CMSs of websites, offer seemingly limitless e-space, where teachers can add content. This arrangement often supports unadvisable behaviour of continuously accumulating content and just making it available to learners, who may eventually face similar information overload as with the Google search. Google becomes a living index and repository for enormous content (Atkins et al., 2007). Also learning course in LMS can contain many resources, which can be intimidating for learners. Without any support, the student can only with difficulties identify which parts of the course are relevant and which are presenting only additional, not that important information (Šimko et al., 2010).

There is also a frequent issue with keeping old files along with the new ones. More effective approach for learner would be refinement of existing resources and keeping their amount at a reasonable level. We now live in a world of abundance where editing and curating become more crucial than ever (Atkins et al., 2007). However user interface of these systems usually does not encourage this desirable behaviour in teachers. Actions that are made easy by the system are more likely to occur, while those that have barriers are less likely to (Rubin et al., 2010). In consequence students are forced to choose the right materials among those offered as learning content. However with the increasing number of available learning materials, it is crucial to be able to support students in their way through the course, to locate, recognize and understand information, which is the most relevant, considering the given time and progress of the student (Šimko et al., 2010). Furthermore, LMS systems are loaded with too much functionality in a complex interface, which often discourage teachers and students from exploration of both basic and advanced functions.

As the main issues related to content management and user interface of course-based learning systems such as LMSs were consequently identified:

- (students perspective) the lack of vizualization for distinguishing:
  - the course basic structure
  - between important and additional (optional) resources
- (teachers perspective) the system´s interface does not encourage:
  - regular revising of existing content
  - disposing of outdated content

### 4.2.3 Analysis performed on a selected LMS

We conducted an analysis of selected computer science courses in Blackboard Learn LMS at the Faculty of Informatics and Management of the University of Hradec Kralove, Czech Republic. Only courses for Czech students in full-time study program were selected for the analysis, the total of 15 courses. The main goals of the analysis were: identify data formats in use, identify types of content and identify content organization.

Every analyzed course contained some information about the course, usually: course requirements and goal, evaluation methods, syllabus, frequently asked questions, course contents and plan of lectures and seminars. These materials were available to students mostly in PDF format or rich text (implemented in LMS by the rich text editors). The majority of learning materials were from lectures and seminars - presentations, lecture notes, instructions and other learning materials. These resources were stored in PPT(X) or PDF, often in both formats (as presentation PPT(X) and print version PDF). Additional resources like examples, tutorials, articles, applications, glossary or recommended literature could be accessed most frequently as PDF files or reference links, but the variety of file formats was the biggest in this category, including also rich text, PPT(X), ZIP files, subject-specific files (usually application files), HTML, image or video files. Finally we defined categories Tasks and Community, which included seminar works, tests, surveys, discussion and announcements, mostly implemented by LMS as special actions. The results of the analysis are summarized in the following table [Table 4].

**Table 4. Identified types of content and data formats of files**

| Defined category | Types of content | more common file types | less common file types |
|---|---|---|---|
| About the course | about the course / subject, goal, requirements, evaluation, FAQ, syllabus, plan of lectures / seminars, course contents | rich text, PDF | HTML, reference link, special |
| Lectures and seminars (practice) | presentations, lecture notes, learning materials, instructions | PDF, PPT(X) | rich text, ZIP, HTML |
| Additional sources | examples, additional sources (tutorials, articles, applications,..), glossary, recommended literature | PDF, reference link | rich text, PPT(X), ZIP, subject-specific, HTML, image, video |
| Tasks | seminar works, tests, surveys | special | rich text, PDF, HTML |
| Community | discussion, announcements | special | rich text |

The last task of conducted analysis was to identify means of content organization. The basic organization schemes are location, alphabet, time, category and continuum (Lidwell et al., 2010). The most common way to organize content in analyzed 15 computer science courses in Blackboard Learn LMS was:

- by category - primary content division, represented also in sidebar navigation, sections usually partially reflect content types as categories,
- by continuum (time) - secondary content division, usually used in lectures / seminars section, which are divided into sessions, ranging from 6 to 13.

The analysis of learning resources in Blackboard Learn LMS brought several issues to our attention, which are discussed in the following paragraphs.

All courses have their own repository within the Blackboard Learn LMS. This has more implications. Firstly, learning materials including their organization, labels, file type and the way it is stored in a LMS depends on the instructor of each course. Although every course has some information about requirements, it can be labelled differently or placed in the different place in the course navigation, so it is quite difficult to process the same content of several courses at once. Secondly, it means that although the courses have similar content types, it is not possible for the learner to navigate through the content by its type. E.g. it is not possible to view requirements of all courses at once, you have to enter each course and look for them there.

To present another example, the analysis confirmed that almost every courses´ seminars and lectures are organized by their sequence, usually from 1. to 13. week of study, which is the length of the school term at the University of Hradec Kralove. However learners cannot organize learning resources by this sequence across more learning courses, which would be surely beneficial for them. As discussed by Rubin et al. (2010), Blackboard has limited tools to enable grouping across different kinds of tools. This means that the elements needed for the week's work are spread across several pages, and require multiple clicks to access the materials within the folders (Rubin et al., 2010). If the students want to display all learning resources from the particular week, they have to enter each course separately and find the materials under different labelling and organization system.

Furthermore the analysis has revealed that LMS often offers more different ways of handling the content with similar result (e.g. Content item, File content type and Page, or Content folder and Learning module). This causes more inconsistencies not only across the courses, but also within one course. Before the user clicks on some item, he does not know if that link would lead to a new page within the LMS, to a PDF file opened within the LMS, to a file opened in a new window or if it triggers downloading the file. Too many functions without an intuitive user interface support unintentional inconsistencies.

To conclude, the performed analysis led us to several conclusions:

- the majority of courses share the same or similar categories of learning content
- many learning courses use similar techniques for organizing content
- the primary division of content is by category in the majority of courses
- the secondary division of main learning content is by sequence (continuum / time) in the majority of courses

LMSs do not use these facts to adapt organization of learning content, which would make acces to resources easier. Traditional LMSs also do not support consistent organization structure across more courses. However the learner is the main user of learning system and he usually attends more than one course. Usability of the learning system would be enhanced if the user could assess content of all his courses in one layout (see chapter 4.4 "Organization and navigation issues", especially sub-chapters 4.4.1 "Disorientation and site maps" and 4.4.4 "Cost in human-computer interactions").

## 4.3 Limitations of repository-based systems

This section presents identified limitations of the existing common solutions, which were classified to the learning systems based on a repository. Some of these limitations were already dealt with in novel approaches, which are discussed and evaluated in section 3.5 "Untraditional approaches". Already researched limitations are reviewed along with new findings, based on the analysis of usability and performance of several LORs.

### 4.3.1 Metadata and reusability

Learning content management systems (LCMSs) or interchangeably learning object repositories (LORs) take advantage of re-usability of learning objects (LOs), however searching and using a LO in the LOR may take too much time (Yigit et al., 2014). As a result, composing a learning course from free LOs in LOR can be much more demanding than managing one´s own learning resources.

Concerning re-usability, the most popular SCORM standard has limitations that are commonly discussed in the research literature, especially in the areas of pedagogy, adaptive learning and learning assessment data (Mason & Ellis, 2009). Rego et al. carried out a comparative analysis of specifications IMS, AICC, SCORM and Dublin Core and they chose IMS specification for their system implementation over SCORM, which was lacking in these features: learner profile and registration, Q&T and DR interoperability, learning design and accessibility (Rego et al., 2010).

In addition, SCORM was created assuming a single authority (teacher) that creates and assigns metadata, but in practice, SCORM content hardly includes metadata content (Redondo et al., 2010). There are many various reasons why users do not fill in metadata completely and correctly, e.g. ignorance of metadata importance or lack of time or motivation. However only the LOs that are appropriately tagged with a metadata record can be retrieved (Garcia-Cabot et al., 2015). If metadata are not initially filled by teacher, it is difficult for a community to alter or add metadata tags within SCORM infrastructure and it is currently impossible for a learner to contribute to a course by adding or altering its content (Redondo et al., 2010). However SCORM is already a well-established standard, so these limitations are difficult to solve.

### 4.3.2 Analysis performed on selected LORs

A comparative analysis of LORs was made by Neven and Duval in 2002. Among the larger LORs were analyzed Ariadne, Smete, Merlot, Careo and Edna (Neven & Duval, 2002). All of them with an exception of Edna (which used Dublin Core profile) used metadata based on IEEE LOM profile. These same LORs were revisited in a comparative study of Roy et al., so these services were still active as of December 2009 (Roy et al., 2010). We tried to access these repositories at the time of writing this treatise. First we used the original link to these repositories, then we used Google search.

**Table 5. Searching for several selected LORs**

| | **Links to repositories** | **Status** |
|---|---|---|
| **ARIADNE** | http://ariadne.grnet.gr/ariadne_finder | working |
| **SMETE** | http://www.smete.org/ | not working |
| **MERLOT** | http://www.merlot.org/ | working |
| **CAREO** | http://careo.org/ | missing link to LOR |
| | http://www.ucalgary.ca/newcurrents/ Vol8.8/careo_nov.html | link to LOR not working |
| **EdNA** | http://www.edna.edu.au/ | not working |
| | http://goo.gl/9MKToz | |

We found out that three out of five LORs (growing and popular at their time) are not active anymore. The Australian journal commented EdNA´s demise, recalling that this service went to work in 1997 as a browser and search engine for education resources, finally overpowered by Google. Consultant Jon Mason said the EdNA service could have and should have evolved into critical infrastructure supporting the education and training sector and the story of EdNA was a failure to develop its full potential for collaboration and networking (The Australian, 2011).

Zervas et al. (2014) conducted a large quantitative analysis of LORs. It is surprising that EdNA appears in their list of 49 currently operating LORs, nonetheless the link is not functioning. At the time of writing this treatise, ARIADNE and MERLOT services are still working, but they are facing several qualitative issues, which will be discussed for each system separately in the next two paragraphs. Sampson and Zervas (2013) proposed a master list of essential functionalities, which should LORs implement from the knowledge management perspective. However the results of the follow-up analysis suggested that LORs functionalities can only marginally affect growth of LOs in LORs (Zervas et al., 2014). In this section, we have inquired into basic usability issues and user experience of selected LORs, namely MERLOT and ARIADNE.

MERLOT (Multimedia Educational Resource for Learning and Online Teaching) is a curated collection of free and open online teaching, learning, and faculty development services contributed and used by an international education community (MERLOT, 2015). In MERLOT you can find materials by browsing all materials organized into categories, but that proved to be quite ineffective, as e.g. "Programming" subcategory (which is not further divided) had 3 882 results at the time of writing this treatise. In addition, hierarchy of categories is not always very intuitive, e.g. subcategory "Mobile App Development" is placed under "Academic Support Services" category, "Content Management Systems" is placed under "Faculty Development" etc. Probably because of the wide range of disciplines presented in MERLOT, the search function also often needs to specify the category and subcategory, e.g. when searching with "php" keyword, there are 1798 results. We need to click through hierarchy of categories to get to "Programming" and "Programming languages" in order to gain access to the materials about PHP programming language, which narrows the list of results to 33. When we look for something more specific like "web design", the system still presents to us many not so related search results (454), because default search is by keywords and it uses OR operator instead of AND. We have to enter advanced search mode and choose "exact phrase" settings to get more relevant results (51). We can further filter the results e.g. by material type, but the advanced search options are not available to refine the search (you have to go to separate advanced search and type all the requirements before starting the search). The learning resources are mostly references on various webpages or files. Tested with results of "web design" keywords, the system offered materials even 15 years old at top positions, some of them are updated, but some of them no longer exist or they are very outdated, which is definitely not suitable for learning, especially in the area of technologies and many other evolving fields of knowledge.

ARIADNE offers standards-based technology infrastructure that allows the publication and management of digital learning resources in an open and scalable way, in order to provide flexible, effective and efficient access to large-scale educational collections in a way that goes beyond what typical search engines provide (ARIADNE, 2015). Browsing through categories is not available with Ariadne LOR, only search by metadata, particularly keywords. On "web design" search term, the system offered 172 results at the time of writing this treatise. The first several results have the same name and almost the same keywords, thus they are not distinguishable from each other. After accessing the resource, which in this case is only displaying details about the entry, these resources are distinguishable only by file name in attachment. Furthermore, these files contain only several rows of text and as such they are approximately the same length as the list of keywords, associated with each of this entry. This excessive amount of keywords and wrongly filled in metadata can be a consequence of various implementations of automation, which aspire to help users with these processes. When searching for "php", 298 results are offered. In ARIADNE we can filter the results by language, context (type of education), resource type, end user role (learner or teacher) or providers. When we narrow the search for English language, another problem appears - several results at top position are still not in English, moreover when trying to access the resource, we found out that it does not exist anymore, which is not very encouraging.

Our analysis of MERLOT and ARIADNE identified several issues related to LORs. One of the main causes of the failing sustainability of LORs is probably a large scale of resources, which are added but not:

- described sufficiently (metadata are non-existent, inaccurate or redundant by automated processes);
- further managed (revised, updated, deleted).

Reusability is one of the main reasons why LORs with LOs are promoted, however practical reusability is not guaranteed. The consequence of insufficient metadata are missing search results, inaccurate search results or search results, which are outdated or contain reference to non-existent resources. Even with the advanced search options, it is not possible to search efficiently if the resources are not described properly. As a consequence, creating a learning course from LOs in LORs can consume much time and effort and in the end it can be much more demanding than managing one´s own learning resources. Also LOs usually cannot be simply reused in other context (than that for which they were created), due to various requirements of each teacher, course or institution. The educational institutions have their own curriculums, teachers have their own learning methods and materials and LOs can be rarely reused without modifications in other contexts. These are the basic issues we encountered during working with these systems:

- an inefficient and confusing hierarchy and labelling of categories
- search options
  - unbalanced default search options
  - advanced search options not available to refine the ongoing search
- search results (also at top positions)
  - are outdated
  - do not exist anymore
- metadata
  - missing metadata
  - wrongly filled in metadata
  - an insufficiently descriptive metadata
  - an accumulation of keywords

# 5 Theoretical proposals

The author´s contribution in theory is presented in this chapter, which is divided into two separate sections. The first section is devoted to the framework of design requirements, which has also quite a useful application in practice. The second section extends the existing theory about organization schemes (see chapter 3.3 for introduction to this topic). This chapter, along with the theory from chapter 3 "State of the art", forms a theoretical foundation for interfaces designs, which are proposed later in this dissertation thesis.

## 5.1 Framework of design requirements

The framework presented in this chapter was used to identify and delimit research areas, which are dealt with in this dissertation. It presents usability and aesthetics attributes, logically sorted into five main groups of design requirements. At the same time, this framework is considered as one of the main contributions of this disseration.

Its practical usage lies in the area of development and testing of web-based systems, especially educational and knowledge-based systems. The existing evaluations of such systems are mostly based on a subjective feedback from end users, in order to measure their satisfaction and experience with the system (e.g. Unal & Unal, 2011; Carvalho et al., 2011). The results usually only indicate which areas are weaker than others; comments obtained from users are often casual and fuzzy. Therefore we propose a systematic review of usability and visual appeal by experts in HCI to complement current practice. This assessment would be based on the presented framework, which provides a concise easy to follow checklist, covering all significant areas of design assessment. This approach takes use of collective intelligence and knowledge in the area of design and usability, since all web-based systems share common principles for information retrieval and interaction. It offers factual design issues which should be dealt with and can be especially useful in cases, where feedback from users is hard to obtain or it does not reveal any useful information.

The proposed framework of design requirements for web-based interfaces is based on an analysis of design guidelines in literature. Many authors attempted for representative list of universal design principles, the same principles are often repeated and amended for specific areas of expertise. We have analyzed several promising publications about web design, interaction design, visual or graphic design and generally user interfaces. We have also explored design guidelines for use in education. References which were analyzed and included in the resulting framework of design requirements are listed in [Table 6].

**Table 6. The list of references used in the framework**

| | Reference | Scope |
|---|---|---|
| O | Williams, 2008 | Universal design principles |
| C | Lidwell et al., 2010 | |
| F | Weinschenk, 2011 | |
| I | Morville & Rosenfeld, 2006 | Web / interaction design, design of user interfaces |
| G | Leavitt & Shneiderman, 2006 | |
| E | Lynch & Horton, 2009 | |
| R | Johnson, 2010 | |
| K | Tidwell, 2011 | |
| P | Colborne, 2011 | |
| H | Golombisky & Hagen, 2013 | Visual / graphic design |
| L | Dabner et al., 2014 | |
| J | Malamed, 2015 | |
| B | Chapnick & Meloy, 2005 | Design in education |
| D | Bozarth, 2008 | |
| M | Vai & Sosulski, 2011 | |
| N | Clark & Lyons, 2011 | |
| A | Horton, 2012b | |

The selection of particular publications was based on their extent of design-themed content, structural and factual quality, assessments, availability, etc. More recent publications were preferred; however several older publications were also included for their quality and comprehensiveness. The extent of publication years - from 2005 to 2015 - also provides solid foundation for our conclusions. The resulting framework is however not just a compilation of design principles from existing sources. The procedure included:

- thorough analysis of identified design principles, rules, guidelines, etc.
- decision about their importance, applicability for researched user interfaces, and similarity or interchangeability with other design principles
- joining of closely related principles under the common concept; resulting design principles or concepts were marked as "design attributes"
- categorization of design attributes into coherent groups; these groups were marked as "design requirements"

The early version of this framework was published under the title "Design Requirements of Usability and Aesthetics for e-Learning Purposes" (see Bartuskova & Krejcar, 2014a). The authors identified usability and aesthetics attributes, based on research of general design principles and relevant principles from e-learning and webdesign. These attributes were logically sorted into five main groups of design requirements, defined by the authors. The framework presented here was thoroughly revised and extended by a number of concepts in comparison to the originally published version. The selection of analyzed publications was extended by works focused on educational design, universal design, web design, interaction design and visual design. Furthemore, original framework was focused only on design of educational materials. Revised framework presented in this thesis is applicable on web-based applications and interfaces; notable addition is thus navigation.

The basic schema of proposed framework of design requirements is indicated in [Fig. 1]. Individual design attributes were logically categorized under five groups of design requirements, which were identified as: readability, visual design, organization, navigation and consistency. These requirements are depicted in [Fig. 1] as top five boxes; design attributes are allocated under the respective requirements. Many design principles are connected with others. Either they are commonly applied together to reach desirable effect or the presence of one principle is unavoidable because it manifests during use of some other principle. This is a common issue in design, as even two principal design dimensions - usability and aesthetics - are interrelated and influence each other.

The simplified schema of proposed framework in [Fig. 1] does not include "similar concepts". Similar concept present a principle or joined concept, which

- can be interchanged with the particular design attribute,
- can be regarded as a part of the particular design attribute,
- is related to the particular design attribute in a way, that excludes it from the same position, i.e. it would present a duplicity

The detailed views of proposed framework are presented individually for each design requirement in the following sub-chapters. In these views are similar concepts listed along with selected design attributes. All design attributes and similar concepts are also associated with literature references, marked by letters A-J. The list of references used in framework was presented in [Table 6]. The reference pertaining to particular design attribute (or similar concept) signifies that this term was presented, proposed, explained or otherwise mentioned in the respective publication. The detailed commentary for each section was omitted from this treatise due to space limitations.

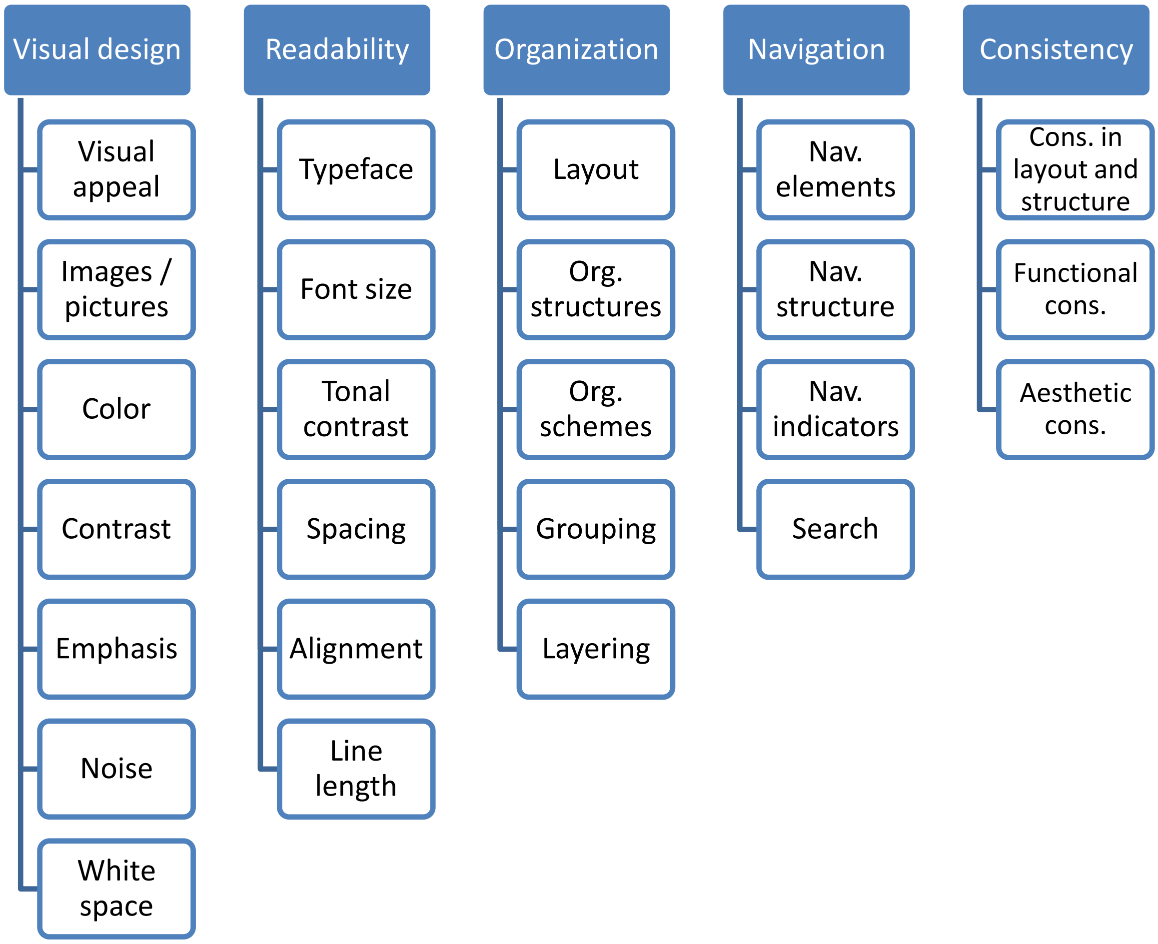



**Fig. 1. Schema of proposed framework of design requirements for web interfaces**

### 5.1.1 Visual design

Visual design (also aesthetic or graphic design) is important in every human-computer interaction. While in disciplines such as web design is aesthetics a key predictor of an overall impression or user satisfaction (Hassenzahl, 2004), its role in e-learning is more of a backstage unobtrusive nature. Horton (2012b) claims that good visual design is about solving problems, not drawing attention. Vai and Sosulski (2011) stated that good visual design supports understanding through simplicity, clarity, and organization. Although learners generally do not appreciate good visual design, it is noticed immediately if learners are confused or cannot find what they need. Horton (2012b) further argues that e-learning communicates visually, yet visual design in e-learning is often ignored or treated as a minor cosmetic detail. The following table [Table 7] presents visual design principles applicable on learning interfaces and standalone learning materials as well.

**Table 7. Design attributes of visual design**

| Requirement | Attributes | Similar concepts |
|---|---|---|
| **Visual design [A,E,I,J,K,M,N]**<br><br>Aesthetic design [B,C]<br><br>Graphic design [E,M,N,O,R] | Visual appeal [E,H,J] | Look and feel [A,B,E]<br>Aesthetic appeal [J,N,O]<br>Aesthetic quality [I,L]<br>Attractive interface / page [D,O]<br>Aesthetic-usability effect [B,C] |
| | Images / pictures [D,G,J,K,L,M,N,R] | Multimedia principle [D,N]<br>Relevant / supportive graphics [A,D,E,J,L]<br>Icons [A,C,D,F,I,M,N]<br>Symbols [L,M,N]<br>Infographic [H,J,K,L]<br>Recognition over recall [C,F,R]<br>Image quality [H,J,L] |
| | Colour [C,D,E,I,J,K,L,M,N,O,R] | Colour meaning [B,D,F.J]<br>Colour palette [B,E,H,L,N,O] |
| | Contrast [D,H,J,K,L,N,O] | Visual contrast [E,J,K,L]<br>Colour contrast [A,E,F,J,L,R]<br>Typographic contrast [E,K,L,O]<br>Size contrast [B,K,L,O] |
| | Emphasis [A,B,D,E,G,J,K,L,M] | Highlighting [C,D,G,I,K,L,M,N]<br>Visual hierarchy [E,H,J,K,L,R]<br>Von Restorff effect [B]<br>Colour emphasis [A,E,J,M]<br>Visual weight [C,H,K]<br>Visual cues / clues [C,D,G,J,N,O,P,R] |
| | Noise [A,C,D,I,K,N] | Cluttered displays / interface [B,G,K,M]<br>Signal-noise ratio [C,E,I]<br>Visual noise [E,K,M,N,R]<br>Clutter [D,G,I,J,O]<br>Visual clutter [L,P,R] |
| | White space [B,D,E,G,H,I,J,K,L,M,N,O,P] | Positive / negative space [H,J,L]<br>Margins [H,J,K,N] |

Visual appeal of an interface, presentation or page helps to create positive attitude towards learning. Visual appeal has the same or similar meaning as aesthetic appeal, aesthetic quality, attractiveness, and overall look and feel. Golombisky and Hagen (2013) discussed adding visual appeal through use of images, both photos and illustrations. Malamed (2015) discussed enhancing visual appeal by means of colour, contrast and graphics. According to Tractinsky (2000), visual aesthetics of an interface significantly influences users´ perceived ease of use of the entire system. This rule is also known as the "Aesthetic-usability" principle or effect. This principle implies that aesthetic designs are perceived as easier to use than less-aesthetic designs (Lidwell et al., 2010).

Use of multiple presentation media is always encouraged (i.e. multimedia principle), as learning is enhanced by the presentation of words and pictures rather than words alone (Bozarth, 2008; Clark & Mayer, 2011). Level of processing is also deeper when images accompany the text, which is essential for recall and retention of the information (Lidwell et al., 2010). Johnson (2010) recommends to use pictures where possible to convey function, because people recognize pictures very quickly and recognizing a picture also stimulates the recall of associated information. This is in accord with the "Recognition over recall" principle, as people are better at recognizing things they have previously experienced (Lidwell et al., 2010; Weinschenk, 2011). However only images that are complementary to the learning process and that supports the learning goal should be used (Malamed, 2015). In other words, graphics have to be relevant otherwise it creates visual noise and disturbs visual hierarchy, which is an important aspect of visual presentation. Supportive graphics as e.g. icons or symbols makes easier to find, recognize, learn and remember objects and concepts (Lidwell et al., 2010). Information graphics, including maps, tables, and graphs, communicate knowledge visually rather than verbally in order for user to learn something (Tidwell, 2011). Today's user interfaces often use pictures to convey function, such as desktop or toolbar icons, error symbols, and graphically depicted choices (Johnson, 2010).

Colour in design is a very powerful tool, which influences the overall appearance and emotional impact on learner. It was confirmed that colour has an influence on the learning process (Malamed, 2015). Colour can also reinforce the organization and meaning of elements in a design (Lidwell et al., 2010). Consequently colour can be used for separation of different functional areas (such as header, navigation, main content, ...) to create visual hierarchy and for highlighting. Impact of colour is mostly subjective, yet there are some general rules e.g. concerning warm and cold colours. Bonnardel et al. (2011) researched which colours are perceived as attractive on websites, where attractivity is defined by feelings, if the colours are perceived as appropriate, pleasant or interesting (Cyr et al. 2010). The study of Hall and Hanna (2004) confirms, that preferred colour scheme leads to higher user rating of website´s aesthetics. Perception and meaning of colours is also subjected to cultural differences (Cyr et al., 2010; Malamed, 2015). Combination of colours for particular interface, page etc. can be expressed by defined colour palette.

Contrast is frequently discussed as a contrast of colour, size, type or generally visual contrast. Colour and contrast are key components of universal usability (Lynch & Horton, 2009). While tonal contrast is explained by difference in luminance, colour contrast is defined by difference in hue. Tidwell (2011) recommends high typographic contrast, including contrasting font weights, sizes and colours. Malamed (2015) defined contrast as a visual difference created by placing elements with opposing features next to each other and introduced a broad list of contrast types: spatial, layout, form, direction, style, size, colour, texture and typographic contrast. Contrast is one of the most effective ways to add visual interest to the page and to create an organizational hierarchy (Williams, 2008) or visual hierarchy (Malamed, 2015) among different elements.

Emphasising or highlighting should be used in moderate rate, recommended amount of highlighted content ranges from 10% (Lidwell et al., 2010) to 15% (Horton, 2012b). Among emphasis mechanisms belong usage of colour, size and bold or otherwise emphasised type. Similar to highlighting is Von Restorff effect. This principle suggests use of different style for elements which are important and should be remembered (Chapnick and Meloy, 2005; Fee, 2009). Highlighting and creating emphasis is closely related to another term: visual hierarchy. Malamed (2015) presented a list of techniques for creating emphasis in order to establish a visual hierarchy. Some of them are using already mentioned design attributes, e.g. colour, scale (size), isolation (white space, proximity) or visual clues (supportive graphics). Other proposed techniques for emphasis were e.g. position, images or density. Visual hierarchy means that the most important content should stand out the most, and the least important should stand out the least (Tidwell, 2011). The hierarchy tells viewers what parts of the layout are more important than others (Golombisky & Hagen, 2013) and provides a way to navigate content (Malamed, 2015). Implementing visual hierarchy includes usage of colours, sizes, spacing and styles in order to visually separate blocks of content. Closely related to emphasis etc. are also visual cues, which are generally used to draw attention to certain elements.

Over-emphasising among others can lead to unadvisable noise in design. Signal-to-noise ratio is a ratio of relevant to irrelevant information in a display (Lidwell et al., 2010). Noise can be also understood in the terms of content as unnecessary or useless information. If successive lines of text contain a lot of repetition, it is hard to pick out the important information (Johnson, 2010). Overuse or inappropriate use of visual features such as decorative graphics, textures or gradients can also create undesired visual noise. Minimizing noise generally means removing unnecessary elements, and minimizing the expression of necessary elements (Lidwell et al., 2010).

Negative and positive space play crucial complementary roles in successful visual communication (Golombisky & Hagen, 2013). Negative or more commonly called white space means the unused areas that are not filled with an image, shape,or text (Malamed, 2015). Ample white space makes it easy to perceive and mentally process information, a crucial formula for effective learning design (Malamed, 2015). White space can be also used to group or separate things (Golombisky & Hagen, 2013).

### 5.1.2 Readability

Readability of text is one of the key usability aspects. It is even more important in the e-learning courses than in traditional courses, because reading on a computer screen is harder than reading paper (Weinschenk, 2011). Readability is sometimes interchanged with another concept - legibility (e.g. Chapnick & Meloy, 2005). While legibility is defined by the visual clarity of text (Lidwell et al., 2010), the definitions for readability vary. Malamed (2015) defined readability as how easy is to read an extended amount of text, which is influenced e.g. by size, line length and emphasizing. According to Lidwell et al. (2010), readability is the degree to which prose can be understood, based on the complexity of words and sentences. Guidelines for readability are more exact than in other areas; Horton (2012b) presented legibility aspects with recommended values based on a half-century of research. The related term - typography - is the process of arranging letters, words and text (Dabner et al., 2014), after which we can evaluate legibility of the particular arrangement. Identified design attributes of readability are presented in [Table 8].

**Table 8. Design attributes of readability**

| Requirement | Attributes | Similar concepts |
|---|---|---|
| **Readability [B,C,G,H,J]**<br><br>Legibility [A,C,E,H,J]<br><br>Typography [A,C,E,H,J,K] | Typeface [C,E,H,J,L,M,N] | Font [A,D,C,F,G,H,I,J,K,L,N,O] |
| | Font size [A,B,C,E,F,H,I,K] | Type size [A,B,C,H,L,M,N,O]<br>Point size [J,L] |
| | Tonal contrast [A,C,E,G,L,M] | Foreground / background [A,D,G,K,R] |
| | Spacing [C,E,F,H,J,K,L,M,O] | Letter / word spacing [B,C,H,J,L,O]<br>Line spacing [A,B,H,J,K,O]<br>Leading [C,H,J,K,L] |
| | Alignment [A,B,C,E,J,K,L,N,O] | Justification [B,H,K,L]<br>Visual alignment [G,O] |
| | Line length [A,C,E,F,G,J,K,L,O] | |

The typeface chosen for learning and information content is a critical decision (Malamed, 2015). We should generally choose font with simple character shapes, preferably san-serif. Serif typefaces are considered easier to read in print, however sans-serif typefaces are considered easier to read on monitors (Tidwell, 2011; Malamed, 2015). Legibility of font indicates the level to which characters in text are recognizable and understandable regarding their appearance. It includes factors such as x-height, character shapes, stroke contrast, the size of its counters, serifs or lack thereof, and weight (Strizver, 2010). Simple typeface is important not only for legibility and pattern recognition but also for e-learning process, because difficulty of reading the text transfers the difficulty on the text itself (Weinschenk, 2011). Typeface and font are often being used interchangeably, however they are different concepts. While typeface refers to the shared design of a collection of characters (e.g. Garamond), font is a complete character set (e.g. Garamond bold 10pt) (Malamed, 2015).

Appropriate font size (also called type size or point size) depends mostly on the type of material, for text documents is minimal recommended font size 10pt (Horton, 2012b). Research has shown that fonts smaller than 12 points elicit slower reading performance from users (Leavitt & Shneiderman, 2006). Font size or size in general can be used for expressing contrast.

Tonal contrast is a usability aspect with direct impact on text readability but also on recognition of pictures. Tonal contrast defines the difference between the perceived lightness of two colours (Stone, 2013). It should be high enough between foreground and background, and kept low in background for ensuring the quiet background (Horton, 2012b; Bozarth, 2008). Noisy background is usually a result of textures or background images. Patterned or textured backgrounds can also dramatically reduce legibility (Lidwell et al., 2010). Leavitt and Shneiderman (2006) stated that complex background images can interfere with reading the foreground text. Hall and Hanna (2004) and Horton (2012b) among others confirmed, that higher contrast leads to better text readability. Stone (2013) recommends, on the grounds of ISO specifications, 3:1 minimum contrast for legibility, with 5:1 preferred, and 10:1 for small text. Colours with contrast 10:1 roughly correspond to the corners of the RGB colour cube (Stone, 2013). Additional issue with tonal contrast is, whether dark text and light background or light text and dark background are preferable. Horton (2012b) states in his research that in light offices and bright monitors is dark text on light background better. Lidwell et al. (2010) and Tidwell (2011) confirms that dark text or generally foreground on light backgrounds is preferred. The same can be said for e-learning materials, which are studied on computer screens. This setting also allows easier transition from electronic to paper materials.

Spacing is discussed usually in relation with typography as letter spacing, word spacing and line spacing (leading). Horton (2012b) recommends line spacing 1/30 of line length. Suitable line spacing is usually computed automatically based on the particular font. Leading is the technical term for line spacing (Golombisky & Hagen, 2013). As for letter spacing, proportionally spaced typefaces are preferred over monospaced (Lidwell et al., 2010). Spacing can be however also understood generally as spacing between individual design elements. In this sense is spacing closely related to visual design, particularly white space (see section 5.1.1.).

Alignment or justification is another design attribute. Its meaning can be limited only to text, then there are only four possibilities: left justified, right justified, centered or fully justified. The best justification for reading is always left justified (flush left with ragged right), which accommodates natural word spacing and provides easy eye tracking (Golombisky & Hagen, 2013). Alignment in the broader sense provides visual order by creating implied vertical or horizontal lines along the edges (Malamed, 2015). When elements in a design are aligned with one or more other elements, it creates a sense of unity which contributes to the design's overall aesthetic and perceived stability (Lidwell et al., 2010). The basic purpose of alignment is then to unify and organize the page (Williams, 2008). Alignment in this broader meaning transcends from readability also to design consistency (see section 5.1.5.).

Appropriate line length is disputable, as people read faster with a longer line length, but they prefer a shorter line length (Weinschenk, 2011; Tidwell, 2011). Still Tidwell (2011) specifies two possible optimal line lengths for easy reading; 10 to 12 average English words per line or 30 to 35 em widths (width of font's lowercase m). Horton (2012b) recommends 40-60 characters per line.

The author encountered several problems from experience with e-learning courses concerning text legibility. First problem arises from automatic processing in PowerPoint presentations - when the text does not fit in the frame, it is made smaller. Switching of font sizes during reading is not very comfortable for learners (see also section 5.1.5 about consistency). This is more significant issue when printing the material, especially with favourite layout of 6 frames per page. Smaller fonts are often hardly legible. The next frequent issue is noisy background - even some of default styles of PowerPoint application have backgrounds with considerable contrast.

### 5.1.3 Organization

Appropriate organization of content is very important for every presentation media. If the information is organized, it is more likely to be read and more likely to be remembered

(Williams, 2008). Organization of learning content is dependent on type and purpose of particular learning interface. It should also reflect user needs and technological changes. E.g. if a use on mobile devices can be expected, flexible layout should be implemented instead of layout with a fixed width. We can however always use general design rules and recommendations as a solid foundation. The design principles related to organization and applicable on learning interfaces are summarized in [Table 9].

**Table 9. Design attributes of organization**

| Requirement | Attributes | Similar concepts |
|---|---|---|
| **Organization [C,E,G,I,L, M,N,O,P]** | Layout [A,B,E,H,J,K,L,M,N,O,P] | Placement of items [C,D,H,K,L,N,O]<br>Composition [C,H,L]<br>Functional areas [A,J,N]<br>Focal point [H,J,K,L,O]<br>Z movement / pattern [D,H,J] |
| | Organization structures [E,I] | Org. models / visuals [K,N]<br>Org. hierarchy [E,N,O]<br>Org. structure [D,L]<br>Relationships [C,G,H,I,K,O,R]<br>Matrix / table [G,K,N]<br>Hierarchical org.[A,C,E,I] |
| | Organization(al) schemes [E,F,I,P] | LATCH [B,C]<br>Five Hat Racks [C,E]<br>Sorting [I,K]<br>Categories / categorization [B,C,F,G,I,K,L,P]<br>Hierarchy [A,B,C,E,G,I,K,N,O] |
| | Grouping [G,J,K,L,O,R] | Proximity (Gestalt) [B,C,E,F,H,J,K,L,N,O,R]<br>Chunking [C,D,E,F,I,J,K,M,N,P]<br>Contiguity principle [D,N]<br>Grouping of related [C,G,O]<br>Colour grouping [G,J,N]<br>Logical grouping [C,E,I] |
| | Layering [C,J,K,P] | Progressive disclosure [F,K,P]<br>Extraneous content [B,G]<br>Extraneous information [D,E]<br>Coherence principle [D,L,N] |

As the main design attributes related to organization were identified: layout, organization structures and schemes, grouping and layering. Many similar or nearly same concepts are combined under these design attributes under different names. At the same time, many terms are being described loosely and embody more meanings.

Layout is how all the elements of a page (text, graphics, navigation elements and other items) are arranged (Chapnick & Meloy, 2005). Accoring to Horton (2012b), the most important characteristic of a layout is that learners find it predictable. This predictability corresponds with other design requirement: consistency, explained in section 5.1.5. Newer definitions of layout were presented e.g. by Dabner et al. (2014); "layout refers to the organization of disparate material that makes up the content of a design", or by Malamed (2015); "a layout creates structure in space through the considered placement of elements in order to solve a problem". Visual design focuses on constructing layouts that are organized to create meaning, which is especially important in learning (Malamed, 2015). Layout, division into functional areas, placement of items and composition are very close in their meaning. According to Dabner et al. (2014), composition refers to the visual structure and organization of elements within a design. According to Golombisky and Hagen (2013), composition means how you arrange items on the layout. Yet Chapnick and Meloy (2005) specified that layout itself is how the items are arranged. It is also useful to apply so called Z-movement to accommodate the eye's natural movement. Important content is given center area, while supporting information like links and navigation icons are placed in positions of less emphasis (Bozarth, 2008; Weinschenk, 2011).

Organization structures (alternatively organizational models, visuals or forms) present yet another way of structuring and visually organizing content. Three types of organization structures are commonly discussed: hierarchy, matrix (or table) and network (e.g. Novick et al., 1999; Tidwell, 2011). These structures are often called differently by various authors but present the same concepts. Individual content items are placed in appropriate organization structures based on the relationships among them. Showing relationships conveys meaning so the content can be interpreted correctly and remembered accurately (Malamed, 2015). Organization structures are discussed in much more detail in chapter 3.2., as the prerequisite for further outcomes of this dissertation.

Organization schemes can be explained as constructs by which the content is organized. Commonly used list of organization schemes is "location", "alphabet", "time", "category" and "hierarchy", known as LATCH (e.g. Wurman, 2000), alternatively called Five Hat Racks (e.g. Lidwell et al., 2010). Categories and hierarchy are very popular ways of organizing the content. Continuum is sometimes used instead of hierarchy. Some schemes faciliate sorting of items in lists or tables, specifically alphabet, time or continuum. Organization schemes are also described in more detail later in this work, see chapter 3.3.

Grouping related elements together into closer proximity automatically creates organization (Williams, 2008). The theory behind grouping and also alignment is based on four Gestalt principles: proximity, similarity (see section 5.1.5), continuity and closure (Tidwell, 2011; Malamed, 2015). Continuity includes lines formed by alignment of individual items, closure is based on simple closed forms (Tidwell, 2011) Grouping can be enforced e.g. by using background colours (Leavitt & Shneiderman, 2006) or more commonly white space (Malamed, 2015). Grouping lets learners know what elements are related to each other and thus enhances learning in several ways: it improves speed of perception, supports comprehension, reduces cognitive load, facilitates recall and improves visual hierarchy (Malamed, 2015).

Grouping techniques support visual chunking, which happens automatically, prior to conscious awareness (Malamed, 2015). Chunking means division of content into logical units (Lynch & Horton, 2009). Grouping and hiding chunks of content can be a very effective technique for decluttering an interface (Tidwell, 2011). This is very useful principle in e-learning as the brain can only process small amount of information at a time (Weinschenk, 2011). Chunked information is then easier to process and remember (Lidwell et al., 2010). Chunking works in correspondence with use of proximity principle and white space (see section 5.1.1). Spatial proximity has a strong impact on how viewers organize visual information (Malamed, 2015). Gestalt principle of proximity states, that elements which are close together are perceived to be more related than elements that are farther apart (Lidwell et al., 2010; Lynch & Horton, 2009). Similarly contiguity principle recommends that related content should be placed on pages or screens in an integrated fashion (Clark & Lyons, 2011).

According to Lidwell et al. (2010), the process of organizing information into related groupings in order to manage complexity and reinforce relationships in the information is called "layering". It involves organizing information into related groupings and then presenting or making available only certain groupings at any one time (Lidwell et al., 2010). However according to Malamed (2015), layering refer only to chunking information into overlapping surfaces. Colborne (2011) describes perceptual layering as placement of several elements on top of each other or alongside each other in a way, that allows reader to focus on just one set at a time, e.g. by using different colours. Layering information using colour takes advantage of the way the mind works, so it places very little load on the user (Colborne, 2011). Grouping was defined as an individual design attribute in the proposed framework, so we see layering more as the process after the grouping, in accordance with explanations by Malamed (2015) and Colborne (2011). Layering in this sense is similar to yet another term - progressive disclosure. Progressive disclosure is about presenting only the information the learner needs at that moment (Weinschenk, 2011). It also presents one of the solutions to prevent noise and information overload (Lidwell et al., 2010). Leavitt and Shneiderman (2006) stated that displaying too much information may confuse users and hinder assimilation of needed information. Progressive disclosure involves separating information into multiple layers and only presenting layers that are necessary or relevant (Lidwell et al., 2010). Clark and Lyons (2011) suggest using previews and overlays to control the amount of information presented at one time when the content involves complex visuals. The term "extraneous content" is similar to noise in visual design (see section 5.1.1).

### 5.1.4 Navigation

The navigation system should present the structure of the information hierarchy in a clear and consistent manner (Morville & Rosenfeld, 2006). This statement applies to all human-computer interaction systems including websites and educational systems. Navigation is an important part of usability of any website (Bartuskova & Krejcar, 2014a) and affects site credibility (e.g. Fogg et al., 2001; Kalbach, 2007). It is a complex construct, which depends on many design decisions. Structure, organization, labelling, browsing, and searching systems all contribute toward effective navigation (Morville & Rosenfeld, 2006). Fang and Holsapple (2007) defined two main approaches related to knowledge acquisition from a website: search (via keywords) and navigation (via links). The following table [Table 10] presents identified navigation concepts applicable on e-learning systems.

**Table 10. Design attributes of navigation**

| Requirement | Attributes | Similar concepts |
|---|---|---|
| **Navigation [A,C,D,E,F, G,H,I,K]** | Navigation(al) elements [E,G,L,N] | Navigation(al) options / choices / links / items [C,E,G,H,I,K]<br>Navigation(al) devices / tools [B,D,H,K]<br>Navigation(al) information [D,G] |
| | Navigation(al) structure [E,G,K,L] | Menu [A,C,G,K,N]<br>Navigation system [H,O]<br>Navigation(al) interface [E,N]<br>Site map [D,G,H,I,K,L]<br>(Concept) map [A,B,K,N]<br>Index [A,G,I,N]<br>Depth and breadth [A,I] |
| | Navigation(al) indicators [I,N] | Pagination / paging [A,E,G,K,L]<br>Bookmarks [A,I,K]<br>Location / "You are here" indicator [A,K]<br>Progress indicator [F,G,N] |
| | Search [A,G,I,P] | Search facilities [A,E,K]<br>Search options [E,G,I]<br>Search interface / system [I,P] |

Navigational elements help learners move through the training (Clark & Lyons, 2011) and generally help users move through any interface. Navigation(al) elements can be interchanged with navigation(al) options, choices, links or items, alternatively navigation(al) devices or tools (these are however usually used in relation to multimedia and other controls). Navigational elements are generally items, which represent choices for user, function as links to requested pages or functionalities and are identified by labels or icons or both. These items are usually grouped in a horizontal or vertical navigation bar. A navigation bar is a distinct collection of hypertext links that connect a series of pages, enabling movement among them (Morville & Rosenfeld, 2006). Navigation bar presents an implementation of menu, which is placed under the "navigation structure" design attribute, discussed in the next paragraph.

A navigation structure determines the possible sequences for accessing pages and imposes an organized layout on the site's web objects (Fang & Holsapple, 2007). Navigation structure reflects organization of individual pages on the website. Terms with similar meaning are navigation system or navigation interface. Navigation is sometimes being interchanged with menu, however there is a difference. Navigation as a rather abstract term usually includes all the concepts related to navigability of the website. According to Kalbach (2007), web navigation is defined as all of the links, labels and other elements that provide access to pages and help people orient themselves while interacting with a given web site. Menu can be defined as an externalization of navigation structure on the website or just a collection of navigational items. Kalbach (2007) specified, that most navigation types fall into three primary categories - structural (global), associative and utility. Tidwell (2011) associated terms "navigation structure" and "menu" in this statement: "Global navigation usually takes form of menu and presents a way of how users move around the formal navigational structure". Same as any other hierarchy structure, menu can be deep and narrow or broad and shallow. Depth refers to the number of choices required to descend the menu from the top to a specific topic and breadth refers to the number of choices on each level of the menu (Horton, 2012b). Another term closely related to the navigation structure is a site map. Site map presents a recapitulation of the website's navigation structure (Dabner et al., 2014). Index presents an alphabetically sorted list of navigation items, usually pages or topics.

As the next design attribute was proposed navigation(al) indicators, along with similar concepts such as location indicators, progress indicators, pagination controls and bookmarks. Location or alternatively "you are here" indicators help learners develop a mental model of how the course is organized (Horton, 2012b). Weinschenk (2011) recommends to always provide progress indicators so people know how much time something is going to take. Bookmarks can be regarded as a personalization technique, closely related to navigation. Bookmarks present a convenient way to navigate to a point of user´s choice even if it's deep inside a navigational structure (Tidwell, 2011).

Finally, search presents an alternative to whole navigation system. However according to Lynch and Horton (2009), even though web search is powerful, it is no substitute for a coherent site architecture, carefully expressed in the page design and navigation. Users often do not know what they should look for or they express it in a way which will not find desired information. According to Trattner et al. (2012), there are two commonly recognized types of search tasks - lookup search and exploratory search. Lookup search is performed to find a specific item and is considered to be relatively simple. More complicated search tasks are called exploratory search tasks and require multiple searches interwoven with browsing and analysis of the retrieved information (Trattner et al., 2012). This indicates, that search alone is often not enough, and user still needs to work with available navigation structure. Search can be also specified as search facilities, mechanisms, options, interface or system.

### 5.1.5 Consistency

Consistency of a visual experience supports learning in several ways: it reduces cognitive effort, creates a focused message and improves the aesthetic experience (Malamed, 2015). Johnson (2010) stated that learning and long-term retention are enhanced by user-interface consistency. Systems are generally more usable and learnable when similar parts are expressed in similar ways (Lidwell et al., 2010). Also within any logical grouping, elements should be aesthetically and functionally consistent with one another (Lidwell et al., 2010). The term consistency is often interchanged with another term: unity. As design consistency refers to both usability and aesthetics, two aspects of consistency are considered - aesthetic (consistency of style and appearance) and functional (consistency of meaning and action) (Fee, 2009; Chapnick & Meloy, 2005; Lidwell et al., 2010).

**Table 11. Design attributes of consistency**

| Requirement | Attributes | Similar concepts |
|---|---|---|
| **Consistency [A,B,C,E,G, I,J,L,O,**R]<br><br>Unity [A,H,J,O] | Consistency in layout and structure [A,E,L] | Consistent placement (position/location) [G,I,K,R]<br>Grid [A,B,C,E,H,J,K,L,P]<br>Templates [A,H,I,J,L,K]<br>Similarity (Gestalt) [C,E,H,J,K,R]<br>Repetition [J,L,N,O] |
| | Functional consistency [B,C] | Consistent navigation [B,G,H,I,J,O]<br>Consistent icons [D,E]<br>Mental models [C,F,I,N]<br>Affordances [C,J,K]<br>Clickability cues [G] |
| | Aesthetic consistency [B,C,E] | Consistent look and feel [A,B,D,K,O]<br>Graphics consistency [N,O]<br>Visual consistency [G,H]<br>Visual unity [H,J]<br>Consistent appearance [I,R]<br>Theme [A,H]<br>Symmetry [C,L,R]<br>Harmony [C,L]<br>Balance [E,H,J,L] |

Consistent approach to layout and navigation allows users to adapt quickly to design and to predict the location of information (Lynch & Horton, 2009). Consistency in layout and structure can be defined as a consistent placement of similar items through repetition or similarity. One of the most effective ways to achieve unity is through the repetition of a design elements (Malamed, 2015). Repetition is a conscious effort to unify all parts of a design (Williams, 2008). Consistency in layout and structure can be established easily by use of grids or templates. They make it easier for the user to navigate and absorb the information, because elements are in an expected location and order (Chapnick & Meloy, 2005). Both templates and grids introduce a level of consistency that is difficult to achieve otherwise (Malamed, 2015).

Grid, which is a series of horizontal and vertical lines charting out an area, helps to organize items on the layout (Golombisky & Hagen, 2013). A simple page grid establishes discrete functional areas, and adequate negative space defines the figure-ground relationships for the page (Lynch & Horton, 2009). Grids are needed for complex or multiple-page layouts to give their designs unified cohesive skeletal structures (Golombisky & Hagen, 2013). Malamed (2015) divided grids into three groups - column, modular and hierarchical. A template can be regarded as a master design, which can be used repeatedly and consists of a layout with designated placeholders for visuals and text (Malamed, 2015). The definitions and approaches for grids and templates vary. According to Tidwell (2011), a layout grid is a structural template for a set of pages or layouts.

Functional consistency includes mostly usability aspects, such as navigation and orientation. Navigation, multimedia controls and menus help visitors move through content, and they should be consistent (have similarity) across pages (Golombisky & Hagen, 2013). Morville and Rosenfeld (2006) discussed functional consistency in relation to navigation and labeling. It is important to reflect the users´ expectations, because people understand and interact with interfaces based on their mental models. By meeting these expectations, the efficiency of interaction can be enhanced (Roth et al., 2010). Successful interaction is also connected with affordances. Affordance is how the physical properties of an object influence its action possibilities or function (Malamed, 2015). When the affordance of an object or environment corresponds with its intended function, the design will perform more efficiently and will be easier to use (Lidwell et al., 2010). Similar to affordances are clickability cues or emulating real-world objects in order to help user (Leavitt & Shneiderman, 2006).

Aesthetic consistency refers to consistency of style and appearance (Lidwell et al., 2010). It contributes to visual appeal and emotional feeling, which has great impact on reader´s motivation and progress. Several other terms bear the same meaning as aesthetic consistency, e.g.: visual consistency or unity, graphics consistency, consistent appearance or consistent look and feel. E-learning appears coherent and pleasant with a consistent look and feel that unifies the entire course (Horton, 2012b). It is ensured by use of the same or similar visual appearance for the same or similar elements and thus is closely connected with functional consistency and also similarity and repetition, discussed earlier in this chapter. In fact all of the presented types of consistencies are interrelated and together form a resulting effect. According to Leavitt and Shneiderman (2006), visual consistency includes the size and spacing of characters; the colours used for labels, fonts and backgrounds; and the locations of labels, text and pictures. The location of elements would however be better placed under consistency in layout and structure.

Symmetry, harmony and balance are also terms, which are connected to aesthetic consistency. Symmetry is the most basic and enduring aspect of beauty, which should be used in design to convey balance, harmony, and stability (Lidwell et al., 2010). Again, the theories vary. According ot Malamed (2015), balance can be found in asymmetry as well as in symmetry. Golombisky and Hagen (2013) present balance as one of the principles of good design and introduce three kinds - radial, symmetrical and asymmetrical. Harmony is often being associated with colour, which can work in contrast or in harmony (Dabner et al., 2014). Only limited number of colours should be dominant across the learning material, usually only one or two. The dominant colour should be then accompanied by complementary or neutral colours.

### 5.1.6 Application on Blackboard LMS

The proposed framework from the original research paper (see Bartuskova & Krejcar, 2014a) was applied on Blackboard Learn LMS in the follow-up study (see Bartuskova et al., 2015). The evaluation by this framework was performed on selected computer science courses at the Faculty of Informatics and Management of the University of Hradec Kralove. Two main objectives were stated: a) validate the proposed framework and show an application in real scenario, b) reveal potential design issues in Blackboard Learn, which is one of the most popular LMSs.

The framework used in this study differs slightly from the framework presented in this disseration. It is more focused on learning courses, materials and resources, rather than on whole systems. The respective design requirements were organized according to the following table [Table 12].

**Table 12. Design requirements focused on learning resources [12]**

| Requirement | Individual attributes |
|---|---|
| Legibility | Typeface, Font size, Tonal contrast, Spacing, Alignment, Line length, Media legibility |
| Design consistency | Functional consistency, Aesthetic consistency, Consistency in layout and structure |
| Visual presentation | Aesthetic design, Colour, Colour contrast, Relevant graphics, Supportive graphics, Visual hierarchy |
| Content arrangement | Layout, Organization, Navigation mechanism, Multiple presentation media |
| Content adjustment | Chunking, White space, Gestalt Proximity, Emphasis mechanisms, Noise reduction |

In order to apply the proposed framework, enough time was dedicated to visual assessment and interaction with Blackboard Learn. Both features on the system level and features implemented in individual learning courses were analyzed, as they both participate on the final design. The system was evaluated with a regard to the end user – the learner. Some design requirements could be analyzed through visual appearance, in case of e.g. functional consistency or navigation, the actual use of the system was performed in a sufficient amount and diversity of use.

For the detailed overview of each design requirement and its individual attributes see the original study (Bartuskova et al., 2015). The pivotal results of the evaluation are represented by a list of factual design issues, summarized in the following table [Table 13].

**Table 13. Summarized results of the evaluation of LMS Blackboard Learn [12]**

| Requirement | Usability Issues |
|---|---|
| Legibility | small font (10.6px) which cannot be customized |
| | insufficient contrast (2.87:1) in the default colour scheme |
| | oversized uncomfortable line length (200 chars) |
| Design consistency | inconsistent appearance of links within the course (visual) |
| | inconsistent behaviour of links within the course (functional) |
| Content arrangement | predefined navigation items, empty or without purpose |
| | the lack of navigation and organization options for users (sorting of items, searching for text or files within the course) |
| | support of duplicities which make the interaction cost higher |
| Content adjustment | unbalanced layout with large unused areas of white space |
| | the lack of advanced means of styling the content |

The results indicate that several design issues were revealed by the assessment of Blackboard Learn, which can be performed better to comply with approved standards and best practice. Most of the encountered problems in the area of legibility and content adjustment could be solved by changes in default CSS styles. Design consistency could be generally solved by reducing available functions for content management and making the remaining ones more versatile and easy to use. Content arrangement would also benefit from reduction of complexity. Navigation would be enhanced by adding sorting and searching functions. Nearly all areas would benefit from customization in both visual styles and organization.

The framework of design requirements showed a different approach to evaluation of web-based learning systems and resources than usual method of inquiries on user satisfaction. The performed assessment revealed a set of factual design issues, which can be used for enhancing both usability and visual design of the system in order to improve user (learner) performance, experience and satisfaction.

## 5.2 Organization schemes revisited

This section presents an extension of organization schemes theory, proposed by the author. It also forms a part of theoretical grounding for solutions in later chapters, especially for section 6.2 "Interface for repository-based systems" and chapter 7 " Proposal of web-based educational system".

### 5.2.1 Continuous vs. categorical data

Previously reviewed arrangements of organization schemes (see chapter 3.3 "Organization schemes") did not take into consideration a difference between continuous and categorical data. As Tversky et al. (2012) proposed, there is a difference in visually representing discrete (categorical) data and continuous data. E.g. frequency (continuous concept) is more congruently matched to a continuous visual variable, such as distance or thickness, and similarly grouping (categorical concept) is more congruently matched to a categorical visual variable such as containment (Tversky et al., 2012).

Continuous and categorical variables can be treated very differently. Different strategies are needed for manipulation or display in graphical user interfaces including web-based systems. While values of continuous variables can be compared among themselves and displayed in a row or column, values of categorical variables do not represent any sequence. With a regard to different treatment of continuous and categorical data, we propose a division of organization schemes by data type.

Apparently category will fall to the categorical concept. Time can be regarded as a special type of continuum and they both belong under the continuous concept. Alphabet can be considered as a hybrid scheme, because the items can be unambiguously sorted as a continuous variable, however it is not a typical continuum and the items can be equally divided into "category" groups by alphabet. Location as an organization scheme is not defined very precisely and it can be implemented on various levels of granularity from e.g. categorization into the countries (more matched to the categorical concept) to the precise GPS coordinates (more matched to the continuous concept). Furthermore, we propose separation of category as (identically named) "category" for mutually exclusive groups and "tags" for groups which facilitate cross-listing. This separation is justified by an increasing trend in classifying content by tags, usually several at once, while traditional category (as well as hierarchy) should remain mutualy exclusive without cross-listing.

This categorization is summarized in [Table 14].

**Table 14. Continuous and categorical organization schemes**

| | **Continuous** | **Categorical** | **Hybrid** |
|---|---|---|---|
| **Org. scheme** | continuum, time | category, tags | alphabet, location |

### 5.2.2 Possible values and adjustments

The commonly used arrangement of organization schemes also does not distinguish between sets of possible values for each organization scheme. We propose these three types of variables:

- with unlimited set of values
    - continuum and time / date - connected to numbers, which are infinite
    - location - combinations of coordinates (also numbers) in 3-dimensional space are also infinite

- with limited open set of values
    - categories, tags - limited count of values with possibility to add more
- with limited closed set of values
    - alphabet - limited count of values with no possibility to add more

Presented suggestions are summarized in [Table 15]. The default set of possible values for each scheme reflects the common use in traditional or digital solutions. E.g. alphabet, categories and tags are in theory also unlimited, but in practice we have predefined alphabet sets and limited number of categories and tags. An unlimited set of values can be turned into a limited set of values and a limited set of values can be further restricted.

These means of adjustment can be applied in order to make the organization more usable and efficient, in both input processes (e.g. selecting options instead of filling in the text fields) and output processes (e.g. more efficient filtering and sorting).

**Table 15. Proposed arrangement of organization schemes**

| Variable | Org. scheme | Possible values | |
|---|---|---|---|
| | | Default set | Means of adjustment |
| Continuous | continuum | unlimited | granularity, range of values |
| | time / date | | |
| Categorical | category (exclusive) | limited, open | maximum count |
| | tags (cross-listing) | limited, open | maximum count in total and per entry |
| Hybrid | alphabet | limited, closed | charset |
| | location | unlimited | granularity, range of values |

Values of continuous variables and location can be restricted by adjusting the level of granularity or narrowing the range of values. E.g. location can be turned into a limited set of values if we restrict the applicable area and specify the level of granularity to only several large distinguishable entities. Alphabet can be restricted by specifying the charset. Categories and tags can be limited by a defined amount. Categories are usually kept at low numbers to promote system´s usability regarding organization of information. Tags per entry should also be limited to avoid overwhelming users.

### 5.2.3 Sorting and filtering

In this section is proposed yet another approach to arrangement and classification of organization schemes. Hübscher et al. (2011) used the Baxley's (2003) "Universal Model of the User Interface", which distinguished different aspects of a user interface. Baxley's model has nine layers grouped into three tiers - structure, behavior and presentation (Baxley, 2003). One of the categories named "Viewing and navigation" contains topic

"Viewing lists of data", which includes sub-topics "Changing column sets", "Paging", "Sorting", "Filtering" and "Searching" (Hübscher et al., 2011). The distinctive navigation mechanisms which take use of organization schemes were consequently identified as sorting and filtering.

Based on this conclusion, the so far proposed arrangement of organization schemes was complemented by the information about possible sorting and filtering. If the values of the particular variable are sortable without help of another organization scheme, we consider them basic. Continuum, time and alphabet are therefore suggested as basic organization schemes. On the other hand, category, tags and location can be sorted with their help, i.e. by basic organization scheme. E.g. category can be sorted by the category name (alphabet), by the date of last modification (time) or by the amount of items in the category (continuum). These organization schemes are therefore marked as complex.

Filtering can be implemented easily by alphabet, category or tags. Filtering by continuum, time or location is possible after some adjustment, specified in [Table 15]. These proposed characteristics are summarized in the following table, complemented by the previous arrangement [Table 16].

**Table 16. Additional properties of proposed organization schemes**

| | **Org. scheme** | **Sortable** | **Filterable** | **Variable** |
|---|---|---|---|---|
| **Basic** | continuum | yes | if adjusted | continuous |
| | time / date | yes | if adjusted | |
| | alphabet | yes | yes | hybrid |
| **Complex** | location | by basic type | if adjusted | |
| | category | by basic type | yes | categorical |
| | tags | by basic type | yes | |

This concludes the proposal of theory extension regarding organization schemes, which will be partly used in section 6.2 "Interface for repository-based systems".

# 6 Proposals of interfaces

This chapter is dedicated to the author´s design proposals of web-based interfaces. These designs are based on both the theory from thorough literature review and the conclusions proposed by the author. The first proposal is intended for course-based systems, the second for repository-based systems. As was already mentioned in the beginning, these were identified as two major approaches regarding educational systems. Especially the second proposal has however much wider usage, as the design proposal of navigation schema can be used on any information-rich website or web-based system.

## 6.1 Interface for course-based systems

This chapter presents the proposal of smart user interface for course-based educational systems. Motivation for research on this topic was discussed in chapter 4.2 "Limitations of course-based systems", especially sub-chapter 4.2.3 "Analysis performed on a selected LMS" and partially sub-chapter 4.2.1 "Fixed structure and content". The presented techniques are however not limited only to educational systems. We believe that any system, where content can (and should) be organized by more atributes, can benefit from the presented approach. Especially web-based systems, where time is one of these attributes, e.g. systems managing workflow, time tables etc.

The interface-related issues, which we intend to solve in our proposal, were presented in chapter 4.1 "Organization and navigation issues", especially sub-chapters 4.1.1 "Disorientation and site maps" and 4.1.4 "Cost in human-computer interactions", partially also 4.1.2 "Subjectivity in creating navigation" and 4.1.3 "Descriptive potential of navigation". The reasons and explanations are not repeated here due to space limitations.

Our proposal of smart user interface for course-based systems is based on the analysis of three basic organization structures - table, hierarchy and network (see section 3.2 "Organization Structures"). In addition we performed the analysis of types of learning content and data formats for selected computer science courses in Blackboard Learn LMS (see section 4.2.3 "Analysis performed on a selected LMS"). We aim to solve the issue with inconsistent content organization and labelling and reduce common navigational and organizational issues (see section 4.1 "Organization and navigation issues") in facilitating simultaneous visualization of all educational courses in one layout.

### 6.1.1 Table / matrix

We performed the first implementation with table organization structure. Based on our conclusions about content division, we used vertical and horizontal axis for category (resource type) and sequence. The table cells contain individual items of learning content, according to their place in the learning course. An example of this arrangement is shown in [Fig.2]. The choice of particular content types (lectures, practice,..) is for illustration only, it does not represent any key types of learning content.

In this implementation we reached the united structure across courses, but not yet simultaneous visualization of all courses in one layout. The top navigation bar is used for switching between individual courses. The navigation system should indicate the user's current location (Morville & Rosenfeld, 2006) as is illustrated in the figure. Proposed implementation also takes into account that some learning content cannot be assigned to a particular time frame. We can however divide this content into "before course" group, which includes e.g. information about the course, and "after course", including e.g. additional resources.

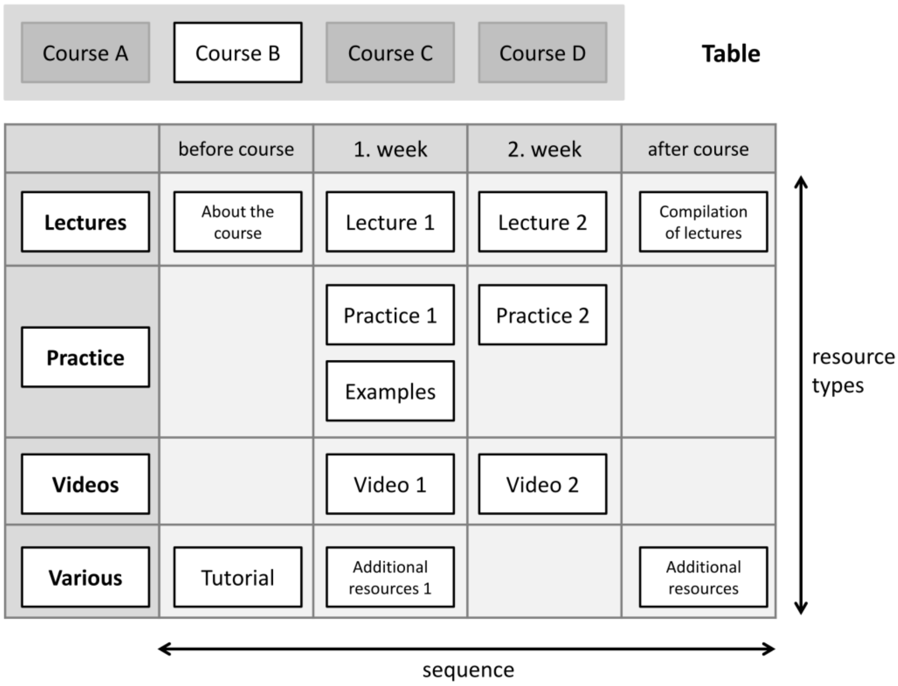



**Fig. 2. Table / matrix organization of learning resources**

### 6.1.2 Hierarchy / tree structure

The second implementation was performed on hierarchy organization structure. Again we used category (resource type) and time for organizing the content. The first level of the hierarchy are courses, still functioning as a navigation bar, used for switching between individual courses. The second level are categories (resource types) and the rest of the levels are individual items. These items are sorted horizontally by the respective resource type and vertically by their sequence in the learning course.

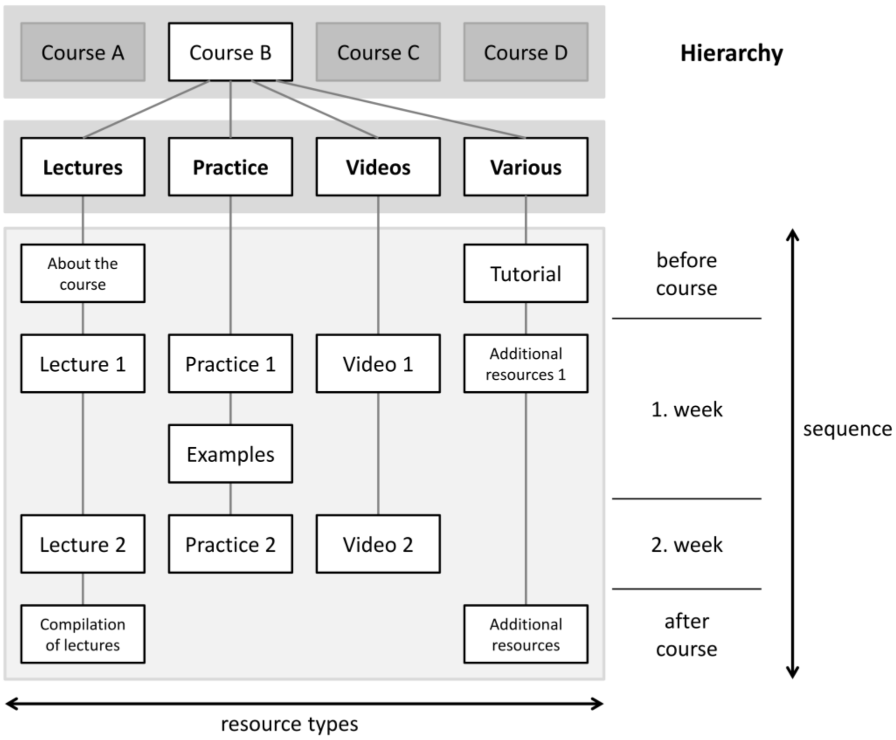



**Fig. 3. Hierarchy / tree structure organization of learning resources**

### 6.1.3 Hypertext / network

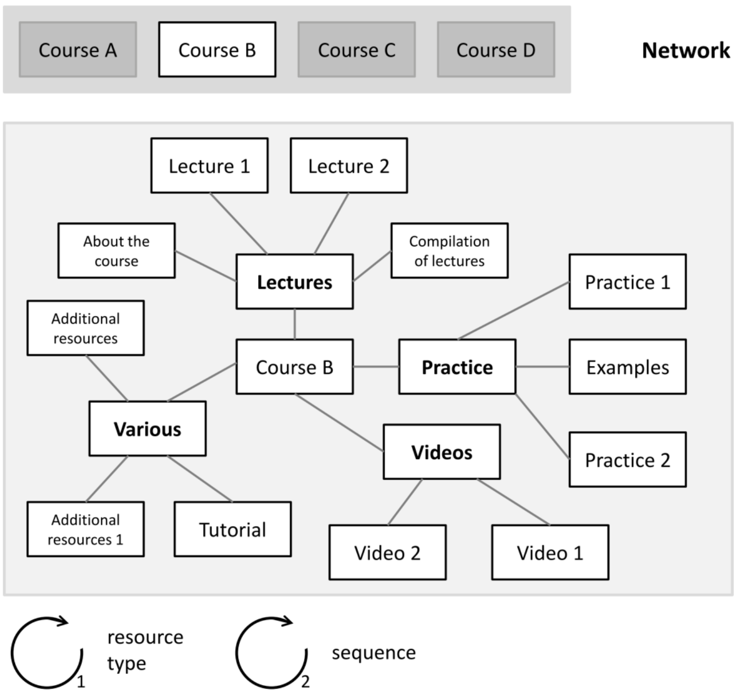



**Fig. 4. Hypertext / network organization of learning resources**

The third implementation was performed on network organization structure. The top navigation bar with courses is the same as in previous examples, otherwise this arrangement is very loosely organized. The central point of the network is the relevant course, the first level from the centre is categories, and the second level is individual items. We can sort them clockwise around the central element, but it is not as well-arranged as in previous two examples.

### 6.1.4 Enhanced table / matrix

All three implementations solved the issue with inconsistent organization and labelling, making the browsing more efficient in the united structure. However our ultimate goal was to facilitate simultaneous visualization of all courses in one layout. For this purpose, we need to choose the most versatile structure out of the three presented organization structures. First we excluded the network due to a poor arrangement of items, which leaves the hierarchy and the network. These two are very similar in our implementation, with the exception that the axis are switched and the hierarchy supports better sequence visualization, however on the other hand it is taking up more space.

Finally we have selected table as the most common and versatile structure. Table is a basic representation device known to be easy to use and adopted by teachers in standard practice (Sobreira & Tchounikine, 2015). The proposed implementation was organized by the course, category (resource type) and sequence (which are the most common content separators in courses, based on the analysis in section 4.2.3). As stated by Rubin et al. (2010), an LMS that allows all the materials needed in one week to be visually grouped on a single page by means of contiguous placement makes it easier for students to consider all the elements as part of the week's tasks, and therefore more likely for them to access all the materials. The example is shown in the following figure, revealing only part of the table for illustration [Fig.5].

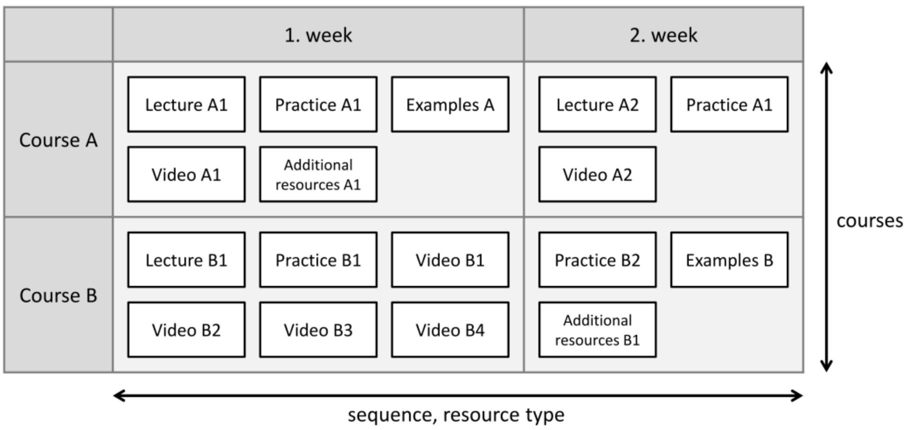



**Fig. 5. Table / matrix organization - all resources of all courses visible**

Finally, we decided to refine this arrangement. So far we have used labels. However meaning is extracted from pictures faster than from words, because pictures represent meaning more directly than alphabetic written languages (Tversky, 2001). Icons can be used to complement the textual labels, since repeat users may become so familiar with the icons that they no longer need to read the textual labels, icons can be useful in facilitating rapid menu selection (Morville & Rosenfeld, 2006). Also use of icons will take up less space and we can group together more resources of the same type in one table cell.

This arrangement will further support consistency across the whole table. For the first-time visitors, a legend is available to explain meaning of icons. The example in [Fig.6] takes into account the limited width of displaying device, the arrows in the table indicate an interaction of expansion into other time frames. The other possible implementation is to keep the table in full width with a use of horizontal scroll bar.

In the previous example in [Fig.5], all the resources were displayed as individual items. In the enhanced version in [Fig.6], we applied summarized (grouped) view on content of the same type. This means that e.g. several videos in the same time frame will be represented by one video icon, with number indicating the count of resources of this type. This way we prevent overcrowding the table with numerous learning content, while keeping its purpose in displaying content of the learning courses. The user interface should of course ensure an interaction, by which the grouped resources could be expanded to reveal individual items.

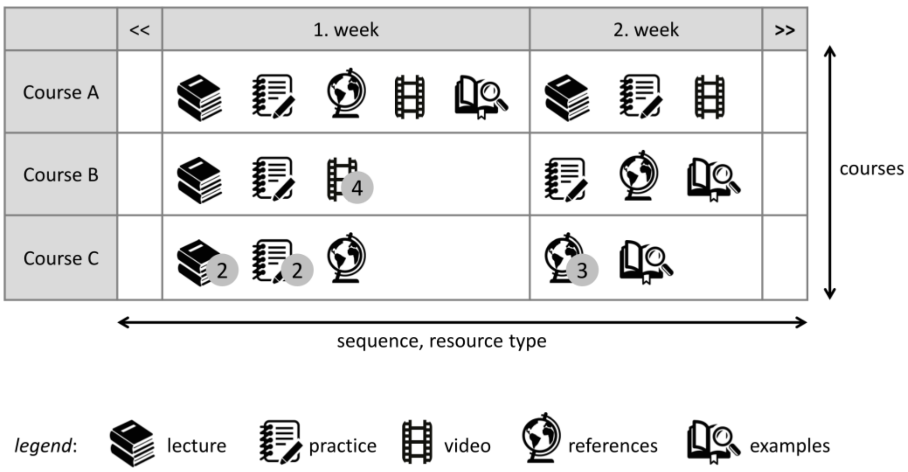



**Fig. 6. Table / Matrix organization - summarized resources of all courses visible**

## 6.2 Interface for repository-based systems

Motivation for research on this topic was discussed thoroughly in chapter 4.1 "Organization and navigation issues", including all sub-chapters; 4.1.1 "Disorientation and site maps", 4.1.2 "Subjectivity in creating navigation", 4.1.3 "Descriptive potential of navigation" and 4.1.4 "Cost in human-computer interactions". The reasons and explanations are not repeated here due to space limitations. The technique presented in this section can be applied on repository-based educational systems, where we identified number of limitations, especially in the area of metadata and consequent search function. See chapter 4.3 "Limitations of repository-based systems", especially sub-chapter 4.3.2 "Analysis performed on selected LORs".

Furthermore, this approach can be applied basically on any website or web-based system. However the discussed advantages will express themselves only with a more sizeable content; such as number of webpages, items in repository etc. Then we can transform traditional website navigation to smart navigation, which presents a visual arrangement by all organization schemes in one layout.

In this chapter we present a method for constructing an information-rich navigation, based on advantages of vertical menus, site maps and tag clouds. Our solution is theoretically grounded in classification of organization schemes and presents an arrangement by all organization schemes in one layout. Layers of organization are distinguished by a combined use of textual, spatial and visual techniques. Presented method features a constantly visible navigation area, objective means of organization, increased information density and reduced interaction cost and attention-switching cost. This arrangement is expected to facilitate efficient browsing and retrieval of information.

The interface proposal was partially published under the title "The Novel Approach to Organization and Navigation by Using all Organization Schemes Simultaneously" (Bartuskova & Soukal, 2016).

### 6.2.1 Conceptual proposal

Websites commonly use hierarchies as the basis of their structure (Danielson, 2002; Morville & Rosenfeld, 2006). Navigation is based on the website´s structure, so hierarchical menus are traditional way for dealing with intra-site navigation. Tags facilitate higher information density (Trattner et al., 2012; Walhout et al., 2015), they are however not being used as a primary navigation, possibly because of their lack of any formal structure. Our solution is then to combine high information density of tags with structural quality of traditional hierarchical navigation. The presented method also implements advantages of vertical menus (constantly visible site maps), which prevent user disorientation (Danielson, 2002), are more efficient and preferred over dynamic menus (Leuthold et al., 2011) and are more usable and easier to scan (Fowler & Stanwick, 2004).

The proposed method can be characterized as a layering technique, defined by Lidwell et al. (2010) as the process of organizing information into related groupings in order to manage complexity and reinforce relationships in the information. An arrangement by each scheme then presents one layer of organization and all layers can be seen simultaneously, which creates an information-rich navigation area. Presenting more information in one place is also presumed to reduce interaction and attention-switching cost and increase usability. Another benefit of this solution is a decreased subjectivity in construction of navigation by implementing several exact means of organization.

Tag clouds emerged as a usable technique in presenting more information through navigation while occupying a relatively small space. What appears to be most appreciated with tags is their higher information density. Tags can be regarded as a categorical organization scheme, considering that the text labels (keywords) denote classification to a group. Tags in tag cloud are usually sorted alphabetically, so they are also arranged by an alphabet organization scheme. Typical tag cloud also includes an arrangement by continuum (usually number of articles assigned to the particular tag), which is implemented as a difference in font size.

The concept of tags is very inspiring as it offers organization by three organization schemes simultaneously. The objective of the proposed solution is to implement more than three organization schemes in one arrangement. It will however not use concept of tags with many-to-many mapping, which can be confusing because it does not create any formal organization structure. The desired approach would be to create layers of organization by validated schemes in one navigation area. High information density of tags with be then combined with the structural quality of traditional hierarchical navigation.

Objectives of the proposed solution are based on identified navigation issues [Table 17]. The first idea is to provide web users with a constantly visible navigation area, which should diminish their disorientation. The next goal is to reduce a subjectivity in navigation by objective means of organization. Because different organization schemes can be useful in different web browsing strategies, the proposed solution will utilize several of them at the same time. Implementing arrangement by these organization schemes will create added information value to navigation items and increase information density of the navigation area. We can imagine individual arrangements as layers, stacked in a way, that facilitate selective attention to each of them. Presenting more navigation links and more information about them in one place will also reduce interaction cost (users can better process links before clicking on them) and attention-switching cost (users will less likely click on the wrong link, followed by Back button, which equals to two page reloads).

**Table 17. Summary of identified issues with possible solutions [14]**

| **Objective / benefit** | **Implementation** |
|---|---|
| reduced disorientation of users | by providing constantly visible navigation area |
| reduced subjectivity | by using objective means of organization |
| increased information density | by utilising design elements for adding information value to navigation items |
| reduced interaction and attention-switching cost | by presenting more information about navigation items in one layout |

The arrangement by several organization schemes in one layout is expected to be very flexible for different styles and purposes of user web browsing. However it is known that as the flexibility of a system increases, the usability of the system decreases (Lidwell et al., 2010). The trick to designing navigation systems is to balance the advantages of flexibility with the dangers of clutter (Morville & Rosenfeld, 2006). To prevent cluttering of the navigation area, the solution will utilize a combined use of textual, spatial and visual techniques. Gestalt Laws will be used as well. The grouping resulting from similarity reduces complexity and reinforces the relatedness of design elements (Lidwell et al., 2010). Use of several distinguished formatting techniques will also allow for selective attention to arrangements by different organization schemes.

### 6.2.2 Differentiation by visual and spatial aspects

Golombisky and Hagen (2013) presented the seven elements of design as basic units of visual communication - space, line, shape, size, pattern, texture and value. Tversky (2001) and Fowler and Stanwick (2004) proposed using visual cues like colour, size and font to signify organization into groups. In this section we will discuss selected design elements as means for an arrangement by different organization schemes.

We should keep in mind that it is desirable to reduce complexity by reducing the number of elements needed to organize and communicate information (Lidwell et al., 2010). According to Simple Web Design by Hunt (2008), every element should have a good reason to be displayed on the website. In accordance with these recommendations, we should prefer inclusive representation rather than to add new design elements to convey meaning. By inclusive representation is meant visual and spatial formatting which can be applied directly on the navigation item. Sometimes however the simple solution will bring serious usability issues, as will be discussed further in the text along with the assessment of design aspects for differentiating navigation items. The summarization is in [Table 18].

**Table 18. Proposed aspects of design for differentiating items [14]**

| Object | Design aspects | |
|---|---|---|
| | **Visual** | **Spatial** |
| text | colour, size, font | starting position (x,y) |
| shape | colour (or pattern), size | |

Colour is used in design to group elements and indicate meaning (Lidwell et al., 2010). The simplest solution would be to attach colour to the text of navigation item. However we would find very limited number of text-background combinations, which are all distinguishable among each other and have sufficient contrast at the same time. Contrast is a usability aspect with direct impact on text readability (Hall & Hanna, 2004; Bartuskova & Krejcar, 2014a).

Web Content Accessibility Guidelines (WCAG) 2.0 level AA requires a contrast ratio of 4.5:1 for normal text and level AAA requires a contrast ratio of 7:1 for normal text (W3C, 2008). Poor legibility and recognition of differently coloured text is mainly due to thin lines of text characters. Therefore instead of colouring text of navigation items, it would be possibly more usable to add solid coloured elements (e.g. square shapes) spatially associated with these items.

Size is a design element, which can be used for signifying importance or magnitude. This technique is used in tag clouds, where the font size reflects the number of matching instances for each tag (Zhang et al., 2014). Horton (2012b) suggested 10pt as the minimal recommended font size. It was confirmed that smaller fonts are often hardly legible on the computer screen (Bartuskova & Krejcar, 2014a). Therefore to create a sufficient difference in font size for individual navigation items, we would have to use larger fonts. However it would 1) create a problem to fit them on the screen and 2) most likely disrupt easy scanning of arrangements by other organization schemes. Additionally, the slight changes in font size would not be easily noticeable and their deciphering would increase the user´s cognitive load.

With font type we deal with a similar situation. Lidwell et al. stated that a detectable difference between fonts is difficult to achieve without also disrupting the aesthetics of the typography (Lidwell et al., 2010). Additionally Golombisky and Hagen (2013) demonstrated, that various fonts of the same size of 10 points take up different amounts of vertical and horizontal space. Therefore the changes neither in font size nor in font type are suitable for our purposes to indicate organization.

Space can be regarded in many different ways. We are now interested in the position in space, particularly position of navigation items in the navigation area of the website. In a two-dimensional display like a computer monitor, the element´s position is defined by horizontal and vertical value. Typically implemented sorting order of items is in fact vertical arrangement based on a difference in vertical value. This is one way of spatial arrangement by some organization scheme. The next is naturally a horizontal arrangement, where the difference between items is provided by different value in horizontal position.

As we have exhausted the usable possibilities for design aspects applicable on navigation items themselves (i.e. on the text labels), additional design elements will be used for the arrangement by remaining organization schemes. These additional elements (i.e. shapes) can signify differentiation by some of the already mentioned techniques - colour, size and position. Use of solid shapes in comparison to text has an advantage in case of black and white displays, where the colour can be replaced by texture to convey meaning such as e.g. relatedness to a group.

### 6.2.3 Mapping to an arrangement by all schemes

The proposed solution of website navigation is capable of supporting all organization schemes, which are: alphabet, time, category (and/or tags), continuum and location. We can divide these organization schemes into continuous and categorical variables. The underlying theory was covered in chapter 5.2 "Organization schemes revisited".

The differentiation of each arrangement from others is ensured by combined use of textual, spatial and visual techniques. We have also already mentioned that the inclusive representation is preferable in order to avoid cluttering of the navigation area, however in some cases its implementation reveals usability issues. In that case, adding another set design elements is preferable for creating a new layer of arrangement by different organization scheme. We tried to find balance between advantages of inclusive representation (expressed by differences in colour, size or position) and necessity of adding new design elements. Individual methods based on these design variations were consequently assigned to known organization schemes, see the following table [Table 19].

**Table 19. Proposal of individual methods for designing navigation [14]**

| Org. scheme | Method | Explanation |
|---|---|---|
| alphabet | vertical arrangement | Items are sorted by alphabet in a traditional way. |
| time | horizontal arrangement | Items are arranged by time using difference in horizontal starting position. |
| category | square with dif. colour / pattern | Items are visually associated with a colour (or pattern), different for each category. |
| subcategory | text label | Individual items are grouped into subcategories, represented by the displayed text labels |
| continuum | bar rating with different length | Items are visually associated with a bar of length reflecting the value. |
| location | associative link | Items are linked to a position in the adjacent map. |

Category can be best implemented by the principle of grouping or similarity. We propose its implementation in visual arrangement by colour, because similarity of colour results in the strongest grouping effect (Lidwell et al., 2010). Every category would be assigned a colour, and every individual item which belongs to this category will be marked with this colour. The colour will be added not as the text property but in a form of a new element, spatially associated with respective items (using the principle of proximity).

Organization by alphabet (i.e. common sorting by alphabet) can be done either horizontally, by sorting items as inline elements, or vertically like block elements. Tags are typically sorted as inline elements. We will choose the second approach to maintain better readability and to keep space for implementing other layers of organization.

Continuous organization schemes - continuum and time - can be best implemented by variable size (width, height) or position (horizontal, vertical). Differences in values can be represented in either mono-spaced or proportional manner. In the first case, the differences will reflect only the order, in the second case, they will reflect also the exact values. Which arrangement is better - mono-spaced or proportional - depends mostly on the purpose and particular organization scheme. Vertical arrangement was already assigned to alphabet, so for continuous variables we propose as the first technique a horizontal arrangement. Arrangement by difference in size of text labels was rejected earlier in the text from several reasons. Therefore as the second technique we propose adding a new element, which will specify value of continuous variable by difference in its width (line height should be kept the same for better readability and saving space), this technique can is similar to bar rating or progress bar. Consequently each item will be associated with its bar rating, with length representing the value of continuum variable. The colour of this element would correspond with the item´s category to further support grouping effect.

Finally, location can be represented by an associative link to the adjacent map. We would like to note that not every set of navigation items can be organized by all organization schemes. E.g. if the items are not associated with any location, then the organization by location cannot be implemented.

The two techniques for continuous variables are theoretically interchangeable and can be used either for continuum or time. It was researched that vertical arrays take precedence over horizontal ones, so the horizontal axis is standardly used for neutral dimensions such as time (Tversky, 2001). As the horizontal arrangement reflects this rule better, we propose using it for time organization scheme, which leaves bar rating for representing continuum. All of these conclusions are summarized in [Table 19].

Subcategory, which is present in the summarization, is not an elementary organization scheme. It is in fact a category on lower hierarchical level and is implemented only if the number of items is too high, in that case grouping them under subcategories is reasonable. By an individual navigation item is meant single webpage, document or reference link, which has an explicit URL. To conclude, text labels represent individual items (in the case of a small number of items) or a collection of items grouped in a subcategory (in the case of a large number of items). The proposed solution is consequently applicable on both small and large websites.

### 6.2.4 Spatial design of the solution

This section brings a closer look on spatial design of the proposed solution. The following design proposals combine conclusions from previous sections regarding 1) conceptual proposal and argumentation, 2) use of design techniques for the defined objectives, and 3) arrangement by all organization schemes using these techniques.

To implement organization by categories, text labels of categories have to be included in the navigation area. The list of categories should be easily accessible for users; therefore it would be placed at the top. The list will accomplish two functions here: 1) provide a legend for interpreting classification of items, 2) offer a basic overview of website content.

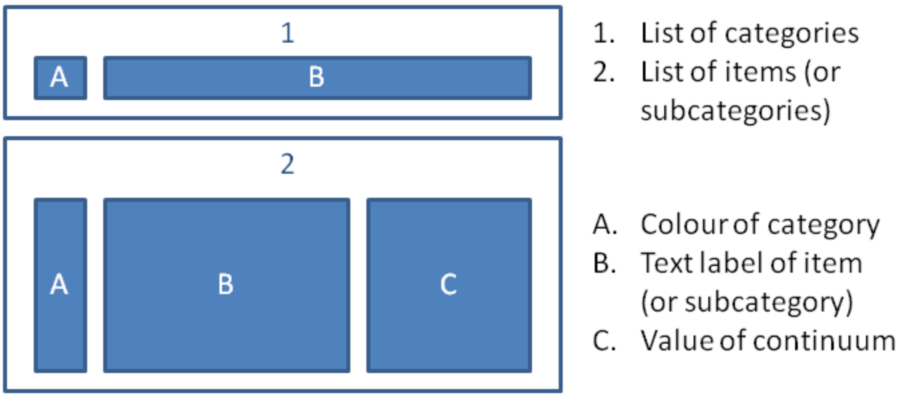



**Fig. 7. Schema of the spatial arrangement with organization by categories**

The above figure (Fig.7) depicts basic spatial arrangement: the placement of categories and individual items and space allocation for colours, text labels and continuum value. The next figure (Fig.8) depicts an arrangement by alphabet (order of items), time (difference in starting position) and continuum (bar length in the allocated space).

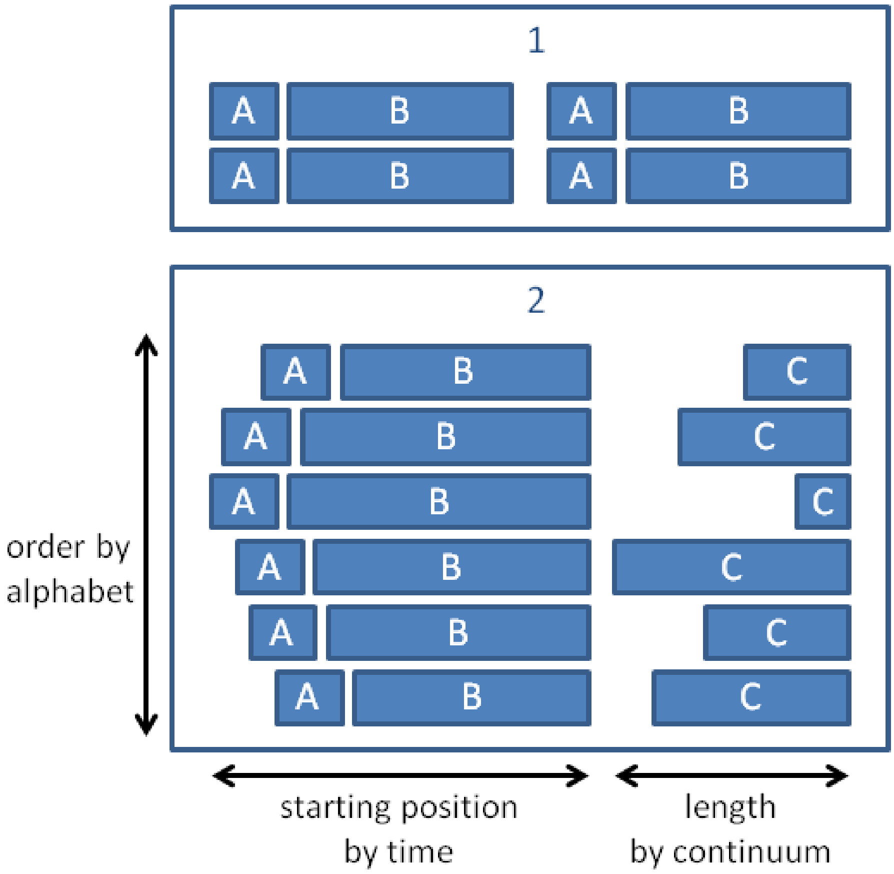



**Fig. 8. Schema of the spatial arrangement by the remaining organization schemes**

The last figure in this set (Fig.9) adds an arrangement by location. This figure also adds colour for distinguishing the arrangement by category.

In order to enhance visual search performance, navigation frames should be placed either at the top or the left of the screen (van Schaik and Ling, 2001). Eye-scanning studies indicate that users commonly start looking at a page by scanning the left-hand list (Fowler & Stanwick, 2004). Therefore the whole navigation area should be placed on the left side of the screen with content on the right.

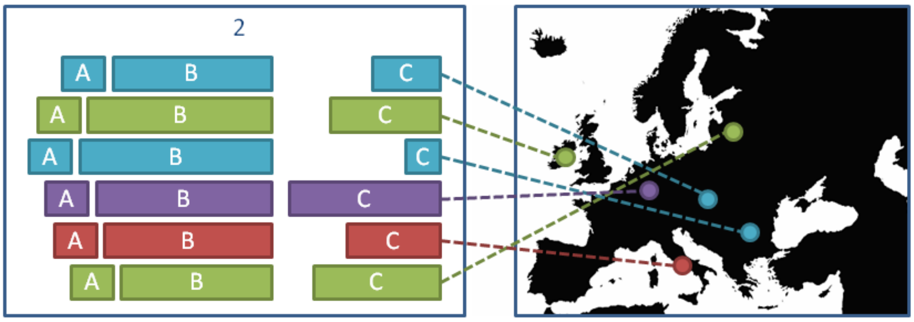



**Fig. 9. Schema of the arrangement by location, colour for distinguishing category**

Additionally, we can assess the proposed design in a context of organization structures. The next figure [Fig. 10] shows correspondence of our solution to matrix and hierarchy - which are easy to understand and commonly used for visualization purposes. This figure also indicates simple visual design. For clearer depiction of matrix structure, horizontal arrangement by time is omitted from this figure. This can be regarded as an example of the situation, when the items cannot be organized by any time variable (or when it would not be useful or usable to do so). In the case of non-applicable time arrangement, the items will simply share the same horizontal starting position.

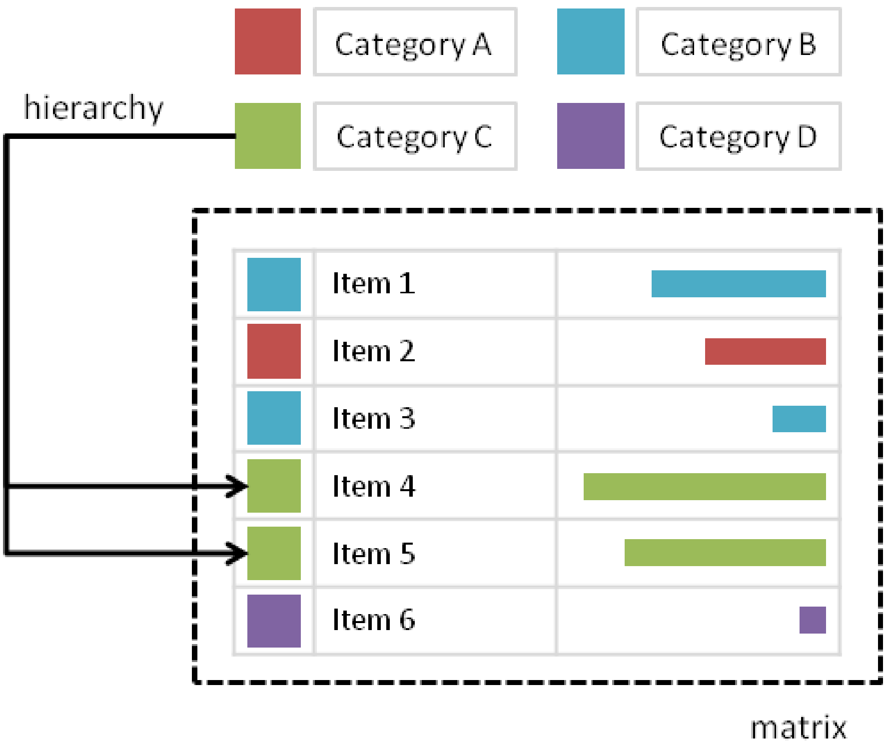



Fig. 10. Visual design and the correspondence with organization structures

The hierarchical organization by category, which is a common implementation of website navigation, is retained also in our solution. In contrast to usual solution of placing items directly under category label, our solution uses colour to visually associate category and its items, in order to facilitate arrangement by remaining organization schemes. These schemes are applied in the matrix of items, creating a parallel arrangement. In this organization structure is information based on the organization of other information (Lidwell et al., 2010). Colour can be replaced by texture in case of black and white displays. Colour is placed next to the navigation item, following the principle of proximity. We avoided a cluttered layout by physically grouping items together, that belong together (Golombisky & Hagen, 2013).

Finally, the summarized schema concludes this section [Fig. 11]. This figure combines organization by all organization schemes and indicates also spatial arrangement by all organization structures.

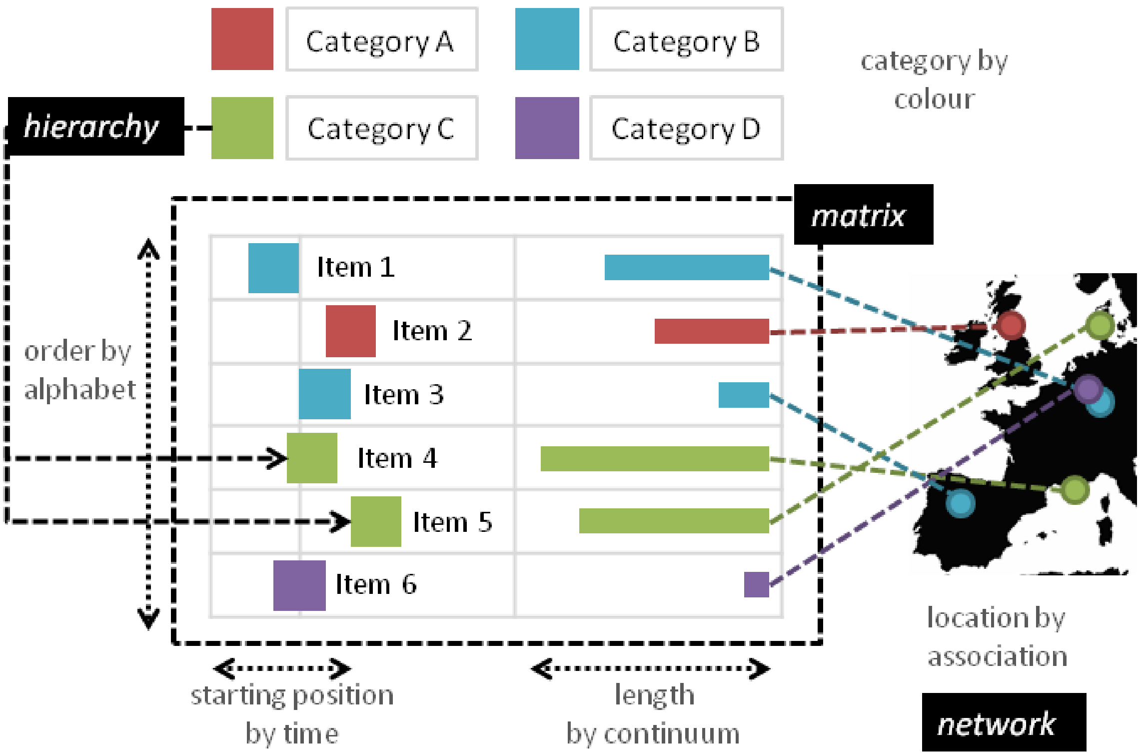



**Fig. 11. The summarized schema of all schemes and structures [14]**

### 6.2.5 From organization schemes to actual variables

Until now we have discussed organization schemes in general without actual variables. While concept of alphabet or category is apparent, implementation of time and continuum should be further specified. What organization scheme is possible to use and what will be useful at the same time, depends on particular website and its content. As for time, we can use specific data such as when the item was added or last edited and organize items accordingly. We can also use some relative time measures, e.g. the time order in which the user should proceed, which would be especially useful in sites with learning or instructional purposes. Organization by time when the item was added (i.e. by newest items) would be very usable in news or blog websites.

While organization by time was mostly exact, organization by continuum can easily facilitate social navigation. As a continuum we can use e.g. popularity, implemented as number of views, number of comments (in case of blog articles) or value of rating (if the rating system is implemented). It is known that recommendations based on popularity are appreciated by users, especially when they are not familiar with particular topic.

In the case of using subcategories, continuum can represent a number of individual items in the category. By implementing this organization scheme, the user can identify right away, which topics (represented by subcategories) are the most frequent on this website. This is a very useful information to receive at the first sight and would take much longer to realize by using traditional navigation.

Some of the organization schemes need initial settings, like division into categories. Social navigation facilitated by continuum relies on input from users, like every other type of social navigation. Organization by alphabet or exact date does not require any manipulation and therefore is objective, in accordance with their classification as exact organization schemes. By presenting more layers of organization, with some of them exact, we have reduced the navigation subjectivity.

### 6.2.6 Scope and the technical implementation

As was already mentioned, the proposed solution is suitable for websites of various sizes, as subcategories can be used to represent groups of individual items in the case of larger websites. The scope of this solution is however not limited only to websites. The proposed approach can be used in any information or knowledge system to enhance its traditional navigation system, as it can enhance any navigation from a list of items to a dynamically updated overview of all content in the system. Nowadays when we are overwhelmed with all available content, such consistent visualization can save us a lot of time and effort. The navigation is not even necessary for implementation, as any meaningful list of items can be turned into this arrangement and can facilitate efficient orientation in presented choices.

Web-based systems were however our primary intention, so the demonstration of this method will be presented in the web environment. As the implementing technology for demonstration purposes was used combination of HTML, CSS and JavaScript. These are standard languages for developing web applications - HTML for structure, CSS for visual style and JavaScript for client-side interaction.

In a real scenario, the use of some server-side language is a necessity, at best with application of some content management system for easy website administration. This is because a static webpage, which was developed for the purposes of this research, has not a capacity for dynamically organizing and updating items. In a dynamic website, the organization processes can be automated so they do not require further attention except for the initial implementation and settings.

The following table specifies technical solution for implementing each organization scheme into the final arrangement [Table 20]. Location is omitted from implementation, because it is not common on websites that navigation items are connected to location.

**Table 20. Implementation with a use of technologies for web development**

| Org. scheme | Technical implementation |
|---|---|
| alphabet | order of items in code editor |
| time | value of items´ left margins according to their differences in time variable, in the demonstration implemented as mono-spaced |
| category | square visual elements adjacent to individual items and categories, associated by the same background colour |
| continuum | visual element adjacent to individual items with a width according to their value in continuum variable, implemented as proportional |

The visual representation schema is presented in the following figure [Fig. 12].

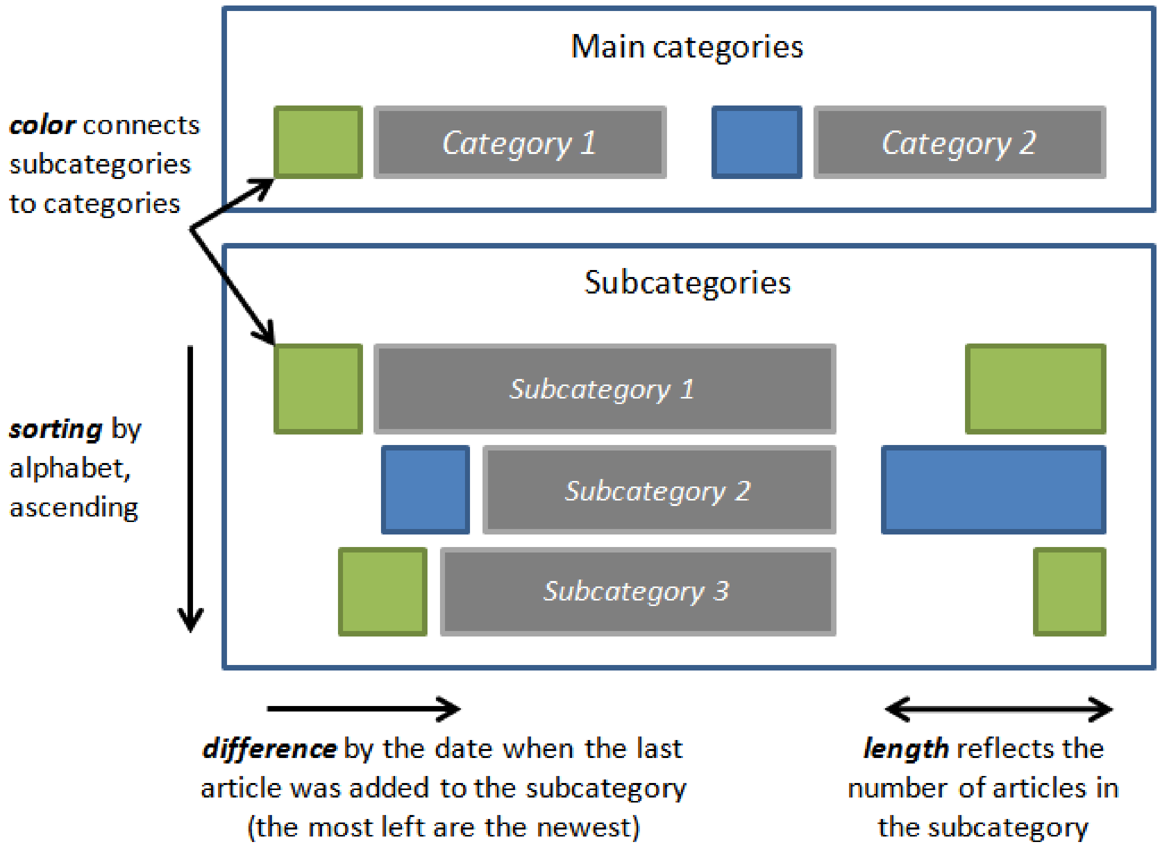



**Fig. 12. The schema of visual representation**

It is important to note that individual aspects of implementation can vary for various websites according to their purpose, content and audience. Incorporating each organization scheme into the resulting navigation should be both feasible and useful for users. In the next two sections, proposed technique will be demonstrated on two existing websites. The author is not associated in any way with these websites and do not have access to server-side code and database. As a result, the variables for demonstration were chosen according to publicly available information, which can be accessed from user´s perspective. In a real scenario, more useful variables can be defined. These particular websites were selected because they represent popular choices in their area of expertise and the proposed technique is expected to be applicable and usable on these websites.

### 6.2.7 Application on navigation of W3 Schools

W3Schools (2014), available on http://www.w3schools.com/, claims to be the world's largest web developer site, optimized for learning, testing, and training. The majority of content on this website are tutorials along with explanations, examples etc. W3Schools is in fact a learning repository, with learning content which is updated or newly added from time to time. The navigation structure is hierarchical, main division made by topics (categories). The following table specifies variables for organization schemes, proposed for W3Schools, along with ranges of values. The values summarize information gathered by manual clicking and searching inside the website´s content. The data was collected at the time of writing this dissertation.

**Table 21. Organization schemes applied on variables for W3Schools**

| Org. scheme | Variable used by the org. scheme | Range of values * |
|---|---|---|
| subcategory | labels of navigation items | count: 29 |
| alphabet | the first letter of every sub-category | from a “Learn AJAX” to a “Web statistics” sub-category |
| time | - | - |
| category | the category, under which the particular sub-category belongs | count: 6 |
| continuum | number of web pages in the particular sub-category | minimum value: 7<br>maximum value: 88 |

* at the time of writing this dissertation

In the case of W3Schools, we have omitted arrangement by time, because it represents an insignificant added value in this context. However if the navigation was implemented for a lower hierarchy level, where items would be represented by individual instructional web pages to the same topic, it would be useful to implement organization by time order in which the user should proceed. Continuum will be represented by number of web pages in the respective sub-categories, to indicate the amount of learning content in the particular sub-category. The rest of the variables are specified in [Table 21].

The following figure depicts an example of implementing the proposed method on W3Schools website. For illustration purposes, a simple webpage was produced, using technologies HTML and CSS. The figure is in fact a cropped screenshot of how it was displayed in a web browser [Fig. 13].

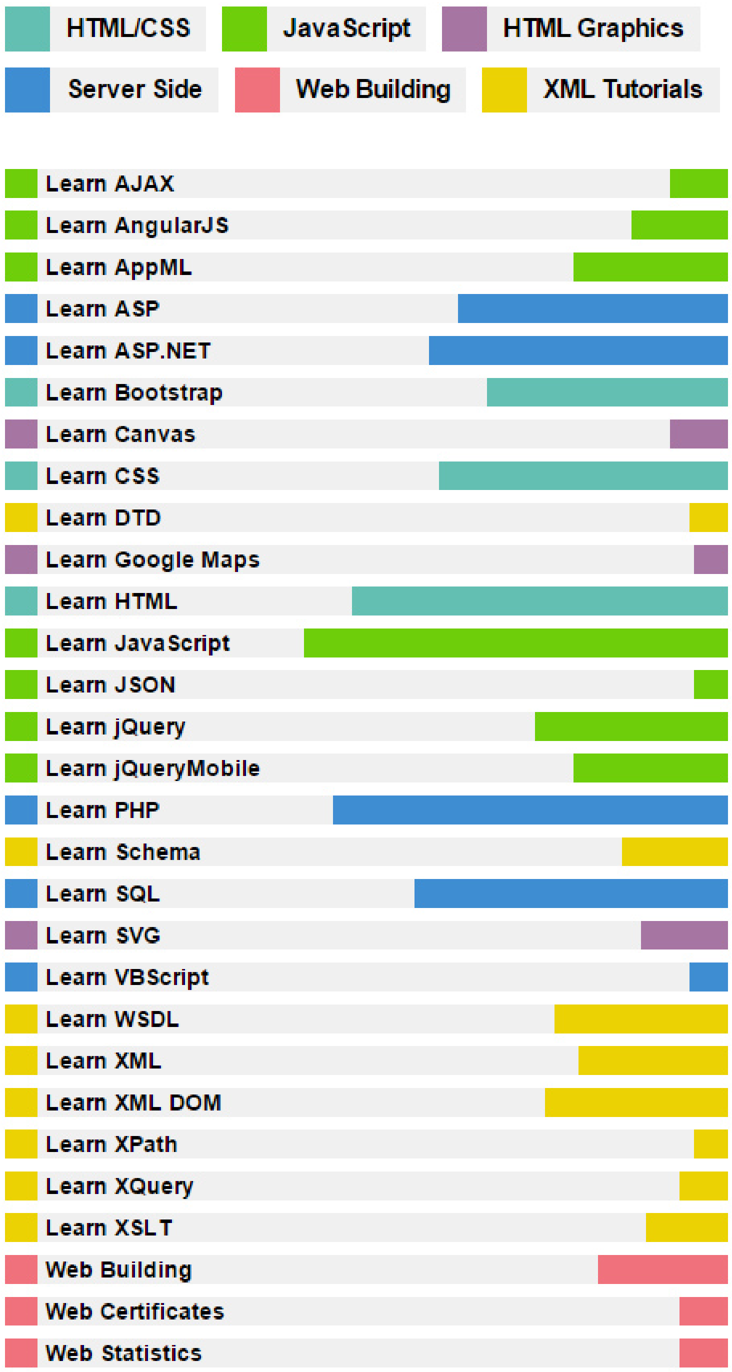



**Fig. 13. Implementation of the proposed method for W3Schools**

### 6.2.8 Application on navigation of Smashing Magazine

Smashing Magazine (2014) delivers useful and innovative information to web designers and developers and is available on http://www.smashingmagazine.com/. This website also contains tutorials and ideas, but its structure is very different from that of W3Schools. Smashing Magazine functions as a magazine with articles and every day or every few days a new article is published. The primary navigation structure consists of the first level by categories and the second level by tags (which by visual design look like sub-categories, but they are not mutually exclusive). The content area (on home page or after clicking on particular category or tag) is filled with previews of articles, sorted by time from the newest. The category view in addition contains its description and popular tags in the category, which are however often different from the tags displayed in the navigation, which can cause users further confusion. Some tags, which are used for describing articles, are displayed nor in the navigation neither among popular tags. The following table specifies variables for organization schemes, proposed for Smashing Magazine, along with a range of values, which summarize information gathered by manually clicking and searching. For the purposes of this study, we dealt with tags as with sub-categories and only with those included in the primary navigation.

**Table 22. Organization schemes applied on variables for Smashing Magazine**

| Org. scheme | Variable used by the org. scheme | Range of values * |
|---|---|---|
| subcategory | labels of navigation items | count: 23 |
| alphabet | the first letter of every sub-category | from an “Android” to a “Web design” sub-category |
| time | the date when the last article was added to the sub-category | from 18.3.2013 to 2.3.2015 |
| category | the category, under which the particular sub-category belongs | count: 6 |
| continuum | number of articles in the particular sub-category | minimum value: 22<br>maximum value: 270 |

* at the time of writing this paper

In the case of Smashing Magazine, we would find it useful to organize sub-categories by the date when the last article was added into this sub-category. This will allow users to identify on the first look, where he can find the latest articles and on what topics, which is especially useful for returning users. Continuum will be, as in the case with W3Schools, represented by the number of items in the respective sub-categories. The number will indicate the amount of content on the particular topic (i.e. sub-category), so the user can identify on the first look, which topics are covered to a greater extent on this site. The rest of the variables are specified in [Table 22]. If the navigation was to be implemented also for the lower level of hierarchy, arrangement by continuum could facilitate social navigation. In the case of Smashing Magazine, popularity would be represented by number of comments associated with the particular article.

The following figure depicts implementation of the proposed method on Smashing Magazine website, as it was displayed in a web browser [Fig. 14].

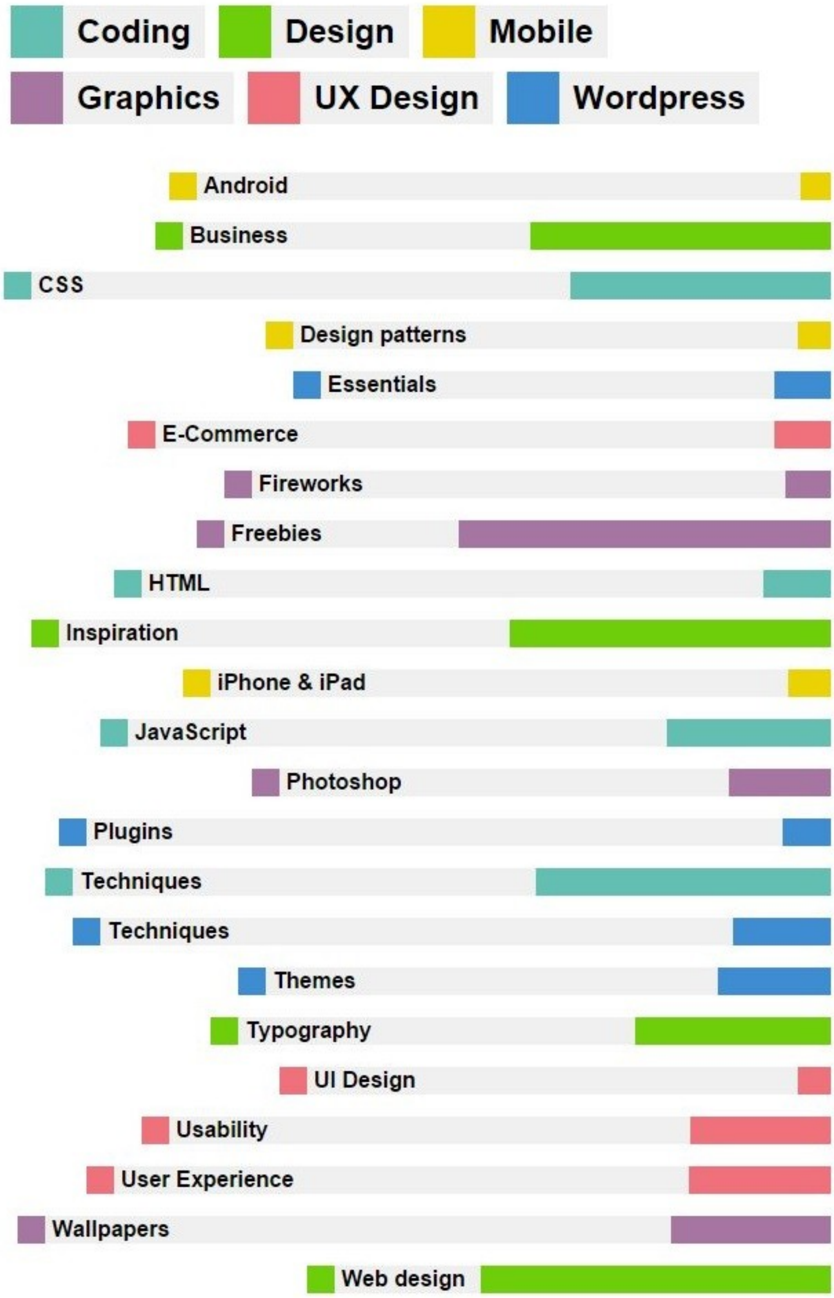



**Fig. 14. Implementation of the proposed method for Smashing Magazine**

## 6.3 Testing of usability

This chapter is devoted to testing of usability of proposed solutions. Usability is a very important quality criterion in e-learning (Gasparini et al., 2010), as was already stated in the State of the art, chapter 3.1.2 "Usability". Usability of system´s interface influences user´s performance and number of errors (objective usability) but also his ease of working with the system, satisfaction and willingness in using the system again (subjective usability). Most widely used method for measuring usability is user testing, an inspection and an inquiry (Fernandez et al., 2011). Our usability testing includes both objective and subjective measures, which is discussed in detail in respective sub-sections.

### 6.3.1 Introductory presumptions

The idea of visualization of learning resources is not new (see eg. Klerkx et al., 2014). Exactly our approach was not implemented before (to our best knowledge), however applications of visualization in e-learning are many, with similar argumentation such as ours. E.g. in the "Mastery Grids" of Loboda et al. (2014), students are able to see all available resources, represented by rows of a grid. As a consequence, we consider our solution for course-based systems as less "innovative" than our proposal for repository-based systems. Therefore also testing of usability in this chapter is focused primarily on the solution for repository-based systems (section 6.2). The novelty of proposed arrangement needs to be tested in order to validate its contribution and practical use.

By implementing the proposed method, we expected to achieve several major advantages over traditional navigation: 1) reduced disorientation of users by providing constantly visible navigation area, 2) reduced subjectivity by using objective means of organization, 3) increased information density by utilising design elements for adding information value to navigation items, and 4) reduced interaction and attention-switching cost by presenting more information about navigation items in one layout. Testing of contribution towards better usability for each individual advantage is however hardly achievable. Therefore we will focus on testing general usability of the new interface by standardly used usability tests (see section 6.3.2).

Considering it is a novel arrangement, we have to take a learning curve into account. We can expect both performance and user satisfaction to improve especially in repeated visits, after introduction with the system. People get used to certain positions for certain elements on the webpage (Roth et al., 2010). Effect of violation of these standards was researched by Santa-Maria and Dyson (2008) on the experimental online discussion forum in two versions - one with conventional design and the other violating these conventions. Users of the other version were disoriented and confused, however after short adaptation, the performance of both groups were almost equal, as well as the number of subsequent visits of the website. Consequently, this arrangement is expected to be more useful on websites which are visited repeatedly, such as news servers, blogs, educational or knowledge-based websites. Also the results of performed usability testing will not reflect actual usability in case of interface´s continuous use. The results will indicate only the immediate usability after short introduction to the new interface.

### 6.3.2 Selected usability tests

Several evaluation tests were performed in order to validate the proposed interface. For this purpose we have used commonly used tests for measuring usability and user experience. The first test is measuring task time as an objective usability metrics. This is a precise measurement of user performance, however it does not take into account possible user distractions. They can be negative for performance but positive for overall user experience. This metrics will be referred to as "time" for brevity.

The second test is the post-task self-reported metrics, which is appropriate to use in order to test new interfaces. Tedesco and Tullis (2006) compared a variety of post-task self-reported metrics in an online usability study. Out of the five tested rating techniques, the best correlation was observed with this one-item rating scale: "Overall, this task was: Very easy...... Very difficult.". This rating scale was also the most reliable at smaller sample sizes (Albert & Tullis, 2013). 5-point scale was used here, with values from 1 to 5. This metrics will be referred to as "inquiry" for brevity.

The third test belongs to performance metrics regarding task success. Levels of success can be examined in terms of the user experience. We can use four-point scoring method for each task: 1 = no problem; 2 = minor problem; 3 = major problem; 4 = failure / gave up (Albert & Tullis, 2013). The researcher has to determine the respective level of success according to the user experience and performance. This data are ordinal, so they will be presented as frequencies for each level. This metrics will be referred to as "success".

The last test is one of the most widely used tools for assessing the perceived usability - the System Usability Scale. SUS is a simple ten-item scale giving a global view of subjective assessments of usability (Brooke, 1996). The SUS consists of 10 questions:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

(Brooke, 1996)

SUS was proved to be a reliable and valid measure of perceived usability (Sauro, 2011). It was further discovered that SUS not only measures perceived usability but also learnability. According to Lewis and Sauro (2009), items 4 and 10 provide the learnability dimension and the other 8 items provide the usability dimension. For the purposes of this testing, the inquiries were translated into Czech and "system" was specified as the way of organizing items in web navigation.

### 6.3.3 The procedure of testing

The procedure of testing was the following; After the introduction, participants were presented with the written instructions and answer sheet. The instructions included brief explanation, what will be tested, specified as the way of organizing items in website navigation. See the attachment 12.1. and 12.2. (Instructions and answer sheet for usability testing - pg. 1 and pg. 2) for details. This material was accompanied by the schema (see the attachment 12.3. Schema used for usability testing) and the navigation interface applied on Smashing Magazine (see Fig. 13). The instructions contained information, that the attached schema presents rules for organizing items and the website navigation (Fig. 13) follows these rules. The participants were given time to make familiar with the interface before they began fulfilling the tasks.

Testing sessions were carried out individually for each participant for several reasons. Primarily this arrangement allowed the researcher (author) to observe participant´s dealing with tasks. This enabled evaluating task success correctly, along with checking the measured time. The influence of participant´s performance on each other was also eliminated this way. The writtten form was used in order to keep the conditions same for all participants. The researcher (author) was present at the testing sessions but did not interfere. No verbal explanation of the interface or the discussion was provided before or during testing. The relevant materials were translated into Czech for Czech participants.

These questions (tasks) were selected for the testing:

0. Which subcategory contains the newest article (from all categories)? (sample question, provided with correct answer)
1. Which subcategory contains the newest article (only in category "Design")?
2. Which subcategory is the largest (i.e. contains the biggest number of articles)?
3. Which category is the smallest (i.e. contains the least number of articles)?
4. Is this website more focused on "UX Design" or "Design"? (i.e. contains more content on which of these two topics?)
5. Is this website more focused on Techniques for Coding or for Wordpress?

The tasks were chosen according to the main strength of the interface - an information value accessible without need of further actions. The tasks were formulated as questions, because users were supposed to find the answer without the necessity of clicking, scrolling etc. They are focused on basic orientation in structure and content of the web interface. Amswer and the first three metrics were collected separately for each task. Answer, inquiry and time were provided by the participant. Levels of success were collected by the researcher. The evaluation of success consisted of observing participant´s struggle with the task and also the correctness of the answer. Participants were instructed to find answers by looking at the navigation, however they were allowed to look also at the schema if they needed. After processing all six questions, the final assessment of the interface was conducted (SUS).

Before the actual experiment, preliminary usability testing with 5 users was carried out (these users did not participate on the main experiment). During and after this testing, users were inquired about their experience. Especially if they understood written instructions correctly, if the schema was easily comprehensible etc. Based on the collected data, several modifications to the schema and instructions were made. In the preliminary testing, the schema from chapter 6.2.6 (see Fig 11.) was used, however based on feedback from these participants, it was modified to the more descriptive form in the actual experiment (see attachment 12.3.). The instructions were carefully simplified to make them more readable and the sample question was added for better understanding. The preliminary testing definitely helped making the actual experiment less vulnerable to errors. Errors which would manifest as a poor performance and frustration of participants, caused needlessly by wrong wording or unsufficient explanation.

Furthermore, preliminary testing showed that some participants tend to forget measuring time at the right time or at all. The researcher therefore also recorded the time elapsed between estimated finishing reading task and writing down an answer. Time measurement collected by the researcher was used in cases when participant´s time measurement was clearly wrong. However time measurement from user was preferred. Since its start was defined as "after reading and understanding the question" and end by "formulating the answer", the participant´s own measurement should be more precise.

### 6.3.4 Results and conclusions

The collected values for each question (Q1 - Q5) are presented in the following table for each participant (P1 - P13) [Table 23]. For the summarized view with frequencies and averages see the next table [Table 24].

**Table 23. The results for each question (format: answer | time | inquiry | success *)**

| | Q1 | | | | Q2 | | | | Q3 | | | | Q4 | | | | Q5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | 1 | 5 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 9 | 1 | 1 | 1 | 7 | 1 | 1 | 1 | 8 | 2 | 1 |
| P2 | 1 | 10 | 2 | 2 | 1 | 5 | 1 | 1 | 1 | 8 | 2 | 1 | 1 | 14 | 3 | 2 | 0 | 42 | 5 | 4 |
| P3 | 1 | 4 | 1 | 1 | 1 | 7 | 2 | 1 | 1 | 11 | 2 | 1 | 1 | 8 | 4 | 1 | 1 | 25 | 4 | 2 |
| P4 | 1 | 3 | 1 | 1 | 1 | 7 | 1 | 1 | 1 | 15 | 3 | 1 | 1 | 4 | 1 | 1 | 1 | 5 | 2 | 1 |
| P5 | 1 | 10 | 1 | 1 | 1 | 10 | 1 | 1 | 0 | 16 | 2 | 4 | 1 | 25 | 2 | 2 | 1 | 30 | 2 | 1 |
| P6 | 1 | 8 | 2 | 1 | 1 | 8 | 2 | 1 | 1 | 9 | 2 | 1 | 1 | 12 | 2 | 1 | 1 | 10 | 2 | 1 |
| P7 | 1 | 5 | 1 | 1 | 1 | 4 | 1 | 1 | 1 | 10 | 2 | 1 | 1 | 14 | 3 | 1 | 1 | 12 | 3 | 1 |
| P8 | 1 | 7 | 1 | 1 | 1 | 9 | 2 | 1 | 0 | 17 | 3 | 4 | 1 | 9 | 2 | 1 | 1 | 21 | 4 | 2 |
| P9 | 1 | 15 | 1 | 1 | 1 | 12 | 1 | 1 | 1 | 28 | 2 | 2 | 1 | 21 | 2 | 1 | 1 | 32 | 2 | 1 |
| P10 | 1 | 9 | 1 | 1 | 1 | 6 | 1 | 1 | 1 | 13 | 1 | 1 | 1 | 16 | 3 | 1 | 1 | 11 | 3 | 1 |
| P11 | 1 | 12 | 2 | 1 | 1 | 13 | 1 | 1 | 1 | 17 | 2 | 2 | 1 | 19 | 2 | 1 | 0 | 29 | 3 | 4 |
| P12 | 1 | 11 | 1 | 1 | 1 | 8 | 1 | 1 | 1 | 21 | 4 | 3 | 1 | 15 | 2 | 1 | 1 | 18 | 4 | 2 |
| P13 | 1 | 4 | 1 | 1 | 1 | 6 | 1 | 1 | 1 | 12 | 3 | 1 | 1 | 10 | 1 | 1 | 1 | 14 | 3 | 1 |

* answer: 0 = incorrect, 1 = correct; time: in seconds; inquiry: from 1 (very easy) to 5 (very difficult); success: from 1 (no problem) to 4 (failure).

**Table 24. The results - summarization of collected data for each question**

| | Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|---|
| *frequencies* | 1 \| 2 \| 3 \| 4 \| 5 | 1 \| 2 \| 3 \| 4 \| 5 | 1 \| 2 \| 3 \| 4 \| 5 | 1 \| 2 \| 3 \| 4 \| 5 | 1 \| 2 \| 3 \| 4 \| 5 |
| **Correct answers (%)** | 100% | 100% | 85% | 100% | 85% |
| **Average time (s)** | 7,9 | 7,5 | 14,3 | 13,4 | 19,8 |
| **Inquiries** *(frequencies)* | 10 \| 3 \| 0 \| 0 \| 0 | 10 \| 3 \| 0 \| 0 \| 0 | 2 \| 7 \| 3 \| 1 \| 0 | 3 \| 6 \| 3 \| 1 \| 0 | 0 \| 5 \| 4 \| 3 \| 1 |
| **Levels of success** *(frequencies)* | 12 \| 1 \| 0 \| 0 | 13 \| 0 \| 0 \| 0 | 8 \| 2 \| 1 \| 2 | 11 \| 2 \| 0 \| 0 | 8 \| 3 \| 0 \| 2 |

Q1, Q2 and Q4 were completed by participants with 100% success. These tasks have also the lowest average time and users evaluated them as more easy than the remaining two tasks. Tasks Q3 and Q5 have still high percentage of correct answers (85% each). In comparison with previous tasks, more minor problems and failures were encountered. Users also rated tasks Q3 and Q5 as more difficult and it took them longer to complete them. The results are however still very promising, with only 4 failures out of 52 performed tasks (13 participants with 5 tasks each).

See the following diagrams, which visually represent results of inquiries and levels of success. The first diagram shows ratio between successes and failures of performed tasks [Fig. 15]. The second chart indicates participants´ subjective ratings on inquiries [Fig. 16].

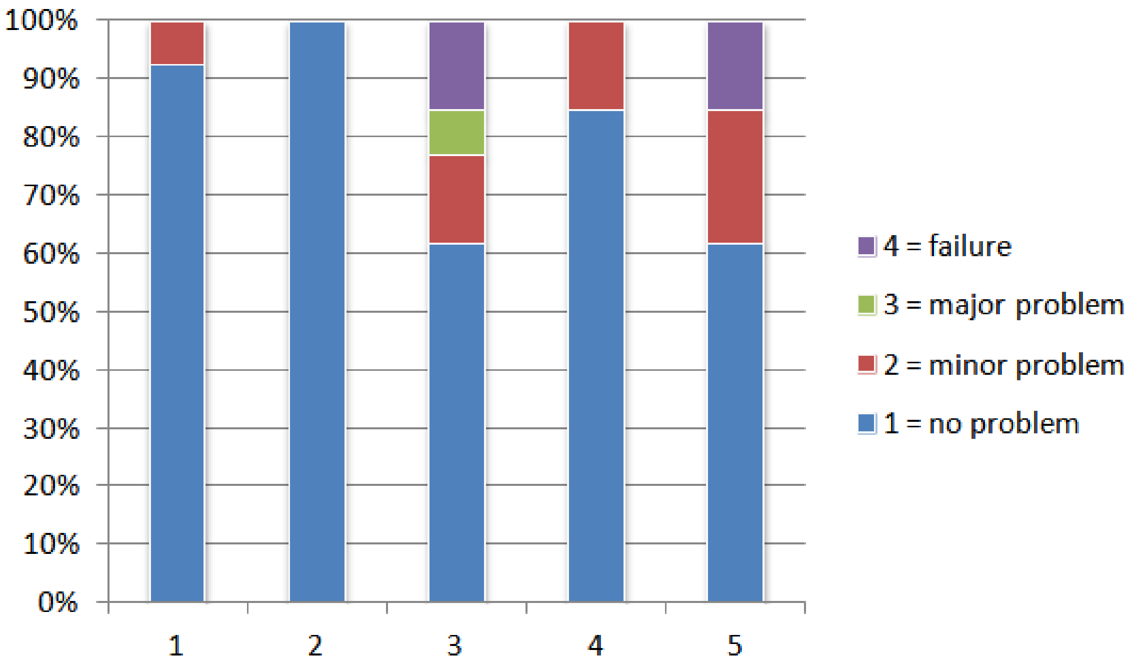



**Fig. 15. The results - frequencies of levels of success**

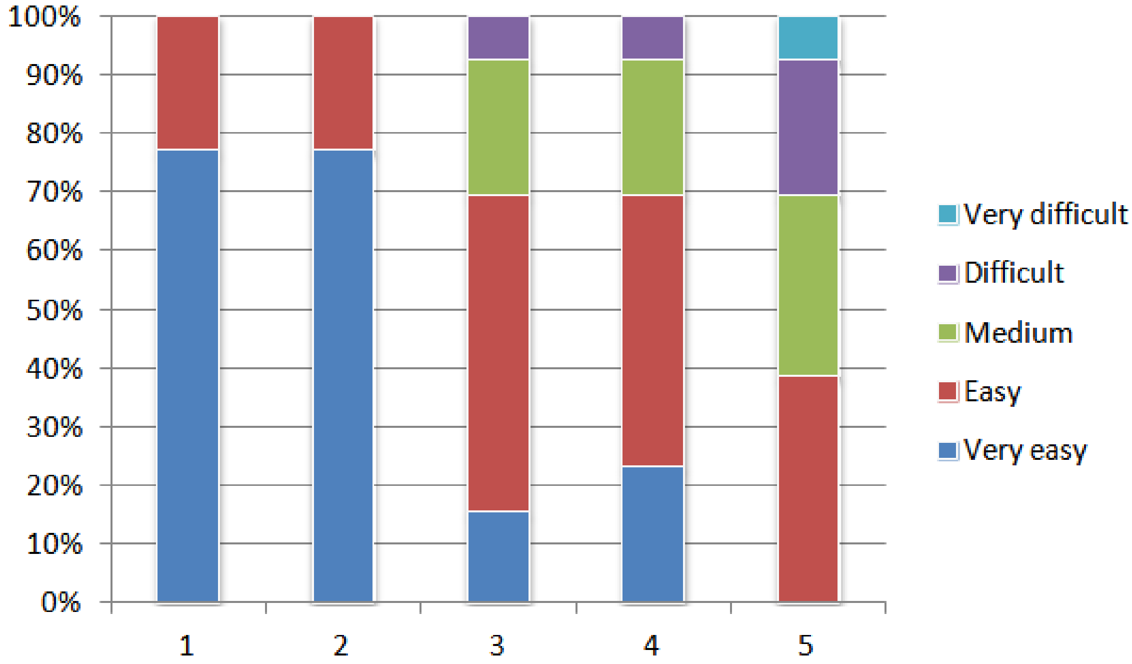



**Fig. 16. The results - frequencies of inquiries**

Reasons for lower rate of success in tasks Q3 and Q5 can be several. First, tasks could be objectively more difficult than the others. Second, the wording of tasks could be at fault. Also based on the discussion with participants after testing, two of four failures were caused by misreading the task. E.g. one participant answered "Android" as the smallest subcategory, instead of correctly answering "Mobile" as the smallest category (Task 3).

Finally the answers on system usability scale are collected in [Table 25]. The "SUS score" values were calculated according to the scoring explained by Brooke (1996). SUS score averaged from all participants is 78,46 in this case. What is a good SUS score varies in interpretation by different authors.

Sauro (2011) reviewed the existing research on SUS and analyzed data from over 5000 users across 500 different evaluations. The average SUS score from all 500 studies was 68. Therefore according to Sauro, SUS score above 68 is considered above average and anything below 68 is below average (Sauro, 2011). Bangor et al. (2009) suggested the following interpretation of SUS scores: <50 not acceptable, 50-70 marginal, >70 acceptable. With our average SUS score being 78,46, we can consider it both acceptable and above average.

**Table 25. The final assessment by system usability scale (1 = disagree, 5 = agree)**

| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | **SUS score** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | 4 | 1 | 5 | 1 | 5 | 2 | 3 | 1 | 4 | 3 | **82,5** |
| P2 | 3 | 3 | 3 | 4 | 5 | 1 | 4 | 3 | 2 | 4 | **55** |
| P3 | 4 | 1 | 4 | 1 | 4 | 1 | 4 | 2 | 4 | 2 | **82,5** |
| P4 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | **100** |
| P5 | 5 | 1 | 4 | 2 | 4 | 2 | 3 | 1 | 4 | 2 | **80** |
| P6 | 5 | 1 | 4 | 1 | 4 | 1 | 5 | 1 | 4 | 1 | **92,5** |
| P7 | 4 | 1 | 4 | 1 | 5 | 1 | 3 | 1 | 3 | 2 | **82,5** |
| P8 | 4 | 3 | 3 | 2 | 4 | 2 | 4 | 2 | 3 | 2 | **67,5** |
| P9 | 5 | 1 | 5 | 5 | 5 | 1 | 5 | 1 | 3 | 3 | **80** |
| P10 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | **100** |
| P11 | 4 | 2 | 3 | 5 | 4 | 3 | 1 | 3 | 2 | 4 | **42,5** |
| P12 | 3 | 2 | 4 | 4 | 5 | 2 | 3 | 2 | 4 | 2 | **67,5** |
| P13 | 5 | 1 | 5 | 2 | 4 | 1 | 4 | 2 | 4 | 1 | **87,5** |

### 6.3.5 Discussion

Very good results were achieved in the performed usability testing. However it needs to be asserted, that repeated testing would show the contribution of the interface better. It was already mentioned, that proposed navigation is expected to be more useful on websites which are visited repeatedly, such as news servers, blogs, educational or knowledge-based websites (see section 6.3.1). Desirable would be long-term testing of system with proposed navigation interface, which would be in active use by stable group of users. However implementation and long-term management and monitoring of such system is beyond the scope of this dissertation thesis.

Finally the short discussion about number of participants concludes this chapter. There is an ongoing argument whether five participants are enough for user testing or not. Nielsen and Landauer researched that the typical proportion of usability problems discovered while testing a single user is 31% (Nielsen, 2000). The five user number then comes from the number of users you would need to detect approximately 85% of the problems in an interface (Sauro, 2010). However, it depends whether you are interested only in usability problems that will probably occur to the majority of users or also the less frequent issues. According to Sauro (2010), testing 13 users would discover 95% of the problems that affect 20% or more of the users. Therefore 13 users are considered as a sufficient sample size and it is also the number of users, which participated on this testing.

# 7 Proposal of web-based educational system

This chapter presents proposal of the whole web-based educational system. This system forms a hybrid approach between course-based systems (see chapter 6.1) and repository-based systems (see chapter 6.2). It supports both learning courses and/or collections of learning resources (i.e. repositories). The schemas, which are presented throughout this whole chapter, are specified for courses rather than collections. In case of collections, organization by time sequence would be simply replaced by other mean of organization, more suitable for the given purpose. Possible organization schemes are discussed theoretically in section 3.3 and their actual usage in section 6.2, especially see sections 6.2.3 and 6.2.5.

In the case of this particular model, presented in this chapter, the first hierarchical level of learning resources is composed by learning courses. Each learning course then creates its own repository, which is the second level of the hierarchy. These repositories can be further divided by categories into groups. Throughout the chapter, there are comments regarding possible extensions or modifications of this basic model, which can be carried out in the actual implementation. The list of these alternations is far from complete. As long as the primary improvements listed in section 7.1 "The conceptual foundation" are implemented in a way suggested in the respective sections. The room for modifications is suggested because of the variable purposes and scopes of actual implementations, grounded in this educational system proposal.

The focus of this proposal is placed not only on the usability-oriented organization and navigation, but also on user-related concepts such as personalization or knowledge building. The ultimate goal is to create up-to-date well-arranged learning environment, which supports collaborative building of learning resources.

The initial proposals of this system were successfully presented at three conferences, specifically in research papers "Knowledge management and sharing in e-learning: Hierarchical system for managing learning resources" (Bartuskova & Krejcar, 2014d), "Framework for managing of learning resources for specific knowledge areas" (Bartuskova et al., 2014) and finally "Personalization of Learning Content and Its Structure, Based on Limitations of LMSs" (Bartuskova & Krejcar, 2016). The proposed system is further developed in this chapter.

This chapter will be structured in the following way:

- 7.1 The conceptual foundation - relation to the previously identified issues
- 7.2 The core management system - management of resources and personalization
- 7.3 Collaborative knowledge building - extension of the core system
- 7.4 Interface design - organization of navigation items and resources
- 7.5 Implementation overview - introduction to selected implementation issues

## 7.1 The conceptual foundation

As the starting point for the proposed solution, the conclusions from previous analyses are summarized here. These issues are associated primarily with educational and knowledge-management systems and some of them were already reflected in the proposed solutions for course-based systems (see chapter 6.1) and repository-based systems (see chapter 6.2). The latter included argumentation related to orientation and navigation, which is not repeated here; please see the relevant table in section 6.2.1 [Table 17]. The ultimate goal of this dissertation is to connect these ideas - smart web user interfaces - into the one system´s proposal. Each of the discussed issue will be labelled for later reference, following this format: *{xxx}* , placed after the relevant issue.

As the main issue related to fixed structure and content of course-based learning systems such as LMSs was identified (see chapter 4.2.1 for details), for both teachers and students:

- an insufficient personalization support for:
  - organization of learning courses *{per1}*
  - organization of learning resources inside courses *{per2}*
  - annotation mechanisms (tags, notes, comments,..) *{per3}*

As the main issues related to content management and user interface of course-based learning systems such as LMSs were identified (see chapter 4.2.2):

- (students perspective) the lack of vizualization for distinguishing:
  - the course basic structure *{mng1}*
  - between important and additional (optional) resources *{mng2}*
- (teachers perspective) the system´s interface does not encourage:
  - regular revising of existing content *{mng3}*
  - disposing of outdated content *{mng4}*

The most common way to organize content in analyzed 15 computer science courses in Blackboard Learn LMS was (see chapter 4.2.3):

- by category - primary content division, represented also in sidebar navigation, sections usually partially reflect content types as categories *{org1}*
- by continuum (time) - secondary content division, usually used in lectures / seminars section, which are divided into sessions, ranging from 6 to 13 *{org2}*

The analysis of selected learning object repositories (see chapter 4.3.2) also identified several issues, which can contribute to the failing sustainability of LORs. These basic usability issues were encountered during working with selected LORs:

- an inefficient and confusing hierarchy and labelling of categories *{res1}*
- search results are outdated or do not exist anymore - resources are not further managed (revised, updated, deleted) *{res2}*
- metadata are missing, inaccurate, wrong or redundant - resources are not sufficiently described *{res3}*

The following table [Table 26] presents the proposed areas of improvement for identified issues of educational and knowledge-management systems. This will be used as a guideline for the new system proposal.

**Table 26. The proposed areas of improvement**

| | **support for issues** | **the most relevant section** |
|---|---|---|
| *{ORG}* organization of navigation items and resources | *{mng1} {mng2} {org1} {org2} {res1}* | 7.4 Interface design |
| *{MNG}* management of resources | *{mng3} {mng4} {res2} {res3}* | 7.3 Collaborative knowledge building |
| *{PER}* means of personalization (in organization and management) | *{per1} {per2} {per3}* | 7.2 The core management system |

Dealing with the identified issues, summarized in [Table 26], is the first goal of the proposed educational system. The personalization requirement is further the prerequisite for the collaborative knowledge building, proposed as the extension of the core system.

## 7.2 The core management system

This chapter is devoted to the proposal of the core management system. In relation to the proposed areas of improvement, this chapter is primarily focused on the means of personalization *{PER}*. The management of resources is naturally also covered, however mainly the fundamentals such as CRUD. The solution for identified issues regarding management *{MNG}* will be subject of later chapters, especially section 7.3 "Collaborative knowledge building".

### 7.2.1 User roles

So far the proposed interface designs were focused on learner as the primary end user of the educational system. The proposed areas of improvement in [Table 26] however interfere in scope to the activities of another user role - the teacher. Especially in the area of management of resources and extended possibilities in the area of personalization. The teacher´s perspective was mentioned already in chapter 4.2.2 while identifying issues of LMSs. The web-based educational system proposed in the whole chapter 7 therefore supports two main user roles - teacher and learner.

The core model assumes many teachers (one teacher per one learning course) and many students (who can attend any number of these courses). This basic model is in accordance with previously presented interface designs. However this arrangement is not strict, it depends on the actual implementation of user roles and their permissions.

### 7.2.2 Core functions

The core functions are represented by the key activities, which can users realize in the system. The key activities regarding management of resources and personalization are depicted in the following use case diagram [Fig .16]. As the primary division of learning content were selected learning courses, as was already mentioned in the introduction to this chapter. Each learning course then creates its own repository, which can be further organized into groups of learning resources - or simply categories. Individual learning resources present separate entries in the system.

Regarding personalization, the first issue to consider is the extent of possible personalization. In current LMSs, a learner can only "read" the content. As Peng et al. stated, learning systems used by colleges aim to display course resources and often neglect users' knowledge management requirement (Peng, 2013). Active students are then forced to create their own repository of learning materials, either as a local copy of course materials or they are accumulating their own resources or the combination of both. The lack of personalization support, which was discussed in section 6.1, can be divided into these two main categories:

- organization of learning content (regrouping, adding, deleting) *{per1}, {per2}*
- modification of learning content (annotation, highlighting, notes) *{per3}*

The presented schemas and proposals are focused on the first category of personalization (organization of content). The second category (modification of content) is contained in the "update" function from the "CRUD" acronym. "CRUD" is the abbreviation for four basic functions of persistent storage: create, read, update and delete.

Organizing is usually a subjective process, when done by ambiguous schemes, and language used for labeling is also often ambiguous (Morville & Rosenfeld, 2006). Therefore learners should be allowed not only to add and modify files, but also change labels or the position of files and thus adapt the learning environment to their needs. With this possibility, they could e.g. relocate the resources used for their thesis to the separate group (category) for easier access.

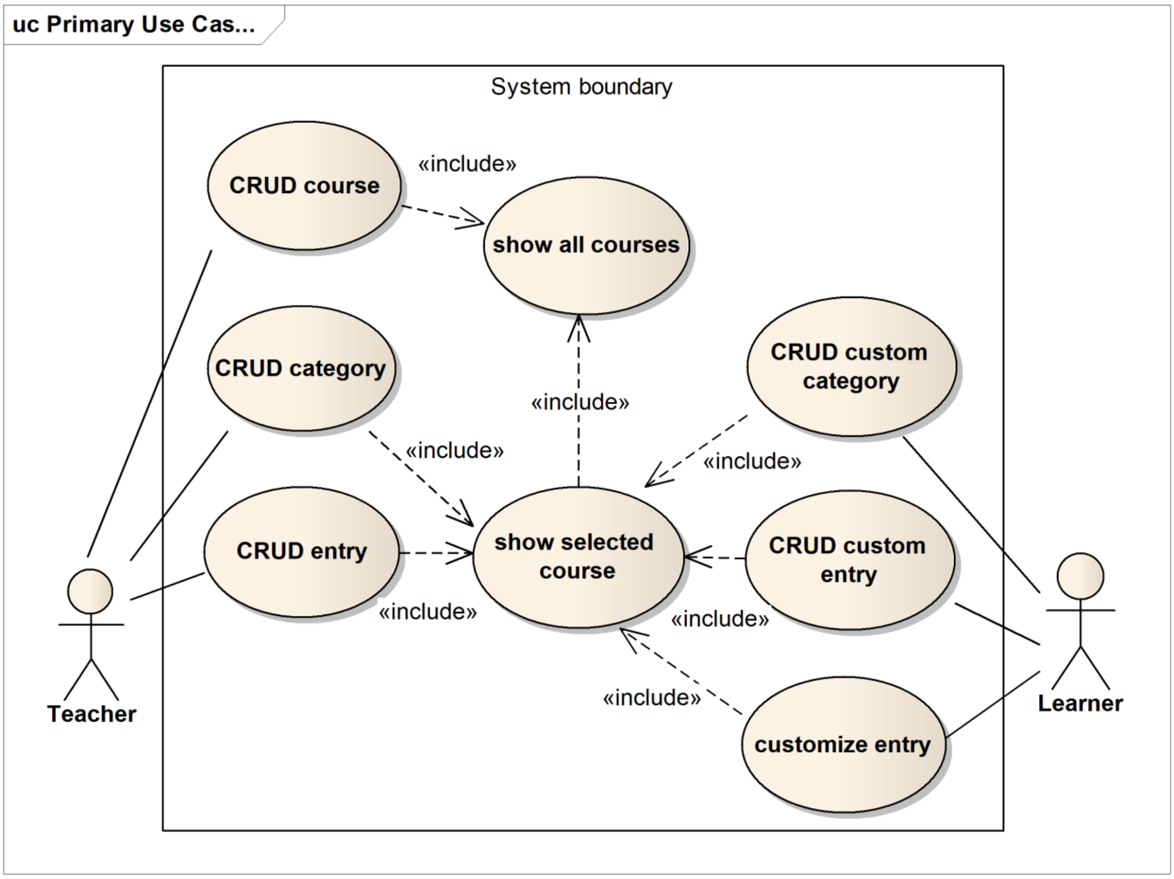



**Fig. 17. Schema of user roles and key activities in the system**

Use cases from the above schema [Fig. 17] can be divided according to their purpose into these groups:

- management of resources from the perspective of teacher
  - CRUD learning course
  - CRUD category within the course
  - CRUD entry within the category
- management of resources from the perspective of learner / student (i.e. learner´s personalization of teacher´s management of resources)
  - CRUD custom category within the course
  - CRUD custom entry within the category
  - customize existing entry within the category
- interface for displaying managed resources
  - show all courses - this use case will correspond with the interface proposal for viewing all learning courses
  - show selected course - this use case will correspond with the interface proposal for viewing the selected course

### 7.2.3 Main segments of the system

The proposed system has two main segments. The first one we would call "core repository" or the repository of learning content, which in fact forms the central knowledge base. This repository provides access to all learning courses with all learning resources to both teacher and learner. Learner´s access can be restricted according to his enrollment or other requirements, this depends on the actual implementation of the system. Learner´s access to the core repository is "read-only", as is the teacher´s access to the learning course of other teacher. Again, according to actual implementation there could be several teachers with rights to manage single learning course, however we will stick to the basic model (see section 7.2.1). The teacher can edit his learning course directly in the core repository, edit categories and edit individual entries. The extent of editing is characterized by CRUD. This changes would affect the view of core repository for every user of the system

The second segment consists of individual user´s accounts, which is in fact the implementation of learner´s personalization. It is not precluded that also a teacher can have his personalized account. However it is desirable that all learners could benefit from teacher´s management of resources, therefore it should take place in the core repository. In the scope of personalized user´s account and selected learning course, the learner can add his own learning content to the course, update the existing resource or delete the extra resources. Of course, these changes would take effect only in the individual user´s view, not in the core repository of learning resources. As far as a learner does not personalize the course, he will only "read" the core repository. When the learner starts manipulating learning content, the changes are logged, new content is stored, and his view of the learning course becomes the personalized learning course. However users should retain the option to display the original course as it is stored in the core repository.

The possibilities of personalized organization of learning content are depicted in [Fig. 18]. The diagram consists of the following use cases:

- user "Teacher A" created "Learning course A", within this course he created three categories (groups) "Lectures", "Examples" and "Tutorials" and within these categories he added several entries in each;
- user "Teacher B" created "Learning course B" and analogically any number of categories and entries;
- user "Learner 1" has access to both courses in the core repository;
- when "Learner 1" changes anything within the scope of any learning course, the personalized version of the respective course is created;
- user "Learner 1" created his personalized course by deleting "Tutorials" category, creating custom "My notes" category, creating custom entries in "Examples" and "My notes" category and customizing entries in "Lectures" category

The prerequisite for applying these use cases is the view of all learning courses and detailed views of the selected courses.

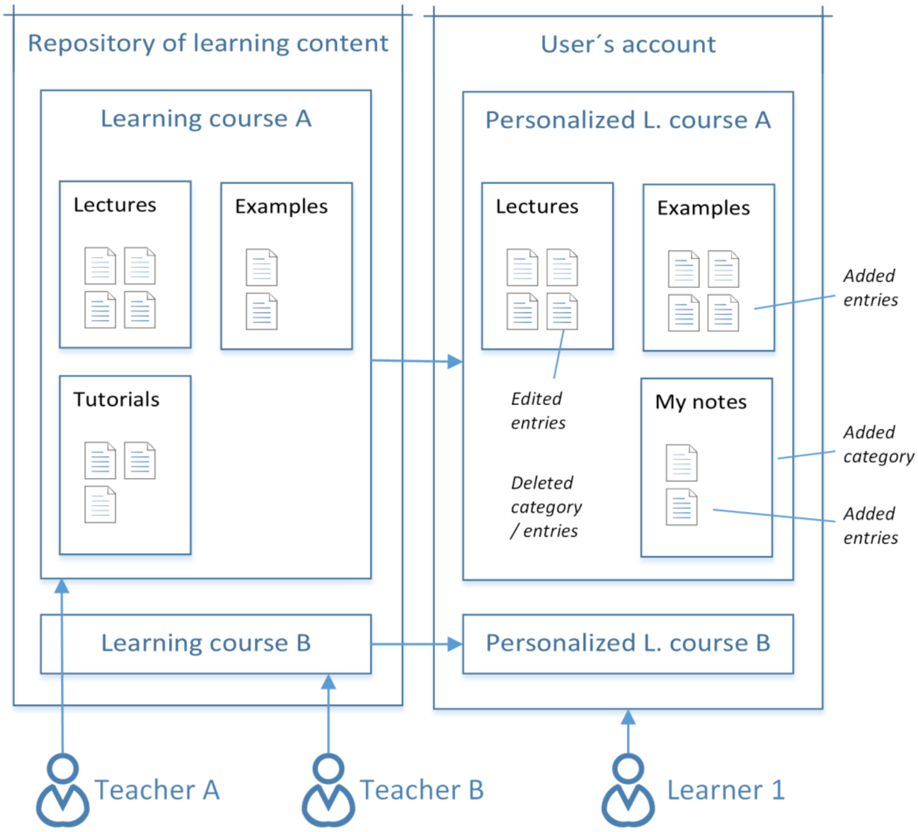



**Fig. 18. Personalized organization of learning content [13]**

The learning resources are for simplicity presented as files in folders, labels were selected arbitrarily for demonstration. For illustration only three users are showed in the schema. However the proposed system supports unlimited number of both teacher and learner roles.

### 7.2.4 Information architecture

In order to specify in more detail the relations between proposed entities, the simplified class diagram was constructed [Fig. 19]. It is important to note that the "custom entry" in the diagram can signify both the new "custom entry" and the customization of existing entry. The concept of "custom category" is analogical. The attributes can differ according to the actual implementation, which depends on many factors, e.g. usual formats of learning resources for the particular field of study. Distinction of user roles is for the sake of simplicity omitted from the diagram, only "user" for the purposes of personalization is dealt with. We can contemplate this "user" to represent "learner" rather than "teacher", since personalization is directed primarily at learners. User role "teacher" would have an association to his learning course and all its categories, entries and topics.

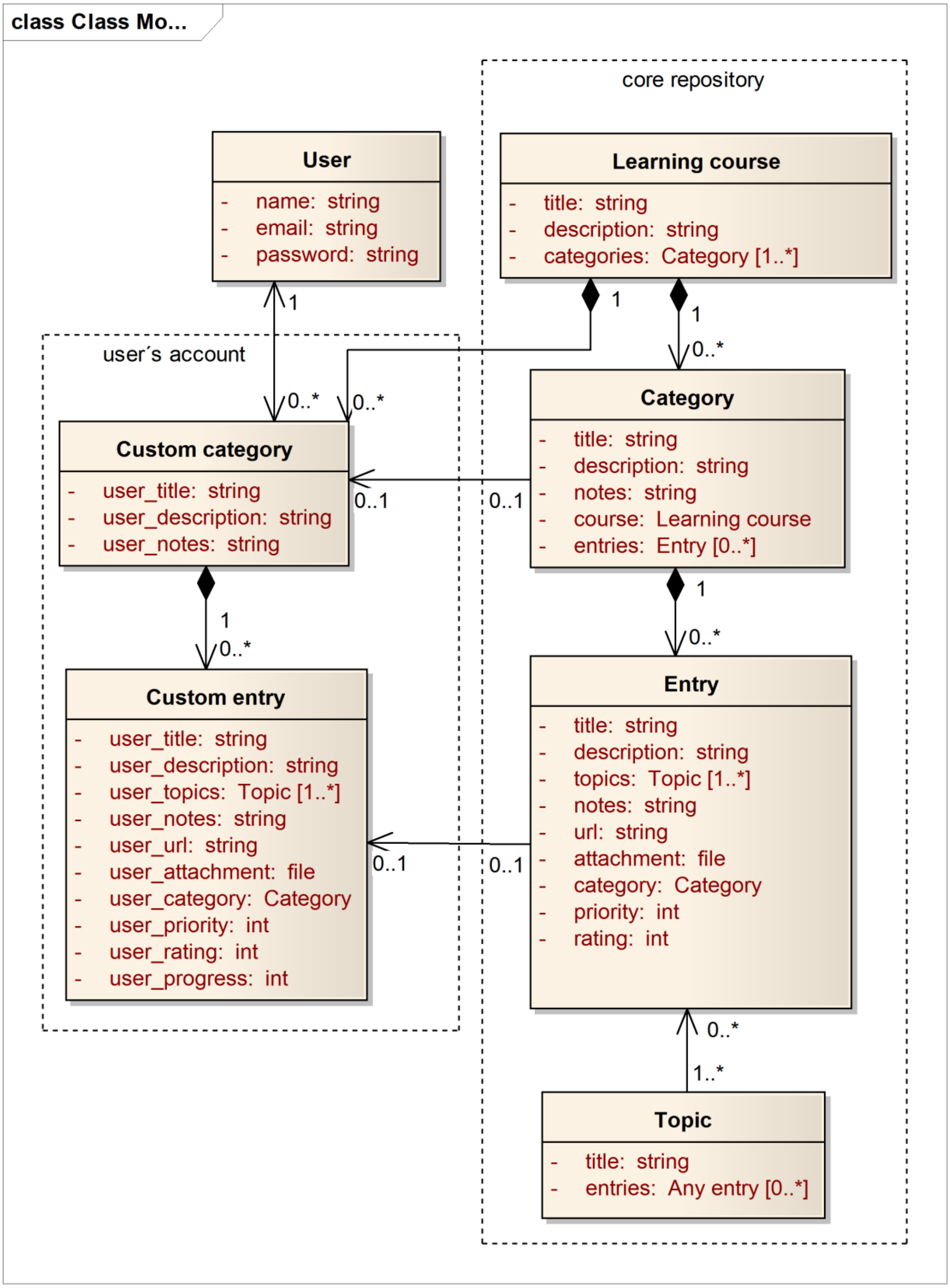



**Fig. 19. Simplified class diagram of the core management system**

The relations expressed in the class diagram are the following:

- Learning course can contain any number of categories, every category has to be placed in exactly one learning course
- Each category can contain any number of entries, every entry has to be placed in exactly one category
- Category : Custom category (with relation to one selected user´s account)
    - 1 : 0 - category, with its only version in the core repository
    - 0 : 1 - custom category, with its only version in the selected user´s account
    - 1 : 1 - customized category, with its default version in the core repository and customized version in the selected user´s account
- Entry : Custom entry (with relation to one selected user´s account)
    - 1 : 0 - entry, with its only version in the core repository
    - 0 : 1 - custom entry, with its only version in the selected user´s account
    - 1 : 1 - customized entry, with its default version in the core repository and customized version in the selected user´s account
- User has exactly one user´s account with any number of custom and customized categories and custom and customized entries

The class diagram also includes some ideas, which are presented for the first time in this chapter. This is especially the case with class "Topic" and attributes "priority", "user progress" and "rating". Attributes "description", "notes", "url" and "attachment" are the examples of possible attributes of each entry. Actual implementation can differ according to the purpose and scope of the developed educational system.

The management of entries by topic presents an alternative way of organization. Topics can either form a hierarchical structure or be implemented as tags. This additional mean of organization would be possibly more useful in the case of collections instead of learning courses (where the primary organization is more straightforward).

Usage of attribute "priority" is intended for time organization scheme. It is filled in by a teacher as a sequence (e.g. the number of week), signifying order of the resource in the course. The priority will determine horizontal arrangement of the navigation list of learning resources (see section 6.2.3). Attribute "user priority" is the customized verison of the same. Learner should be able to switch views between organization by "priority" (common version from the core repository) or "user priority" (personalized).

Attribute "user rating" can be very practical implementation for the continuum organization scheme. This input from "learner" user role is possibly the only one with the effect on the core repository, as the average rating of the respective learning resource. Again, learner should be able to switch views between organization by "average rating" (core repository) and "user rating" (personalized).

Attribute "user progress" is proposed as an additional personalization technique. The system can implement various custom attributes, which can learners add to the learning resources in order to personalize the experience. User progress, expressed as  a number or percentage, could - similarly as user rating - function as a continuum organization scheme. The learning resources in personalized view of the course could be then organized according to the learner´s progress with the resource.

**Table 27. Proposed variables as organization schemes**

| Org. scheme | Variable used by the org. scheme | Personalized variable * |
|---|---|---|
| alphabet | title (of entry) | user title (of custom entry) |
| time | priority (of entry) | user priority (of custom entry) |
| | created / modified time stamp | - |
| category | category | custom category |
| continuum | average rating | user rating |
| | - | user progress |
| tags | topics | user topics |

* custom entry/category is the same as the customized entry/category

The ideas for possible variables as organization schemes are summarized in the above table [Table 27]. An addition to the classical organization schemes are tags with variables "topics" and "user topics". Tags were identified as the categorical organization schemes with cross-listing - see chapter 5.2 Organization schemes revisited.

## 7.3 Collaborative knowledge building

The proposals in this chapter will primarily deal with limitations in the area of management of resources *{MNG}*. By collaborative knowledge building is meant the cooperation of teachers and learners alike in order to keep resources correct and up-to-date. This is very desirable especially in fields of study, which are under continuous progressive development. Fields such as medicine or computer science, where the knowledge (and learning resources as well) needs to be regularly updated. The proposed model´s purpose is to promote regular revising of existing content *{mng3}* and disposing of outdated content *{mng4}*. The lack of such leads to usability issues such as that resources are not further managed or sufficiently described *{res2}*, *{res3}*.

### 7.3.1 Extended functions

The following schema [Fig. 20] is the extension of one for the core system - see [Fig. 17]. Use case "rate entry" is added in order to implement the already mentioned attribute "rating", which enables organization by continuum. Use cases "approve and add custom entry", "reject custom entry" and "show new custom entries" is connected to the new concept of collaborative knowledge building.

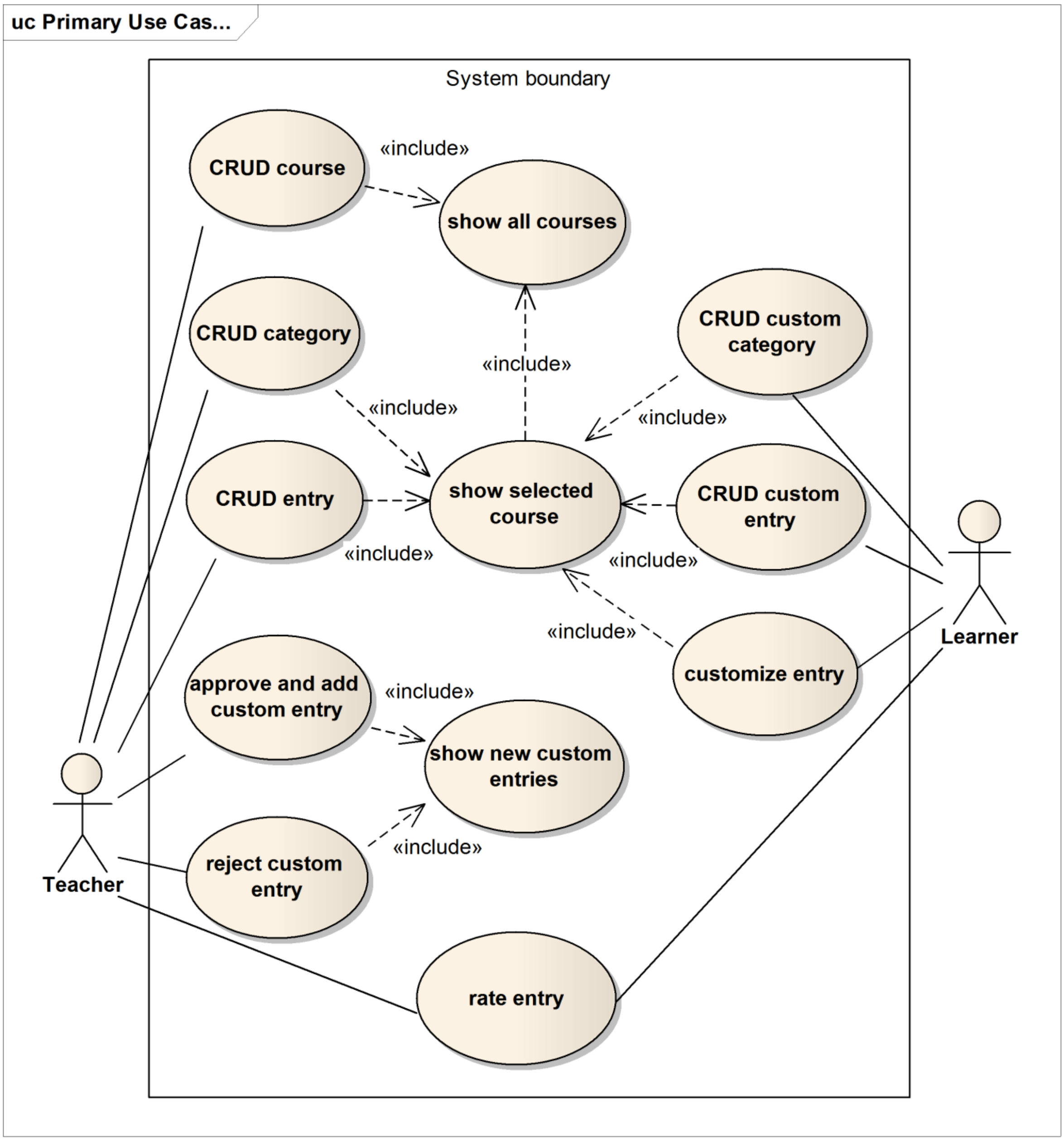



**Fig. 20. Extended schema of user roles and activities in the system**

Collaborative knowledge building in the selected course in the proposed system is formed by cooperation of one teacher and many learners in that course. The actual implementation of the system can of course benefit from cooperation of more teachers or possibly across more courses. Contribution from users are formed by their personalization; custom and customized entries but also deleted entries. These are accessible to the teacher as a list of modifications from all students of his learning course. The teacher can then accept new entries or modifications to the core repository, if he considers it an improvement for the course. If not, the modifications will remain in the particular user´s account and the core repository will remain unchanged for the rest of the learners. This way the moderated improvement of the core repository such as central knowledge base would be managed.

### 7.3.2 Process of knowledge building

The arrangement proposed in the previous section facilitates a follow-up of personalization - knowledge building. Students can access learning courses from the core repository and they can personalize the courses. The "group repository" should reflect all performed personalization, including the new content, modified content, information about deleted content and changed labels and position of the content. Individual single-purposed personalization is this way transformed into a reverse process, spontaneous collective knowledge building. Teachers receive feedback from students and as we assume it will inspire them to regular revising of existing content and disposing of outdated content, which was one of the main discussed issues of current LMSs.

This idea is depicted in [Fig. 21]. Students can access learning courses from the core repository. They can personalize the courses, by which they refine existing content and add new content. This process leads to spontaneous knowledge building, which can be used by teachers (original creators of courses) as a form of feedback. Ideally teachers should be inspired to refine the learning courses based on students personalization. Collaborative building of resources presents a viable solution of knowledge management. In order to transform personalized knowledge management into a collaborative activity, teacher is intended to have access to personalized and newly created entries of learners, which he can evaluate, approve and add to the central repository.

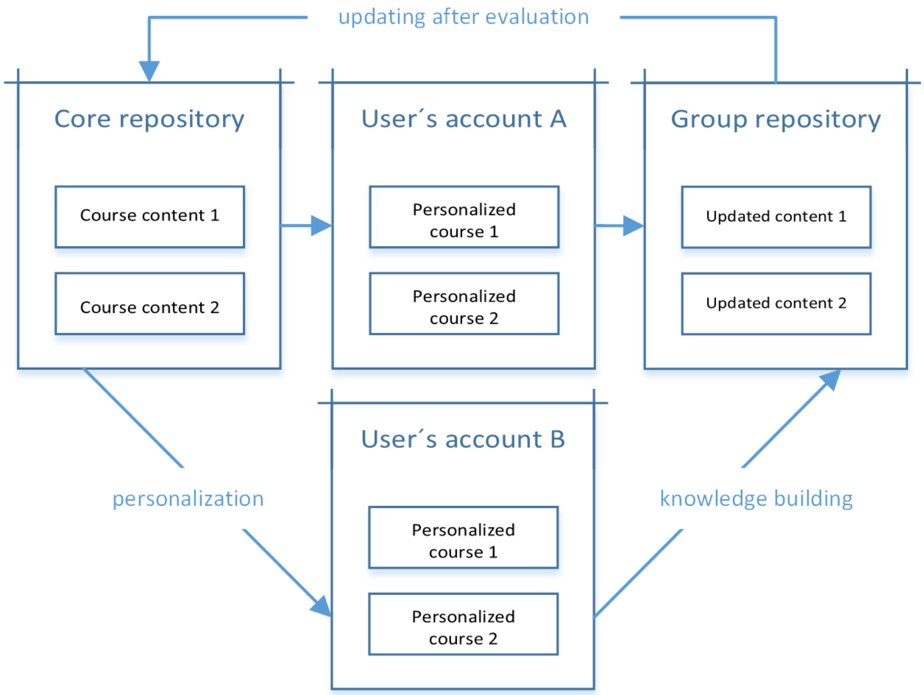



**Fig. 21. The process of personalization leading to knowledge building [13]**

## 7.4 Interface design

This section presents follow-up design proposals, which forms a hybrid approach between course-based systems (see chapter 6.1) and repository-based systems (see chapter 6.2). Two fundamental views of resources will be distinguished; view of all learning courses / collections and view of the selected course / collection. Both are the essential levels in the main hierarchy of the system.

The interface design proposals correspond with the model established in the beginning of this chapter; the learning courses are organized into categories and individual learning resources are separate entries in the system. These entries are displayed in aggregated form in the case of view of all courses (see section 7.4.1). When viewing selected course, the entries are displayed separately with additional information (see section 7.4.2).

### 7.4.1 View of all courses / collections

The following schema [Fig. 22] connects these two proposals:

- the interface presented in 6.1.4 Enhanced Table / Matrix; see [Fig. 6]
- colour association between categories and items, discussed in chapter 6.2

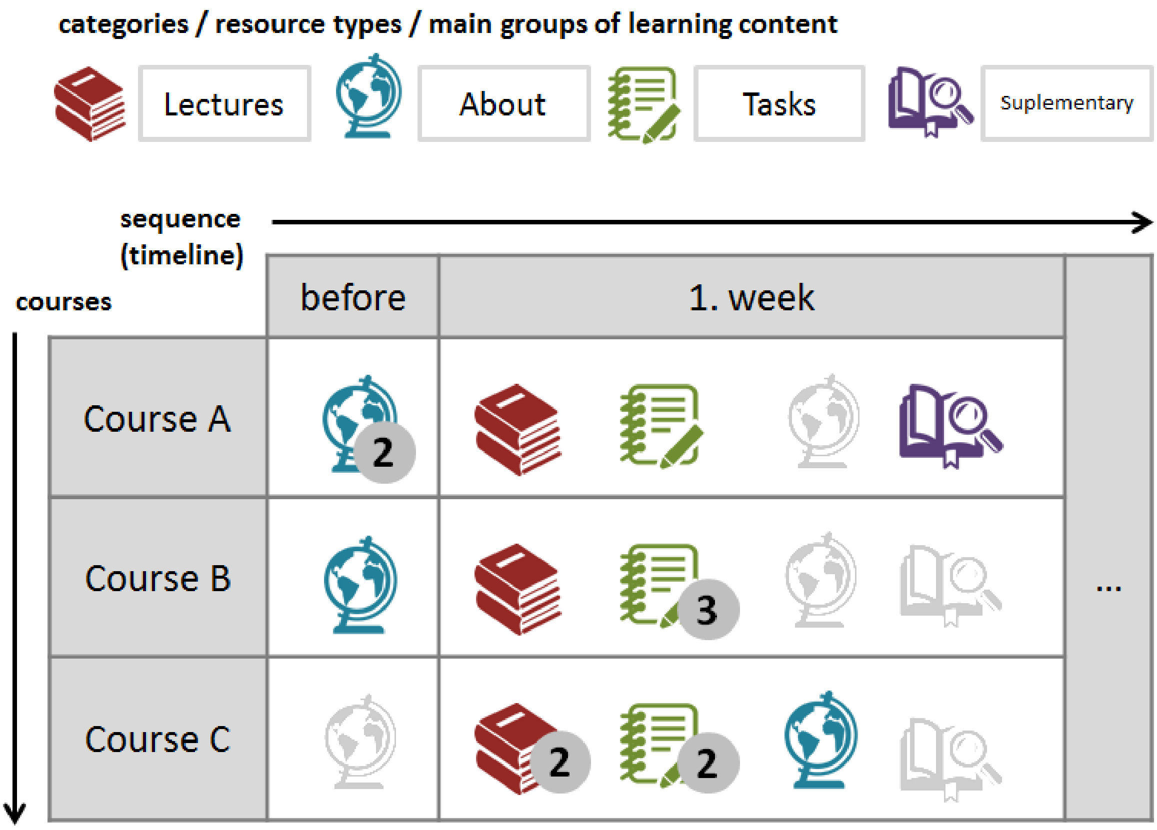



**Fig. 22. The interface schema for viewing all learning resources**

The advantages of this arrangement were discussed in relevant chapters. This combined proposal offers conjoint organization by category *{org1}* and continuum *{org2}*, which were identified as the most common ways of organizing content in learning courses.

### 7.4.2 View of the selected course / collection

The previous view was based on the interface for course-based systems and enhanced by the idea for repository-based systems. This view is based on the proposal for repository-based systems, which was refined for the purpose of educational website. The idea of icons was taken from the proposal for course-based systems. Overall this view presents a more specialized version of the interface for repository-based systems; see the describing schema [Fig. 23] and the actual interface [Fig. 24].

The advantages of this arrangement are the same as in the case of the proposal for repository-based systems (see chapter 6.2). Furthermore this combined proposal provides support for distinguishing the course basic structure *{mng1}* and types of resources *{mng2}*. Finally, by implementing more organization schemes at once, this arrangement is likely to suffer less from confusing hierarchy and labelling of categories *{res1}*.

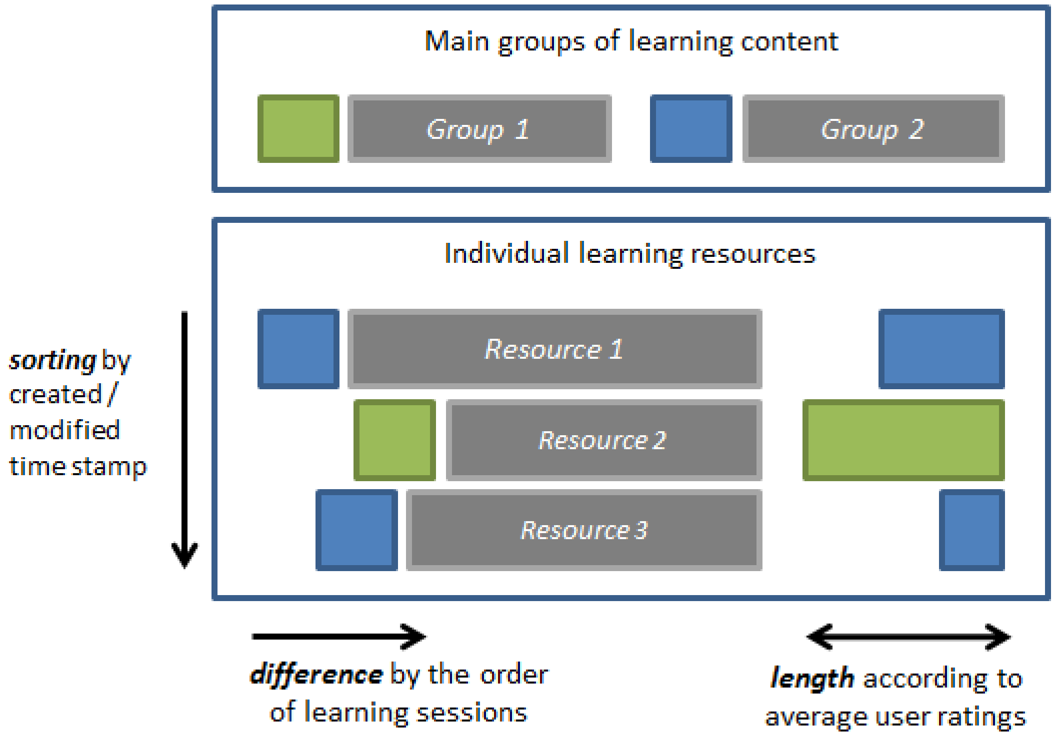



**Fig. 23. The abstracted interface schema for viewing the selected course**

Organization schemes used in the previous schema were selected from the proposals summarized in [Table 27]. Sorting by alphabet was considered as less useful, therefore additional time organization scheme was used instead. Tags are not part of the hierarchical arrangement and therefore are not present in the schema. The schema demonstrates organization by time stamp (by sorting), priority / order (by difference), rating (by length) and finally category (by colour).

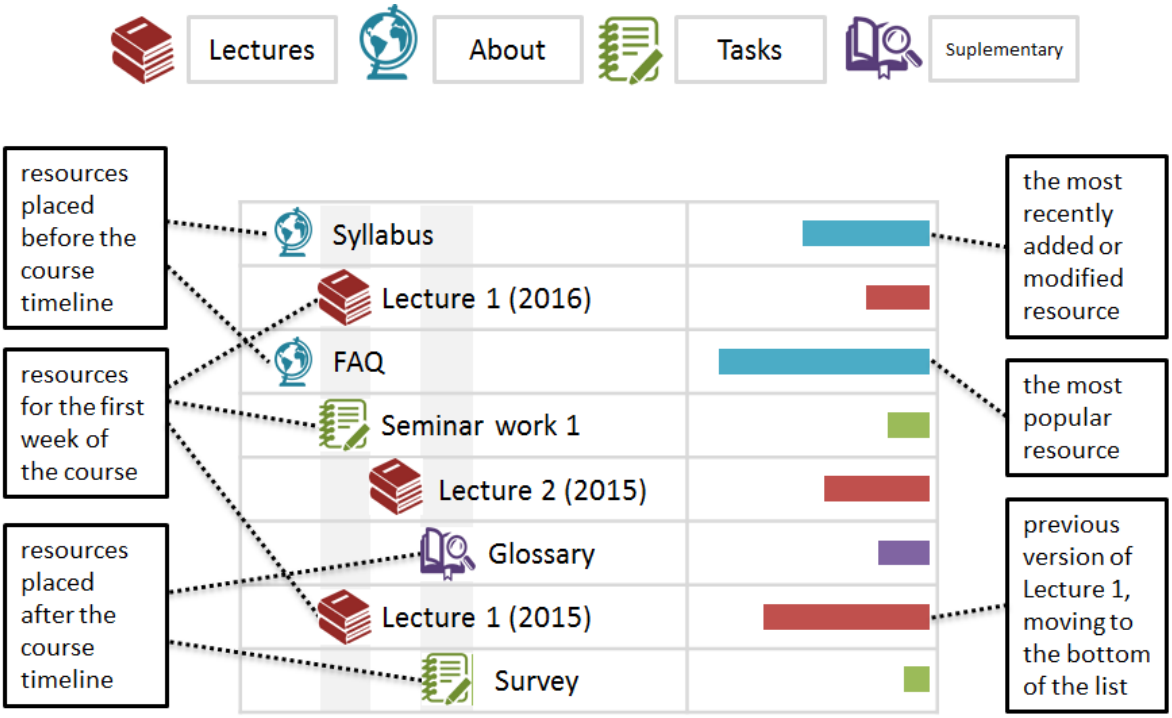



**Fig. 24. The applied interface schema for viewing selected course, with explanations**

The above interface [Fig. 24] uses the same format for categories and entries as the schema for viewing all learning resources [Fig. 22]. This consistency contributes to the overall usability of the proposed solution. Of course these figures are just schematics; visual design of the actual system´s interface can look completely different.

As was already mentioned, there are possible variations of the view according to the user´s preferred organization or his immediate needs related to searching the resources by various parameters. The following table [Table 28] summarizes the view modifications mentioned throughout the chapter and several new ones. These view modifications are more related to the interface schema for viewing the selected course rather than all courses. This is because the possibilities and interchangeability of variables for organization schemes are based on the model for repository-based systems (chapter 6.2). The advanced concept would be supporting multidimensional attributes, e.g. storing different priority of resources for beginners and for intermediate learners. The view could be then switched according to the learner´s estimated level of knowledge.

**Table 28. Default and optional views**

| **Default view** | **Optional view switch** |
|---|---|
| personalized learning course | learning course as is in the core repository |
| all learning resources | only personalized resources |
| sorting (i.e. vertical arrangement) by modified time stamp | sorting by created time stamp, by alphabet or by priority / order |
| difference (i.e. horizontal arrangement) by priority / order | difference by modified or created time stamp |
| length (of the bar) by average rating | length by user rating, by user progress |

Usable interaction design is the necessity for implementing the above features. The switch between views for all courses and for one course should be provided consistently and by expected navigation cues (see sections 5.1.4 and 5.1.5).

## 7.5 Implementation overview

The web-based educational system proposed in this dissertation thesis was not fully implemented. This is mainly due to time demandingness of developing system of such scale. Also the absence of cooperation with an educational organization, which would facilitate active experimental usage of the implemented system and provide feedback. Many partial proposals however underwent a strict review process and were published as research papers. Usability of the core design proposal was further validated by several usability and user experience tests.

This chapter contains selected implementation issues for consideration. The closing section 7.5.4 would suggest possible use cases for real environment application.

### 7.5.1 The system´s variations

As was already mentioned, the presented system´s proposal is not strictly delimited. It provides exact design proposals, grounded in both theory and research, in areas which are the primary focus of this dissertation. These are especially usability aspects such as organization and knowledge-management aspects such as personalization. The final educational system proposal is mostly a conceptual solution rather than delineated and ready-to-use system. Therefore there are many areas, in which the presented proposals serve as a loose guidance or overview of appropriate possibilities. The system´s core can be extended and modified towards the actual implementation´s needs. These can originate e.g. from specific field of study with special requirements on learning resources regarding their attributes or means of categorization.

Entries are presented as a single class in the respective diagram [Fig. 19], which can contain any type of learning content. However the actual implementation can benefit from distinguishing several separate types of content. The type of resource can then serve as another variable of organization schemes. They can also serve as a parameter, by which the entries can be filtered. The possible variations are many. Based on the identified types of content and data formats in Blackboard learning courses [Table 4], the common resource types can be divided as:

- native resource (rich text with media) - text, images and other content processed in the system´s editor - this should be the preferred format since such content is searchable and the format can be customized to the user´s needs
- external resource (link) - only URL link (and possibly description or tags) is stored in the system; this is more suitable for progressively evolving fields of study, however there is a risk of the source being deleted or moved to another location
- resource as a file (PDF, PPT, ZIP,..) - the standalone resource is stored in the system as a file, either viewable in the browser or downloadable depending on the supported formats and settings

The above mentioned types of content should suffice for common educational purposes. However the untraditional specific types can be implemented just the same. The variability of the system was apparent already in the introduction, in supporting both learning courses and collections of resources (repositories). Even though the core system´s proposal was grounded on the concept of courses, it is easily exchangeable by repositories. Organization by time in interface designs would only be replaced by other mean of organization.

### 7.5.2 Web technologies and performance

This section presents a brief overview of suitable technologies for implementing the proposed system. We will distinguish front-end (client-side) and back-end (server-side) technologies. Front-end development should follow the rules of web design, summarized by the framework of design requirements (see chapter 5.1). Back-end development should implement good practice e.g. regarding clean code, performance and security.

The choice regarding front-end technologies is quite straightforward, as the commonly used combination is HTML, CSS and JavaScript. The current versions are HTML5 and CSS3. The core functionality mostly remains the same however new useful features were added. One of the main contributions of CSS3 is the ability of creating visual effects which were only possible by use of images before. More images meant bigger size of webpage and longer response time, i.e. worse performance. Website´s performance has however a significant influence on user experience and satisfaction (Bartuskova & Krejcar, 2015). HTML5 was enhanced especially in the area of API (geolocation, local storage or drag/drop,...) and graphics (canvas, svg) while promoting the use of JavaScript. The browser support is no longer an issue regarding majority of HTML5 features (see the browser support of individual features on http://caniuse.com/). Javascript became the dominant tool for interaction with user, often used in form of libraries, the most popular being jQuery. Known is also an AJAX technique for communication with server-side without reloading the page on the client-side. Finally, modern web applications need to be responsive in order to be usable for users on various devices with various screen sizes.

On the back-end we have more possibilities, however we would prefer combination PHP, MySQL and Apache. The main reason for this choice is existence of many great open source content management frameworks and systems, which can be used for implementing the proposed system. Developing the own technological solution from scratch would be very demanding and ineffective (Bartuskova & Krejcar, 2014d). Based on our previous experience and analysis of these systems, our choice would be CMS/CMF Processwire.

Processwire is a purely API-driven content management framework that is fully functional without any sort of admin interface (Cramer, 2016). Already in our first published proposal for knowledge management, we have stressed the need for content management framework instead of system and proposed Processwire as a viable solution (Bartuskova & Krejcar, 2014d). Processwire can be very easily modified and extended to the needs of particular project. Mechanics of templates, modules and method behaviour modifications are the tools for such extensions.

In the scope of interface design, there are no limits related to number of courses, resources, users etc. We can expect growing numbers of stored content in case of actively used system The actual implementation therefore needs to optimize data storage and procedures to ensure adequate performance. By providing robust well-balanced system for data manipulation, the actual implementation in Processwire can be developed from the start to support great numbers of entries.

Also technical implementation of personalization has to be carefully planned in order to avoid performance issues and duplicities. We propose creating a personalized learning course only when a learner initiates its creation by adding or updating content. Additionally changes in the course will be stored as instructions, by which the personalized course can be reconstructed, not as a hard copy. New and modified content will be then saved into a "group repository", so user accounts will contain only reference to the files and thus they will be as lightweight as possible. This way all references of one piece of learning content will be associated with one file, which can be managed efficiently with version control.

### 7.5.3 Administration interface

In this section, we present an example of the administration interface for teachers - screenshot from the partial implementation. The choice of fields holding data follows the class diagram of the core management system [Fig. 19]. The administration screen of the selected entry [Fig. 25] was constructed using Processwire CMS interface.

The administration screen is opened at the default tab - "Entry". The other tab "Customizations" would contain all customizations made by other users. Demandingness of processing these customizations for teacher would depend on activity of learners and also on system´s functionalities. E.g. with appropriately implemented version control, comparisons could be processed for teacher and only the valid differences and new sontent would be brought to his attention.

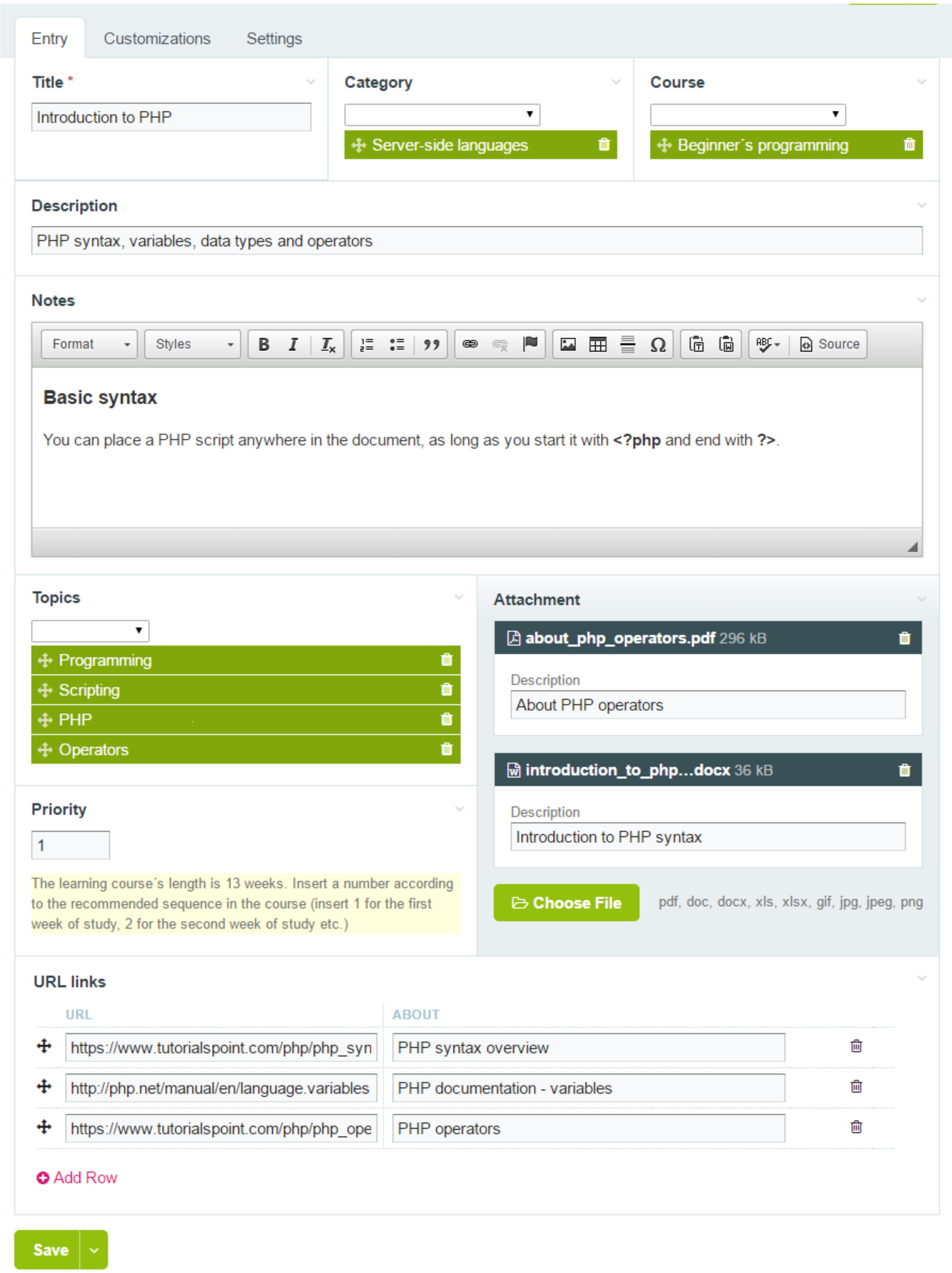



**Fig. 25. Administration interface example (based on Processwire)**

### 7.5.4 Use cases in real environment

In this section will be suggested use cases of applying the proposed system in real environment. The approaches and design proposals in this dissertation thesis were specified for educational usage. However as was already mentioned, they are applicable also for other related domains such as knowledge management.

The most obvious usage of this system would be the management of learning resources at universities. It is however important to note that this system is not the replacement of current LMSs e-learning experience. It was not designed to provide tools for online teaching such as assigments, quizes, evaluation, chats and forums or management of students. The proposed system was designed to provide learners with highly usable learning environment, which can be personalized to their needs. The environment, which promotes up-to-date and important resources over the obsolete and unuseful ones. The system, where can learners easily access both recommended resources and their own.

In the particular model, presented in this chapter, the first hierarchical level are learning courses. Each of them has its own repository, which can be further divided by categories into groups. This basic concept is similar to the LMS´s management of resources and as such this arrangement is suitable for universities and other educational institutions.

The second major area of usage for the proposed system is the knowledge management. The management of knowledge, information, work procedures etc. is important for every larger organization. These organizations can be traditional ones, mostly commercial, or they can be just groups of people connected via the internet, who need to share some knowledge. Wikis are often used for this purpose and sometimes it is sufficient. However in situations where knowledge base has to be used often and efficiently, e.g. as a reference, the demands on organization and navigation are way bigger than wiki-based system can provide. Also in the case of frequently updated resources or resources with multidimensional categorization, the proposed design has major advantages over simple solutions such as wiki. On the other hand wiki´s advantage is that it is easily accessible and manageable and great for quick and ready solutions.

Depending on the requirements of particular project, the resulting system can be course-based, repository-based or hybrid, which supports both courses and repositories in different levels of its hierarchy. E.g. the system could be used for storing and refining information about complex work procedures of the catering company, dealing with foreign guests from different culture backgrounds. Easy and quick orientation in the company´s know-how and accessing the right up-to-date information would be very useful in this case. In the case of sequenced knowledge such as coordinating banquet, the schema for the individual course would be used, which means default organization by time [Fig. 24]. In the case of knowledge collections such as appropriate colours or food dishes for different cultures, the schema could be used without organization by time. Also the summarized view demonstrated on all learning courses could be used [Fig. 22]. This view is suitable for multidimensional organization with "culture/country" on the vertical axis and "colours", "food" etc. on the horizontal axis. The respective resources would be placed accordingly. The possibilities of proposed designs can be combined to the particular needs.

## 7.6 Final thoughts and discussion

Resources in general are typically being accumulated in various management systems and grow in number. This tendency could be also caused because electronic space has no limits such as physical space or time. LMSs and LORs usually suffer from information overload, overlapping of materials and references and also cluttering by obsolete knowledge. The learning resources need to be maintained and refined. Old resources should be replaced by new and better resources should prevail over worse resources. The result should be regularly updated high-quality knowledge repository.

The presented solution provides support for this intended behaviour in several layers. The first layer is presented by mechanisms introduced in the previous sections 7.2 and 7.3. Personalization and subsequent knowledge building should in theory support revising of existing content *{mng3}* and disposing of outdated content *{mng4}*. Consequently also resources as search results should suffer less from these limitations *{res2}*. However the support for this behaviour does not ensure its happening. Therefore the second layer aims to reduce consequences of neglecting the management of learning resources.

The second layer is performed by the organization of learning resources, discussed in the section 7.4. See [Fig.22] and [Fig.24] for details of proposed visual arrangements. Organizing by several schemes provides better navigation among the resources. This is especially useful when they are not sufficiently described by metadata and consequently poorly accessible by search *{res3}*. Furthermore, up-to-date and popular resources are automatically prioritized by their position. Outdated resources are naturally moving to the bottom of the list because of sorting by the created/modified stamp. Unpopular resources, based on average user rating, are also easily distinguished.

Finally, we can add the third layer of prioritizing more relevant resources - filtering. Chapter 5.2.3 contains proposed properties for each organization scheme, including filtering - see the relevant table [Table 16]. Filterable organization schemes used in the proposed interface are alphabet, category and tags (if implemented). Filtering by category would be useful if more groups of categories were implemented, beside type of resource also i.e. theme or difficulty. Filterable schemes after adjustment are continuum and time/date. Possible adjustments are listed in chapter 5.2.2 - see the relevant table [Table 15]. Before filtering by continuum and time/date, we need to determine appropriate granularity. After that, we can offer users filtering by range of values. Considering actual variables, we can offer filtering by modified time stamp, created time stamp, sequence in the course (1.week of study, 2.week of study,..), average user rating, number of user ratings, number of views, number of comments (if implemented) etc.

# 8 Discussion

Several contributions were achieved in this dissertation thesis. First, the framework of design requirements, which covers all significant areas of design assessment (see chapter 5.1). The identified design requirements were structured into five logically coherent groups: visual design, readability, organization, navigation and consistency. This framework takes use of collective intelligence and knowledge and it can be used for a systematic review of usability and visual appeal. It offers factual design issues which should be dealt with and can be especially useful in cases, where feedback from users is hard to obtain or it does not reveal any useful information. The framework was used on the popular LMS Blackboard Learn in order to show an application in real environment.

Piece of theory was developed by the author in the area of organization schemes (see chapter 5.2). It offers a structured view on the identified schemes, complementing them by several attributes. The organization schemes were divided by their data type into three groups: continuous, categorical and hybrid. According to their possible usage for sorting and filtering, they were further divided into these two groups: basic and complex. Finally the distinction of category as (identically named) "category" for mutually exclusive groups and "tags" for groups which facilitate cross-listing was proposed.

The next two contributions are the interface proposals for course-based systems (see chapter 6.1) and repository-based systems (see chapter 6.2). Finally the smart interface for hybrid systems with personalization support was presented (see chapter 7). The principal feature in the majority of proposed designs is an information-rich navigation, based on the arrangement by all organization schemes in one layout. Usability of the proposal was verified by several tests for measuring usability and user experience (see chapter 6.3). Participants completed most tasks with 100% success, the rest of them with still very high 85% success. Furthermore with the average SUS score being 78,46, we can consider the proposed navigation both acceptable and above average.

The proposed navigation is highly versatile in the possible combinations of variables and means of organizing by them. Its scope of use covers all web applications with the need of efficient organization and navigation in their information space. This navigation was also implemented in the final proposal of web-based educational system. The originally proposed navigation by all organization schemes was adjusted in this case to offer more suitable means of organization. Instead of sorting by alphabet, which was regarded as unuseful in this system, two continuum variables were used: average user rating and the order of learning sessions.

The educational system was presented as the core system with possible extension. The core system´s proposal was focused on its main structure (divided into the core repository and individual user´s accounts) and issues regarding organization, navigation and means of personalization. The variety of system´s modifications were suggested because of the variable purposes and scopes of actual implementations. The system further supports variations of the view according to the user´s preferred organization or his immediate needs related to searching the resources by various parameters. Finally the collaborative knowledge building extension was proposed as the way of managing learning resources.

# 9 Conclusion

The primary objective of this dissertation thesis was defined as the enhancement of web-based interfaces regarding their organization and navigation. This objective was fulfilled by many interface design proposals, assembled in these groups:

- interface for course-based systems (see chapter 6.1)
- interface for repository-based systems (see chapter 6.2)
- interface for hybrid educational system (see chapter 7)

These design proposals were focused on the area of web-based education, however they are applicable also in other areas (see chapter 7.5.4). Furthermore above the specified goals, the framework of design requirements and theoretic contribution were presented in this work. The proposal of up-to-date well-arranged learning environment, which supports personalization and collaborative building of learning resources, is the final and most complex contribution of this dissertation thesis.

The presented proposals were validated also by the acceptance on several international scientific conferences. Author´s research papers were published in Springer series LNCS (Lecture Notes in Computer Science), LNEE (Lecture Notes in Electrical Engineering), LNICST (Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering), LNBIP (Lecture Notes in Business Information Processing), SCI (Studies in Computational Intelligence) and various proceedings.

# 10 List of tables



All tables in this thesis are of the author´s own work. The tables published as author´s work in research papers are accompanied by the respective reference.

# 11 List of figures



All figures in this thesis are of the author´s own work. The figures published as author´s work in research papers are accompanied by the respective reference.

# 12 References


Aksac, A., Ozturk, O., & Dogdu, E. (2012). A novel semantic web browser for user centric information retrieval: PERSON. Expert Systems with Applications 39(15): 12001-12013.

Albert, B. & Tullis, T. (2013). Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics. 2nd Edition. Morgan Kaufmann.

Al-Ajlan, A. S. (2012). A comparative study between e-learning features. Methodologies, Tools and New Developments for E-learning, 191-214. Intech, ISBN: 978953-51-0029-4.

Alraimi, K. M., Zo, H., & Ciganek, A. P. (2015). Understanding the MOOCs continuance: The role of openness and reputation. Computers & Education 80: 28-38.

Álvarez, A., Ruíz, S., Martín, M., Fernández-Castro, I., & Urretavizcaya, M. (2009). MAGADI: a blended-learning framework for overall learning. In Int. conf. on artificial intelligence in education (AIED), Vol. 200, 557–564. IOS Press.

Álvarez, A., Martin, M., Fernandez-Castro, I., & Urretavizcaya, M. (2013). Blended traditional teaching methods with learning environments: experience, cyclical evaluation process and impact with MAgAdI. Computers & Education, 68, 129–140.

Amadieu, F., Tricot, A., & Mariné, C. (2009). Prior knowledge in learning from a non-linear electronic document: Disorientation and coherence of the reading sequences. Computers in Human Behavior 25(2): 381-388.

de Angeli, A., Sutcliffe, A., & Hartmann, J. (2006). Interaction, usability and aesthetics: what influences users' preferences? Proceedings of the 6th conference on Designing Interactive systems, University Park, PA, USA.

ARIADNE (2015). Ariadne Foundation. Retrieved from: http://www.ariadne-eu.org/content/about

The Australian (2011). Edna's demise a sign of the times. Retrieved from: http://www.theaustralian.com.au/higher-education/ednas-demise-a-sign-of-the-times/story-e6frgcjx-1226089748336

Atkins, D., Brown, J. S., & Hammond, A. L. (2007). A review of the open educational resources (OER) movement: Achievements, challenges, and new opportunities. Retrieved from: http://www.hewlett.org/uploads/files/Reviewofthe OERMovement.pdf (Accessed July 2015).

Bangor, A., Kortum, P., & Miller, J. A. (2009). Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale. Journal of Usability Studies, 4, 3.

Barker, P. (2005). What is IEEE Learning Object Metadata / IMS Learning Resource Metadata. Retrieved from: http://zope.cetis.ac.uk/lib/media/WhatIsLOMscreen.pdf

Bartuskova, A., & Krejcar, O. (2013). Evaluation framework for user preference research implemented as web application. Computational Collective Intelligence, Technologies and Applications, Lecture Notes in Computer Science, 537-548.

Bartuskova, A. and Krejcar, O. (2014a). Design Requirements of Usability and Aesthetics for e-Learning Purposes. Advanced Approaches to Intelligent Information and Database Systems Studies in Computational Intelligence, Vol. 551, pp 235-245.

Bartuskova, A., & Krejcar, O. (2014b). Sequential Model of User Browsing on Websites - Three Activities Defined: Scanning, Interaction and Reading. In Proceedings of the 10th International Conference on Web Information Systems and Technologies, 143-148, Barcelona, Spain.

Bartuskova, A., & Krejcar, O. (2014c). Handling Procrastination in Mobile Learning Environment - Proposal of Reminder Application for Mobile Devices. In Proceedings of the 6th International Conference on Computer Supported Education, 220-225, Barcelona, Spain.

Bartuskova, A., & Krejcar, O. (2014d). Knowledge management and sharing in e-learning: Hierarchical system for managing learning resources. In Proceedings of the 6th International Conference on Knowledge Management and Information Sharing, 179-185, Rome, Italy.

Bartuskova, A., Krejcar, O., Selamat, A., & Kuca, K. (2014). Framework for Managing of Learning Resources for Specific Knowledge Areas. In 13th International Conference on Intelligent Software Methodologies, Tools, and Techniques, 565-576, Langkawi, Malaysia. IOS PRESS.

Bartuskova, A., Krejcar, O., Soukal, I. (2015). Framework of Design Requirements for E-learning Applied on Blackboard Learning System. Computational Collective Intelligence, Lecture Notes in Computer Science, Vol. 9330, pp. 471-480. Springer.

Bartuskova, A., Krejcar, O. (2015). Loading Speed of Modern Websites and Reliability of Online Speed Test Services. Computational Collective Intelligence, Lecture Notes in Computer Science, Vol. 9330, pp. 65-74. Springer.

Bartuskova, A., Krejcar, O. (2016). Personalization of Learning Content and Its Structure, Based on Limitations of LMSs. Studies in Computational Intelligence, Vol. 642, pp. 455-465.

Bartuskova, A., Soukal, I. (2016). The Novel Approach to Organization and Navigation by Using all Organization Schemes Simultaneously. Lecture Notes in Business Information Processing, Vol. 261, pp. 99-106. Springer.

Baxley, B. (2003). Universal model of a user interface. Proceedings of the 2003 Conference on Designing for User Experiences. ACM, New York, NY, USA, p. 1–14.

Ben-Bassat, T., Meyer, J., & Tractinsky, N. (2006). Economic and subjective measures of the perceived value of aesthetics and usability. ACM Transactions on Computer–Human Interaction (TOCHI) 13 (2), 210–234.

Biasutti, M., & EL-Deghaidy, H. (2012). Using Wiki in teacher education: Impact on knowledge management processes and student satisfaction. Computers & Education 59, 861–872.

Bieliková, M., Šimko, M., Barla, M., Tvarožek, J., Labaj, M., Móro, R., Srba, I., & Ševcech, J. (2014). ALEF: From Application to Platform for Adaptive Collaborative Learning. Recommender Systems for Technology Enhanced Learning: Research Trends and Applications, 195-225.

Biletskiy, Y., Baghi, H., Keleberda, I., & Fleming, M. (2009). An adjustable personalization of search and delivery of learning objects to learners. Expert Systems with Applications 36(5): 9113-9120.

Bouras, C., & Poulopoulos, V. (2012). Enhancing meta-portals using dynamic user context personalization techniques. Journal of Network and Computer Applications, 35, 1446–1453.

Bower, M., Hedberg, J. G., & Kuswara, A. (2010). A framework for Web 2.0 learning design. Educational Media International, 47(3), 177–198.

Bozarth, J. (2008). Better Than Bullet Points: Creating Engaging e-Learning with PowerPoint. Pfeiffer, ISBN: 978-0787992453.

Brooke, J. (1996). SUS: A Quick and Dirty Usability Scale. In: P.W. Jordan, B. Thomas, B.A. Weerdmeester & I.L. McClelland (Eds.), Usability Evaluation in Industry. London: Taylor & Francis.

Brooks, C., & McCalla, G. (2006). Towards flexible learning object metadata. International Journal of Continuing Engineering Education and Life Long Learning, 16(1/2), 50–63.

Brusilovsky, P. (2001). Adaptive Hypermedia. User Modeling and User Adapted Interaction, 11(1-2),87-110.

Brusilovsky, P. (2007). Adaptive Navigation Support. The Adaptive Web. LNCS 4321. Springer, 263–290.

Capterra Inc. (2012). Top LMS Software Solutions Infographic. Retrieved from: http://blog.capterra.com/top-lms-software-solutions-infographic/. (Accessed June 2014).

Carvalho, A., Areal, N., and Silva, J. (2011). Students' Perception of Blackboard and Moodle in a Portuguese University. In:British Journal of Education Technology, 42(5), 824-841.

Chapnick, S., & Meloy, J. (2005). Renaissance eLearning: Creating Dramatic and Unconventional Learning Experiences. Pfeiffer.

Chen, C.-M., & Lin, S.-T. (2014). Assessing effects of information architecture of digital libraries on supporting E-learning: A case study on the Digital Library of Nature & Culture. Computers & Education, 75, 92–102.

Chen, Y. C., Hwang, R. H., & Wang, C. Y. (2012). Development and evaluation of a Web 2.0 annotation system as a learning tool in an e-learning environment. Computers & Education, 58, 1094-1105.

Chiu, D.-Y. & Pan, Y.-C. (2014). Topic knowledge map and knowledge structure constructions with genetic algorithm, information retrieval, and multi-dimension scaling method. Knowledge-Based Systems 67: 412-428.

Chu, K.-K., Lee, C.-I, & Tsai, R.-S. (2011). Ontology technology to assist learners' navigation in the concept map learning system. Expert Systems with Applications 38(9): 11293-11299.

Civan, A., Jones, W., Klasnja, P., & Bruce, H. (2009). Better to organize personal information by folders or by tags?: the devil is in the details. Proceedings of the American Society for Information Science and Technology, 45, 1–13.

Clark, R. C., & Lyons, C. (2011). Graphics for Learning: Proven Guidelines for Planning, Designing, and Evaluating Visuals in Training Materials, 2nd Edition. Pfeiffer. ISBN: 978-0470547441.

Clark, R. C., & Mayer, R. E. (2011). E-learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning, 3rd Edition. Pfeiffer. ISBN: 978-0470874301.

Colborne, G. (2011). Simple and Usable Web, Mobile, and Interaction Design (Voices That Matter). New Riders. ISBN: 978-0321703545.

Corcho, O., Fernández-López, M., & Gómez-Pérez, A. (2003). Methodologies, tools and languages for building ontologies. Where is their meeting point? Data & Knowledge Engineering, 46(1), 41–64.

Costa, C., Alvelos, H., & Teixeira, L. (2012). The use of Moodle e-learning platform: a study in a Portuguese University. CENTERIS 2012 - Conference on ENTERprise Information Systems.

Cramer, R. (2016). Where processwire came from. Retrieved from https://processwire.com/about/background/

Cristea, A. I., & Ghali, F. (2011). Towards adaptation in e-learning 2.0. New Review of Hypermedia and Multimedia, 17(2), 199–238.

Dabner, D., Stewart, S., & Zempol, E. (2014). Graphic Design School: The Principles and Practice of Graphic Design, 5th Edition. Wiley. ISBN: 978-1118134412.
Danielson, D. R. (2002). Web navigation and the behavioral effects of constantly visible site maps. Interacting with Computers, Vol. 14 No. 5, pp. 601-618.
Devedzic, V. (2006). Semantic Web and Education (Integrated Series in Information Systems). New York: Springer.
DeVries, I. (2013). Evaluating Open Educational Resources: Lessons Learned. Procedia - Social and Behavioral Sciences 83: 56-60.
Diigo Inc. (2014). About Diigo. Retrieved from: http://www.diigo.com/about (Accessed June 2014).
Éthier, J., Hadaya, P., Talbot, J., Cadieux, J. (2008). Interface design and emotions experienced on B2C Web sites: Empirical testing of a research model, Computers in Human Behavior, 24(6).
Fang, X., & Holsapple, C. W. (2007). An empirical study of web site navigation structures' impacts on web site usability. Decision Support Systems 43(2): 476-491.
Fee, K. (2009). Delivering E-Learning: A Complete Strategy for Design, Application and Assessment. 4th Edition. Kogan Page. 208 s. ISBN:978-0749453978.
Fernandez, A., Insfran, E., & Abrahão, S. (2011). Usability evaluation methods for the web: A systematic mapping study. Information and Software Technology, 53 (8), 789-817.
Fischer, G. (2001). User Modeling in Human-Computer Interaction. User Modeling and User-Adapted Interaction, 11(1&2): 65-86.
Fogg, B.J., Marshall, J., Laraki, O., Osipovich, A., Varma, C., Fang, N., Paul, J., Rangnekar, A., Shon, J., Swani, P., & Treinen, M. (2001). What makes web sites credible? A report on a large quantitative study. Proceedings of the Conference on Human Factors in Computing Systems CHI 2001. ACM Press, New York, pp. 61–68.
Fowler, S., & Stanwick, V. (2004). Web application design handbook: Best practices for web-based software. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc.
Gaeta, M., Orciuoli, F., & Ritrovato, P. (2009). Advanced ontology management system for personalised e-Learning. Knowledge-Based Systems 22, 292–301.
Garcia-Cabot, A., de-Marcos, L., & Garcia-Lopez, E. (2015). An empirical study on m-learning adaptation: Learning performance and learning contexts. Computers & Education 82: 450-459.
García, J., Amescua, A., Sánchez, M.-I., & Bermón, L. (2011). Design guidelines for software processes knowledge repository development. Information and Software Technology 53(8): 834-850.
Gasparini, I., Pimenta, M.S., Palazzo, J., & Kemczinski, A. (2010). Usability in an adaptive e-learning environment: Lessons from AdaptWeb. IEEE Learning Technology Newsletter 12 (2) 13–15.
Golombisky, K. and Hagen, R. (2013). White Space is Not Your Enemy: A Beginner's Guide to Communicating Visually through Graphic, Web and Multimedia Design. 2nd Edition. Focal Press. ISBN: 978-0240812816.
Gonzalez-Barbone, V. & L. Anido-Rifon (2008). Creating the first SCORM object. Computers & Education 51(4): 1634-1647.
Guerra, J., Sosnovsky, S., & Brusilovsky, P. (2013). When One Textbook Is Not Enough: Linking Multiple Textbooks Using Probabilistic Topic Models. EC-TEL 2013, LNCS 8095, 125-138. Springer, Heidelberg.
Hall, R. H., & Hanna, P. (2004). The impact of web page text-background colour combinations on readability, retention, aesthetics and behavioural intention. Behaviour & Information Technology 23.
Hartmann, J., Sutcliffe, A., & de Angeli, A. (2008). Towards a theory of user judgment of aesthetics and user interface quality. Transactions on Computer-Human Interaction, 15(4).
Hassenzahl, M. (2004). The interplay of beauty, goodness, and usability in interactive products. Human–Computer Interaction, 19(4), 319–349.
Hassenzahl, M., & Tractinsky, N. (2006). User experience - a research agenda. Behaviour & Information Technology 25(2): 91-97.
van der Heijden, H. (2003). Factors influencing the usage of websites: the case of a generic portal in the Netherlands. Information & Management 40 (6), 541–549.
Heradio, R., Fern´andez-Amor´os, D., Cabrerizo, F.J., & Herrera-Viedma, E. (2012). A review of quality evaluation of digital libraries based on users perceptions. Journal of Information Science, 38(3), 269-283.
Hew, K. F. & Cheung, W. S. (2013). Use of Web 2.0 technologies in K-12 and higher education: The search for evidence-based practice. Educational Research Review 9: 47-64.
Hew, K. F., & Cheung, W. S. (2014). Students' and instructors' use of massive open online courses (MOOCs): motivations and challenges. Educational Research Review, 12, 45-58.
Holdaway, X., & Hawtin, N. (2014). The Digital Campus 2014: Major players in the MOOC Universe. Retrieved from: http://chronicle.com/article/The-Major-Players-in-the-MOOC/138817/.

Hong, L., Chi, E. H., Budiu, R., Pirolli, P. & Nelson, L. (2008). SparTag.us: A low cost tagging system for foraging of web content. Proceedings of the working conference on Advanced visual interfaces AVI '08, p. 65-72.
Hornbæk, K. (2006). Current practice in measuring usability: Challenges to usability studies and research. International Journal of Human-Computer Studies, 64 (2), 79-102.
Horton, W. (2012a). E-Learning by Design, 2nd Edition. Pfeiffer, ISBN: 978-0470900024
Horton, W. (2012b). E-Learning by Design, 2nd Edition, Online chapters. Retrieved from: http://horton.com/books/e-learning-by-design/examples-from-e-learning-by-design/
Hübscher, C., Pauwels, S. L., Roth, S. P., Bargas-Avila, J. A., & Opwis, K. (2011). The organization of interaction design pattern languages alongside the design process. Interacting with Computers 23(3): 189-201.
Hwang, W.-Y., Wang, C.-Y., & Sharples, M. (2007). A study of multimedia annotation of Web-based materials. Computers & Education 48(4): 680-699.
IEEE-LTSC (IEEE Learning Technology Standard Committee) (2002). WG12 Learning Object Metadata. IEEE standard 1484.12.1. Retrieved from: http://ieeeltsc.org/ wg12LOM/ (Accessed Aug. 2012).
Iiyoshi, T., & Kumar, M. (Eds.). (2008). Opening Up Education: The Collective Advancement of Education through Open Technology, Open Content, and Open Knowledge. Cambridge, MA: MIT Press.
IMS Global Learning Consortium (2001). IMS Learner Information Packaging Information Model Specification. Retrieved from: http://www.imsglobal.org/ profiles/lipinfo01.html.
IMS Global Learning Consortium (2003). IMS Digital Repositories Interoperability - Core Functions Information Model. Retrieved from: http://www.imsglobal.org/ digitalrepositories/driv1p0/imsdri_infov1p0.html.
IMS Global Learning Consortium (2006). IMS Meta-data Best Practice Guide for IEEE 1484.12.1-2002 Standard for Learning Object Metadata. Retrieved from: http://www.imsglobal.org/metadata/mdv1p3/imsmd_bestv1p3.html.
iNACOL (International Association of K-12 Online Learning) (2010). Learning Management System. Retrieved from: http://www.onlineprogramhowto.org/admin/ learning-management-systems/
iNACOL (International Association of K-12 Online Learning) (2011). Learning Content Management System. Retrieved from: http://www.onlineprogramhowto.org/ admin/learning-content-management-system/
Islam, A. K. M. N. (2013). Investigating e-learning system usage outcomes in the university context. Computers & Education 69: 387-399.
ISO (International Organization for Standardization) (1998). Ergonomics of Human System Interaction - Guidance on Usability, International Standard Organisations ISO/IEC 9241-11.
Johnson, J. (2010). Designing with the Mind in Mind: Simple Guide to Understanding User Interface Design Rules. Morgan Kaufmann. ISBN: 978-0123750303.
Kalbach, J. (2007). Designing web navigation. O'Reilly Media, ISBN: 978-0596528102.
Kang, Y.-S., & Kim, Y. J. (2006). Do visitors' interest level and perceived quantity of web page content matter in shaping the attitude toward a web site? Decision Support Systems 42(2): 1187-1202.
Keinonen, T. (1997). Expected usability and product preference. Proceedings of the Conference on Designing Interactive Systems, Amsterdam, The Netherlands, 197–204.
Klerkx, J., Verbert, K., & Duval, E. (2014). Enhancing learning with visualization techniques. In: Handbook of research on educational communications and technology. New York: Springer, 791–807.
Kurilovas, E., Kubilinskiene, S. & Dagiene, V. (2014). Web 3.0 - Based personalisation of learning objects in virtual learning environments. Computers in Human Behavior 30: 654-662.
Larkin, J. H., & Simon, H. A. (1987). Why a diagram is (sometimes) worth ten thousand words. Cognitive Science, 11, 65–99.
Lavie, T., & Tractinsky, N. (2004). Assessing dimensions of perceived visual aesthetics of web sites. International Journal of Human–Computer Studies, 60(3), 269–298.
Law, K. M. Y., Lee, V. C. S., & Yu, Y. T. (2010). Learning motivation in e-learning facilitated computer programming courses. Computers & Education, 55, 218 – 228.
Leavitt M., & Shneiderman B. (2006). Research Based Web Design and Usability Guidelines. U.S. Government Printing Office.
Lee, S., & Koubek, R. J. (2010a). The effects of usability and web design attributes on user preference for e-commerce web sites. Computers in Industry, 61 (4), 329-341.
Lee, S., & Koubek, R. J. (2010b). Understanding user preferences based on usability and aesthetics before and after actual use. Interacting with Computers, 22(6), 530–543.
Lee, Y., & Kozar, K. A. (2012). Understanding of website usability: Specifying and measuring constructs and their relationships. Decision Support Systems, v.52 n.2, p.450-463.
Lee, J.H., & Segev, A. (2012). Knowledge maps for e-learning. Computers & Education, 59, 353–364.

Leuthold, S., et al. (2011). Vertical versus dynamic menus on the world wide web: Eye tracking study measuring the influence of menu design and task complexity on user performance and subjective preference. Computers in Human Behavior 27(1): 459-472.

Lewis, J. R., & Sauro, J. (2009). The Factor Structure of the System Usability Scale. Proceedings of the HCII International Conference 2009.

Lidwell, W., Holden, K., & Butler, J. (2010). Universal Principles of Design, Revised and Updated: 125 Ways to Enhance Usability, Influence Perception, Increase Appeal, Make Better Design Decisions, and Teach through Design. Rockport Publishers. ISBN-13: 978-1592530076.

Liebowitz, J., & Frank, M. S. (2010). The Synergy between Knowledge Management and e-Learning. Liebowitz, J., and Frank, M. (Eds.) Knowledge management and E-learning. Boca Raton, FL: Auerbach Publications.

Lindgaard, G., Fernandes, G., Dudek, C., & Brown, J. (2006). Attention web designers: you have 50 milliseconds to make a good impression!. Behaviour and Information Technology 25, 115–126.

Loboda, T. D., Guerra, J., Hosseini, R., & Brusilovsky, P. (2014). Mastery Grids: An open source social educational progress visualization. Open Learning and Teaching in Educational Communities, vol. 8719, pp. 235-248, 2014.

López, V. F., de la Prieta, F., Ogihara, M., & Wong, D. D. (2012). A model for multi-label classification and ranking of learning objects. Expert Systems with Applications 39(10): 8878-8884.

Lucas, H. C. (2013). Can the current model of higher education survive MOOCs and online learning? EDUCAUSE Review, 48(5), 54-56.

Lynch, P. J., & Horton, S. (2001). Web Style Guidelines, 2nd Edition. Yale University Press. Retrieved from: http://www.webstyleguide.com/index.html.

Lynch, P. J., & Horton, S. (2009). Web Style Guide: Basic Design Principles for Creating Web Sites, 3rd Edition. Yale University Press. ISBN: 978-0300137378. Retrieved from: http://webstyleguide.com/wsg3/index.html.

Malamed, C. (2015). Visual Design Solutions: Principles and Creative Inspiration for Learning Professionals. Wiley. ISBN: 978-1118863565

Margaryan, A., Bianco, M., & Littlejohn, A. (2015). Instructional quality of Massive Open Online Courses (MOOCs). Computers & Education 80: 77-83.

Marshall, C. & Brush, A. (2004). Exploring the Relationship between Personal and Public Annotations. Proceedings of Digital Libraries'04, p. 349-357.

Mason, R.T. & Ellis, T.J. (2009). Extending SCORM LOM. Informing Science and Information Technology, Vol. 6, 2009. p 863-875.

Mayer, R. H. (1999). Designing instruction for constructivist learning. In C. M. Reigeluth, (Eds.), In C. M. Reigeluth, (Ed), Instructional-design theories and models: A new paradigm of instructional theory, Volume II. pp,141-160.

McAndrew, P., Scanlon, E., & Clow, D. (2010). An open future for higher education. Educause Quarterly, 33(1). Retrieved from: http://oro.open.ac.uk/21894/1/McAndrew-_Scanlon-Clow-EQ.pdf.

McCracken, D. D., & Wolfe, R. J.(2004). User-centered Website Development: A Human-Computer Interaction Approach. Pearson Prentice Hall Inc., Upper Saddle River, NJ.

McDonald, S., & Stevenson, R. J. (1998). Navigation in hyperspace: an evaluation of the effects of navigational tools and subject matter expertise on browsing and information retrieval in hypertext. Interacting with Computers, 10(2), 129-142.

McGreal, R. (2004). Learning Objects: A Practical definition. International Journal of Instructional Technology and Distance Learning 1(9) 21-32.

MERLOT (Multimedia Educational Resource for Learning and Online Teaching) (2015). Retrieved from: http://www.merlot.org/merlot/index.htm

Moodle (2014). Retrieved from: http://moodle.org. (Accessed June 2014).

Morris, R. D. (2011). Web 3.0: Implications for Online Learning. TechTrends, 55(1), 42-46.

Morville, P. & Rosenfeld, L. (2006). Information Architecture for the World Wide Web: Designing large-scale web sites, 3rd edition. O'Reilly Media, Inc. ISBN-13: 978-0-596-52734-1.

Moskal, P., Dziuban, Ch., & Hartman, J. (2013). Blended learning: A dangerous idea? The Internet and Higher Education 18: 15-23.

Mustakerov, I. & D. Borissova (2011). A conceptual approach for development of educational Web-based e-testing system. In: Expert Systems with Applications.

Neven, F., & Duval, E. (2002). Reusable learning objects: a survey of LOM-based repositories. Proceedings of the tenth CM international conference on Multimedia (pp. 291-294). ACM.

Nielsen, J. (1993). Usability Engineering. Academic Press, San Diego, CA.

Nielsen, J. (2000). Why You Only Need to Test with 5 Users. Retrieved from: https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/

Novick, L. R. , Hurley, S. M. & Francis M. (1999). Evidence for abstract, schematic knowledge of three spatial diagram representations. Memory & Cognition, 27, p. 290.

Novick, L. R. & Hurley, S. M. (2001). To Matrix, Network, or Hierarchy: That Is the Question. Cogn Psychol 42(2): 158-216.

Orehovački, T., Granić, A., & Kermek, D. (2013). Evaluating the perceived and estimated quality in use of Web 2.0 applications. Journal of Systems and Software 86(12): 3039-3059.

Organisation for Economic Co-operation and Development. (2007). Giving knowledge for free: The emergence of open educational resources. OECD Publishing.

Pajić, D. (2014). Browse to search, visualize to explore: Who needs an alternative information retrieving model? Computers in Human Behavior 39: 145-153.

Pani, F. E., Lunesu, M. I., Concas, G., Stara, C. & Tilocca, M. P. (2012). Knowledge Formalization and Management in KMS. KMIS 2012, Proceedings of the International Conference on Knowledge Management and Information Sharing, 132-138, SciTePress.

Park, J., & Kim, J. (2000). Contextual navigational aids for two World Wide Web systems. International Journal of Human-Computer Interaction, 12(2), 193 e 217.

Peng, J., Jiang, D., & Zhang, X. (2013). Design and Implement a Knowledge Management System to Support Web-based Learning in Higher Education. Procedia Computer Science 22: 95-103.

Pérez, I.J., Cabreriz, F.J., Morente-Molinera, J.A., Ure˜na, R., & Herrera-Viedma, E. (2014). Reaching Consensus in Digital Libraries: A Linguistic Approach. In: Procedia Computer Science, 31, 449 - 458.

Pilgrim, C. J. (2007). Trends in sitemap designs: a taxonomy and survey. In Proceedings of the eight Australasian conference on User interface - Volume 64 (pp. 95–102). Darlinghurst, Australia, Australia: Australian Computer Society, Inc.

Pirolli, P. (2007). Information Foraging Theory: Adaptive Interaction with Information. Oxford University Press, New York, NY.

Redondo, R. P. D., Vilas, A. F. & Arias, J. J. P. (2010). Educateca: A Web 2.0 Approach to eLearning with SCORM. IFIP Advances in Information and Communication Technology, vol. 341, pp. 118-126.

Rego, H., Moreira, T. & Garcia, F.J. (2010). A Web-Based Learning Information System Resource and Knowledge Management. Knowledge Management, Information Systems, E-Learning, and Sustainability Research Communications in Computer and Information Science, Vol. 111, 591-599.

Reinecke, K. & A. Bernstein (2011). Improving performance, perceived usability, and aesthetics with culturally adaptive user interfaces. ACM Transactions on Computer-Human Interaction 18(2): 1-29.

Reinhold, S. (2006). Wikitrails: augmenting wiki structure for collaborative, interdisciplinary learning. Proceedings of WikiSym'06 d 2006 International symposium on wikis, pp. 47–57.

Robins, D. & Holmes, J. (2008). Aesthetics and credibility in web site design. Information Processing & Management, 44 (1), 386-399.

Roth, S. P., Schmutz, P., Pauwels, S. L., Bargas-Avila, J. A., & Opwis, K. (2010). Mental models for web objects: Where do users expect to find the most frequent objects in online shops, news portals, and company web pages? Interacting with Computers, v.22 n.2.

Roy, D., Sarkar, S. & Ghose, S. A. (2010). Comparative Study of Learning Object Metadata, Learning Material Repositories, Metadata Annotation & an Automatic Metadata Annotation Tool. Advances in Semantic Computing (Eds. Joshi, Boley & Akerkar), vol. 2, pp. 103-126.

Rubin, B., Fernandes, R., Avgerinou, M. D., Moore, J. (2010). The effect of learning management systems on student and faculty outcomes. The Internet and Higher Education 13(1-2): 82-83.

Sampson, D., & Zervas, P. (2013). Learning object repositories as knowledge management systems. Knowledge Management & E-Learning, 5(2), 117–136.

Santa-Maria, L., & Dyson, M.C. (2008). The effect of violating visual conventions of a website on user performance and disorientation. How bad can it be? SIGDOC'08, 47–54.

Santos, O. C., Boticario, J. G., & Pérez-Marín, D. (2014). Extending web-based educational systems with personalised support through User Centred Designed recommendations along the e-learning life cycle. Science of Computer Programming 88: 92-109.

Sauro, J. (2010). Why You Only Need To Test With Five Users (Explained). Retrieved from: http://www.measuringu.com/five-users.php

Sauro, J. (2011). Measuring Usability With The System Usability Scale (SUS). Retrieved from: http://www.measuringu.com/sus.php

van Schaik, P., Ling, J. (2001). The effects of frame layout and differential background contrast on visual search performance in Web pages. Interacting with Computers, 13(5), 513-525.

van Schaik, P., & Ling, J. (2008). Modelling user experience with web sites: Usability, hedonic value, beauty and goodness. Interacting with Computers, 20 (3), 419-432.

van Schaik, P., & Ling, J. (2009). The role of context in perceptions of the aesthetics of web pages over time. International Journal of Human–Computer Studies, 67(1), 79–89.

Schenkman, B., & Jönsson, F. (2000). Aesthetics and preferences of web pages. Behaviour and Information Technology, 19(5), 367–377.

Scherp, A., Schwagereit, F., & Ireson, N. (2009). Web 2.0 and traditional knowledge management processes, KSM2009 1st workshop on knowledge services & Mashups. 5th Conference Professional Knowledge Management, Solothurn, Switzerland, pp. 25–27.

Shneiderman, B., & Plaisant, C. (2004). Designing the user interface, 4th edition. Addison-Wesley.

Smashing Magazine (2014). Retrieved from: http://www.smashingmagazine.com/ about/ (Accessed 2014).

Sobreira, P. & Tchounikine, P. (2015). Table-based representations can be used to offer easy-to-use, flexible, and adaptable learning scenario editors. Computers & Education 80: 15-27.

Somyürek, S. (2015). The New Trends in Adaptive Educational Hypermedia Systems. The International Review of Research in Open and Distributed Learning, 16(1).

Spool, J., Scanlon, T., Schroeder, W., Snyder, C., & DeAngelo, T. (1998). Web Site Usability: A Designer's Guide. Morgan Kaufmann Publishers, San Francisco, CA.

Su, A. Y. S., Yang, S. J. H., Hwang, W. Y., & Zhang, J. (2010). A Web 2.0-based collaborative annotation system for enhancing knowledge sharing in collaborative learning environments. Computers & Education, 55, 752-766.

Šimko, M., Barla, M., & Bieliková, M. (2010). ALEF: A Framework for Adaptive Web-based Learning 2.0. In Reynolds, N., Turcsányi Szabó, M. (Eds.): KCKS 2010, IFIP Advances in Information and Communication Technology, Vol. 324. Held as Part of World Computer Congress 2010. Springer, pp. 367–378.

Tedesco, D.P., & Tullis, T. (2006). A Comparison of Methods for Eliciting Post-Task Subjective Ratings in Usability Testing. Usability Professionals Association (UPA) Conference, Denver, Colorado.

Tezza, R., Bornia, A. C., de Andrade, D. F. (2011). Measuring web usability using item response theory: Principles, features and opportunities. Interacting with Computers 23(2): 167-175.

Tidwell, J. (2011). Designing Interfaces: Patterns for Effective Interaction Design, 2nd Edition. O'Reilly Media, Inc.

Totkov, G., Krusteva, C., & Baltadzhiev, N. (2004). About the Standardization and the Interoperability of E-Learning Resources. CompSysTech 2004 - International Conference on Computer Systems and Technologies.

Tractinsky, N., Katz, A. S., & Ikar, D. (2000). What is beautiful is usable. Interacting with Computers, 13 (2), 127-145.

Trattner, C., Lin, Y. L., Parra, D., Yue, Z., Real, W., & Brusilovsky, P. (2012). Evaluating tag-based information access in image collections. In Proceedings of the 23rd ACM conference on hypertext and social media (pp. 113–122). ACM.

Tuch, A. N., Bargas-Avila, J. A., & Opwis, K. (2010). Symmetry and aesthetics in website design: It's a man's business. Computers in Human Behavior, 26 (6), 1831-1837.

Tuch, A. N., Roth, S. P., Hornbæk, K., Opwis, K., & Bargas-Avila, J. A. (2012). Is beautiful really usable? Toward understanding the relation between usability, aesthetics, and affect in HCI. Computers in Human Behavior, 28(5), 1596-1607.

Tversky, B. (2001). Spatial schemas in depictions. Spatial schemas and abstract thought, pp. 79–111. Cambridge: MIT Press.

Tversky, B., Corter, J.E., Yu, L., Mason, D.L., & Nickerson, J.V. (2012). Representing category and continuum: visualizing thought, Proceedings of the 7th international conference on Diagrammatic Representation and Inference.

UNESCO (2002). Forum on the Impact of Open Courseware for Higher Education in Developing Countries Final report UNESCO. Design, 2002, 1-3.

UNESCO (2012). Open Educational Resources Congress passes historic declaration. World open educational resources congress. Retrieved from: http://www.unesco.org/ new/en/communication-and-information/resources/news-and-in-focus-articles/in-focus-articles/2012/open-educational-resources-congress-passes-historic-declaration/

Unal, Z., & Unal, A. (2011). Evaluating and comparing the usability of web-based course management systems. Journal of Information Technology Education, 1019-1038.

Ungaretti, A. S., & Tillberg-Webb, H. K. (2010). Assurance of Learning: Demonstrating the Organizational Impact of Knowledge Management and e-Learning. Liebowitz, J., and Frank, M. (Eds.) Knowledge management and E-learning, pp. 3-10. Boca Raton, FL: Auerbach Publications.

Vai, M., & Sosulski, K. (2011). Essentials of Online Course Design: A Standards-Based Guide (Essentials of Online Learning). Routledge. ISBN: 978-0415873000.

Villela Dantas, J. R. & Muniz Farias, P. P. (2010). Conceptual navigation in knowledge management environments using NavCon. Information Processing & Management 46(4): 413-425.

W3Schools (2014). Retrieved from: http://www.w3schools.com/ (Accessed 2014).

Walhout, J., Brand-Gruwel, S., Jarodzka, H., van Dijk, M., de Groot, R., & Kirschner, P. A. (2015). Learning and navigating in hypertext: Navigational support by hierarchical menu or tag cloud? Computers in Human Behavior 46: 218-227.
Ware, C. (2008). Visual thinking for design. Burlington, USA: Morgan Kaufmann Publishers Inc.
Weinschenk, S. (2011). 100 Things Every Designer Needs to Know About People. New Riders. ISBN: 978-0321767530.
West, J. A., & West, M. L. (2009). Using wikis for online collaboration: The power of the read-write web. San Francisco, CA: Wiley & Sons.
Williams, R. (2008). The Non-Designer's Design Book, 3rd Edition. Peachpit Press. ISBN: 978-0321534040.
Wordpress (2014). Retrieved from: http://wordpress.org (Accessed Sept. 2014).
Wu, O., Chen, Y., Li, B., & Hu, W. (2011). Evaluating the visual quality of web pages using a computational aesthetic approach. WSDM '11, 337-346.
Wurman, R.S. (2000). Information Anxiety. Indianapolis, QUE.
Yigit, T., Isik, A. H., & Ince, M. (2014). Multi Criteria Decision Making System for Learning Object Repository. Procedia - Social and Behavioral Sciences 141: 813-816.
Zervas, P., Alifragkis, C., & Sampson, D. G. (2014). A quantitative analysis of learning object repositories as knowledge management systems. Knowledge Management & E-Learning, 6(2), 156–170.
Zhang, X., Song, D., Priya, S., Daniels, Z., Reynolds, K., & Heflin, J. (2014). Exploring Linked Data with contextual tag clouds. Web Semantics: Science, Services and Agents on the World Wide Web 24: 33-39.
Zhao, J., & Forouraghi, B. (2013). An Interactive and Personalized Cloud-Based Virtual Learning System to Teach Computer Science. ICWL 2013, LNCS 8167, 101–110. Springer, Heidelberg.

# 13 Author´s published works

[1] Bartuskova, A., Krejcar, O. Evaluation framework for user preference research implemented as web application. In *5th International Conference on Computational Collective Intelligence, ICCCI 2013, September 11-13, 2013 Craiova, Romania*. Computational Collective Intelligence: Technologies and Applications, Lecture Notes in Computer Science, Vol. 8083, pp. 537-548. Springer, Heidelberg. ISBN 978-3-642-40495-5; 978-3-642-40494-8, ISSN 0302-9743, DOI 10.1007/978-3-642-40495-5_54

[2] Bartuskova, A., Krejcar, O., Kuca, K. Evolutionary Approach of General System Theory Applied on Web Applications Analysis. In *1st International Conference on Communication and Computer Engineering, ICOCOE 2014, May 20-21, 2014 Malacca, Malaysia*. Advanced Computer and Communication Engineering Technology, Lecture Notes in Electrical Engineering, Vol. 315, pp. 411-422. Springer. ISBN 978-3-319-07674-4; 978-3-319-07673-7, ISSN 1876-1100, DOI 10.1007/978-3-319-07674-4_41

[3] Bartuskova, A., Krejcar, O., Selamat, A., Kuca, K. Framework for Managing of Learning Resources for Specific Knowledge Areas. In *13th International Conference on Intelligent Software Methodologies, Tools, and Techniques, SoMeT 2014, September 22-24, 2014, Langkawi, Malaysia*. New Trends in Software Methodologies, Tools and Techniques, Frontiers in Artificial Intelligence and Applications, Vol. 265, pp. 565-576. IOS PRESS. ISBN 978-1-61499-434-3; 978-1-61499-433-6, ISSN 0922-6389, DOI 10.3233/978-1-61499-434-3-565

[4] Bartuskova, A., Krejcar, O. Design Requirements of Usability and Aesthetics for e-Learning Purposes. Advanced Approaches to Intelligent Information and Database Systems, Studies in Computational Intelligence, Vol. 551, pp 235-245. 2014. Springer. ISBN 978-3-319-05502-2; 978-3-319-05503-9, ISSN 1860-949X, DOI 10.1007/978-3-319-05503-9_23

[5] Bartuskova, A., Krejcar, O. Sequential Model of User Browsing on Websites - Three Activities Defined: Scanning, Interaction and Reading. In *Proceedings of the 10th International Conference on Web Information Systems and Technologies, WEBIST 2014, April 3-5, 2014, Barcelona, Spain, pp. 143-148*. SciTePress. ISBN 978-989758024-6, DOI 10.5220/0004963901430148

[6] Bartuskova, A., Krejcar, O. Handling Procrastination in Mobile Learning Environment - Proposal of Reminder Application for Mobile Devices. In *Proceedings of the 6th International Conference on Computer Supported Education, CSEDU 2014, April 1-3, 2014, Barcelona, Spain, pp. 220-225*. SciTePress. ISBN 978-989-758-022-2, DOI 10.5220/0004960702200225

[7] Bartuskova, A., Krejcar, O. Knowledge management and sharing in e-learning: Hierarchical system for managing learning resources. In *Proceedings of the 6th International Conference on Knowledge Management and Information Sharing, KMIS 2014, October 21-24, 2014, Rome, Italy, pp. 179-185*. INSTICC Press. ISBN 978-989-758-050-5, DOI 10.5220/0005072201790185

[8] Bartuskova, A., Krejcar, O. The Evolutionary Approach of General Systems Theory Applied to World Wide Web. In *Proceedings of the 2nd International Conference on Context-Aware Systems and Applications, ICCASA 2013, November 25-26, 2013, Phu*

*Quoc Island, Vietnam*. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Vol. 128, pp 188-197. Springer International Publishing. ISBN 978-3-319-05938-9; 978-3-319-05939-6, ISSN 1867-8211, DOI 10.1007/978-3-319-05939-6_19

[9] Krenek, J., Kuca, K., Bartuskova, A., Krejcar, O., Maresova, P., Sobeslav, V. Artificial Neural Networks in Biomedicine Applications. In *Proceedings of the 4th International Conference on Computer Engineering and Networks, CENet 2014, July 19-20, 2014, Shanghai, China, pp 133-139*. ISBN 978-3-319-11103-2; 978-3-319-11104-9, DOI 10.1007/978-3-319-11104-9_16

[10] Bartuskova, A. Výzkum v oblasti web designu. *Sborník příspěvků 14. mezinárodní konference IMEA 2014, Září 25-26, Sychrov, ČR*. ISBN 978-80-7494-106-1

[11] Bartuskova, A., Krejcar, O. Loading Speed of Modern Websites and Reliability of Online Speed Test Services. In *7th International Conference on Computational Collective Intelligence Technologies and Applications, ICCCI 2015, September 21–23, 2015, Madrid, Spain*. Computational Collective Intelligence, Lecture Notes in Computer Science, Vol. 9330, pp. 65-74. Springer. ISBN 978-3-319-24305-4; 978-3-319-24306-1, ISSN 0302-9743, DOI 10.1007/978-3-319-24306-1_7

[12] Bartuskova, A., Krejcar, O., Soukal, I. Framework of Design Requirements for E-learning Applied on Blackboard Learning System. In *7th International Conference on Computational Collective Intelligence Technologies and Applications, ICCCI 2015, September 21–23, 2015, Madrid, Spain*. Computational Collective Intelligence, Lecture Notes in Computer Science, Vol. 9330, pp. 471-480. Springer. ISBN 978-3-319-24305-4; 978-3-319-24306-1, ISSN 0302-9743, DOI 10.1007/978-3-319-24306-1_46

[13] Bartuskova, A., Krejcar, O. Personalization of Learning Content and Its Structure, Based on Limitations of LMSs. In *8th Asian Conference on Intelligent Information and Database Systems, ACIIDS 2016, March 14-16, 2016, Da Nang, Vietnam*. Studies in Computational Intelligence, Vol. 642, pp. 455-465. Springer. ISBN 978-3-319-31276-7; 978-3-319-31277-4, ISSN 1860-949X, DOI 10.1007/978-3-319-31277-4_40

[14] Bartuskova, A., Soukal, I. The Novel Approach to Organization and Navigation by Using all Organization Schemes Simultaneously. In *15th International Conference on Perspectives in Business Informatics Research, BIR 2016, September 15–16, 2016, Prague, Czech Republic*. Lecture Notes in Business Information Processing, Vol. 261, pp. 99-106. Springer. ISBN 978-3-319-45320-0; 978-3-319-45321-7, ISSN 1865-1348; 1865-1356, DOI 10.1007/978-3-319-45321-7

[15] Bartuskova, A., Krejcar, O., Sabbah, T., Selamat, A. Website Speed Testing Analysis Using Speedtesting Model. Jurnal Teknologi (Sciences & Engineering). eISSN 2180-3722. - in print

# 14 Attachments

## 14.1 Instructions and answer sheet for usability testing - pg. 1

Thank you in advance for your participation on this experiment. The subject of testing is a novel way of organizing (arrangement) items in website navigation. During this experiment, you are expected to search for items, specified in each task.

Look at the attached ***schema***. This ***schema*** illustrates rules for organization of items. When confident with understanding this ***schema***, continue to the next paragraph.

Look at the attached ***navigation***. This is the ***navigation*** of particular website and the questions will be related to it. The ***navigation*** is composed according to the rules of the ***schema***.

After you looked at the ***navigation***, read these instructions for individual questions:

- Always read the question first, then start measuring time
- Look for answers to the questions on the picture of ***navigation*** (however you can look also at the ***schema*** if needed)
- Fill in the "Answer" field with name of the (sub)category
- Measure time till formulating an answer and write it in seconds to "Time" field
- At the end of each question in field "This task was..." please evaluate difficulty of the task (use "x" symbol to mark the particular field)

Question 0. is the sample question. The answer is correct, the values are only illustrative - fill in according to your immediate experience. Then answer the questions 1. to 5.

**Individual questions**

**0. Which subcategory contains the newest article (from all categories)?** ***(sample)***

Answer: CSS    Time: 10

| This task was... | very easy | easy | average | difficult | very difficult |
|---|---|---|---|---|---|
| | | | x | | |

**1. Which subcategory contains the newest article (only in category "Design")?**

Answer:    Time:

| This task was... | very easy | easy | average | difficult | very difficult |
|---|---|---|---|---|---|
| | | | | | |

**2. Which subcategory is the largest (i.e. contains the biggest number of articles)?**

Answer:    Time:

| This task was... | very easy | easy | average | difficult | very difficult |
|---|---|---|---|---|---|
| | | | | | |

**3. Which category is the smallest (i.e. contains the least number of articles)?**

Answer:    Time:

| This task was... | very easy | easy | average | difficult | very difficult |
|---|---|---|---|---|---|
| | | | | | |

## 14.2 Instructions and answer sheet for usability testing - pg. 2

4. **Is this website more focused on "UX Design" or "Design"? (i.e. contains more content on which of these two topics?)**

| | | | | | |
|---|---|---|---|---|---|
| Answer: | | | | Time: | |
| This task was... | very easy | easy | average | difficult | very difficult |
| | | | | | |

5. **Is this website more focused on Techniques for Coding or for Wordpress?**

| | | | | | |
|---|---|---|---|---|---|
| Answer: | | | | Time: | |
| This task was... | very easy | easy | average | difficult | very difficult |
| | | | | | |

Finally please fill in (by using "x" again) the following questionary, which relates to whole your experience so far. By "system" is meant the tested ***navigation*** of website, i.e. generally this way of organizing items in web navigation.

**Concluding questionary**

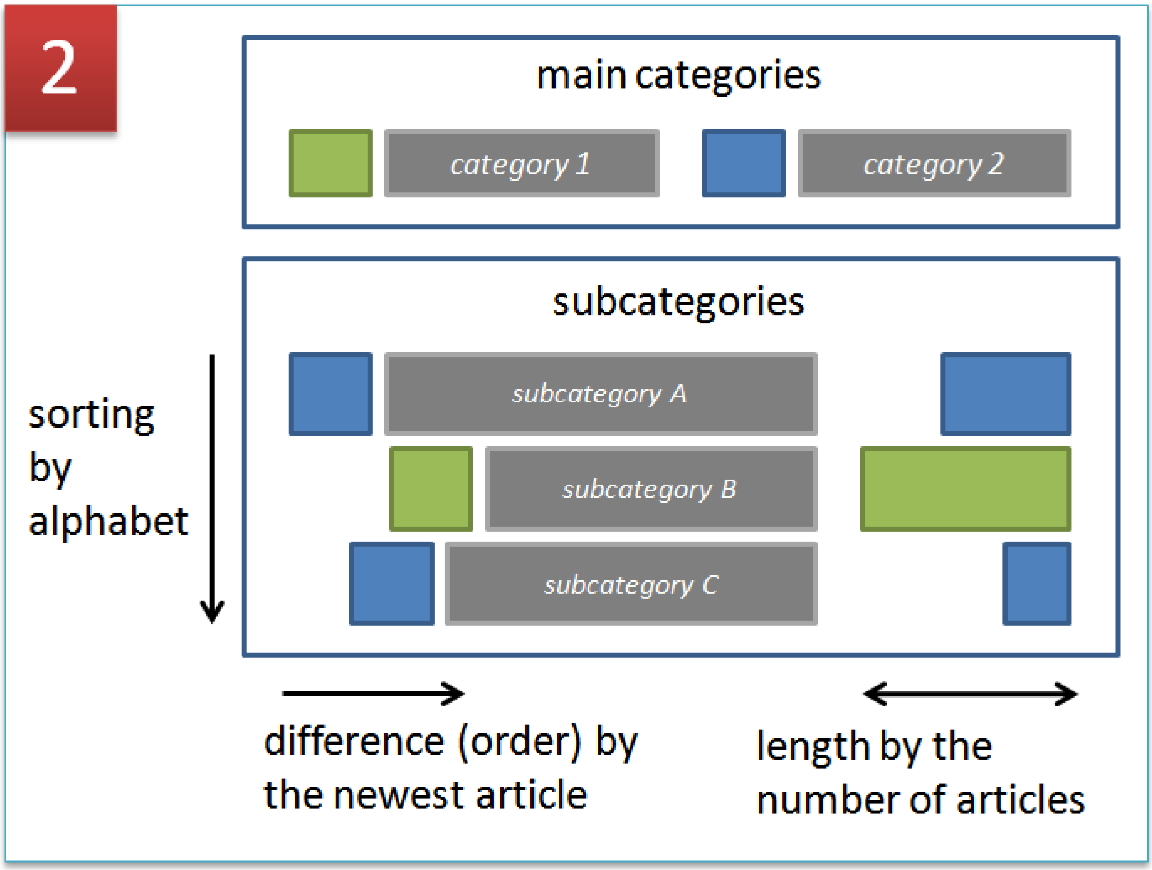
| | **1 (Strongly disagree)** | **2** | **3** | **4** | **5 (Strongly agree)** |
|---|---|---|---|---|---|
| I think that I would like to use this system frequently | | | | | |
| I found the system unnecessarily complex | | | | | |
| I thought the system was easy to use | | | | | |
| I think that I would need the support of a technical person to be able to use this system | | | | | |
| I found the various functions in this system were well integrated | | | | | |
| I thought there was too much inconsistency in this system | | | | | |
| I would imagine that most people would learn to use this system very quickly | | | | | |
| I found the system very cumbersome to use | | | | | |
| I felt very confident using the system | | | | | |
| I needed to learn a lot of things before I could get going with this system | | | | | |

Thank you for your time!

## 14.3 Schema used for usability testing

**1**

Each main category has its colour and contains more subcategories.
Each subcategory has the same colour as its superior category.




**3**

**What can we see in this schema**

Subcategory A belongs to the category 2, it is the first subcategory by alphabet and also contains the newest article.

Subcategory B belongs to the category 1, it is the latest updated subcategory (all other subcategories has newer articles) and it contains the largest amount of articles.

Subcategory C belongs to the category 2, it is the last by alphabet and it contains the least number of articles.