Learning with Semantic Wikis

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Abstract. The knowledge society requires life-long learning and flexible learning environments that allow learners to learn whenever they have time, whereever they are, and according to their own needs and background knowledge. In this article, we investigate how Semantic Wikis – a combination of Wiki and Semantic Web technology – can support learners in such flexible learning environments. We first summarise common features of Wikis and Semantic Wikis and then describe different aspects of Semantic Wikis for learning. We also introduce our Semantic Wiki system called IkeWiki and show why it is particularly promising as a learning tool.

1 Introduction

Recently, many different Semantic Wikis have been described in the literature (cf. e.g. *Platypus* [1], *Semantic MediaWiki* [2], *SemWiki* [3], *WikSAR* [4], *IkeWiki* [5,6]). All or most of these articles target knowledge management or aim at enhancing the Wiki "experience" by improved navigation, browsing, and searching. In this article, we aim to investigate another area where Semantic Wikis might play an important role: learning. A possible separation from knowledge management is that whereas knowledge management focusses on the *result*, learning focusses on the *process* that leads to the result.

Fig. 1. "Schulmeister von Esslingen": traditional teacher-centred learning

In our dynamic society, learning plays an increasingly important role, and the way learning is perceived has changed significantly. Whereas traditionally learning was limited to school and university, it is now seen as a life-long process (*"life-long learning"*) requiring learners to constantly update and adapt their knowledge to new developments [7]. Whereas school and university teaching often used to be rather transfer of information from the teacher to the students without much student interaction (Fig. 1), learning in modern learning theory is considered an active process where learners participate and teachers are merely coaches in the

learners' learning process. And whereas individual skills used to be in the centre of traditional learning processes, cooperative and group learning are becoming more and more important as problems are usually solved by teams and not by individuals.

Such learning requires more flexible learning environments where learners can develop their skills as needed ("on-demand learning") and when they have time ("just-in-time learning"). This, in turn, requires that content can be accessed, authored, reused, and combined easily. Social Software (i.e. *Weblogs*, *Wikis*, *ePortfolios*, *Instant Messaging*) and Semantic Web technology could play an important role in such learning environments. Where Social Software gives users freedom to choose their own processes and supports the collaboration of people anytime, anywhere, Semantic Web technology gives the possibility to structure information for easy retrieval, reuse, and exchange between different systems and tools.

In this article, we focus on a very specific technology that combines Social Software and the Semantic Web: Semantic Wikis. In Section 2, we sketch the development from traditional Wikis to Semantic Wikis. Section 3 summarises the current usage of Wikis in learning and investigates how Semantic Wikis can be beneficial. We then introduce our own Semantic Wiki called *IkeWiki*, which we believe is particularly well suited for learning (Section 4). We conclude with an overview over related work (Section 5) and perspectives for further research (Section 6).

2 From Wikis to Semantic Wikis

2.1 Traditional Wiki Systems

"Wiki" is the short form for "WikiWikiWeb" and is derived from the Hawaiian expression "wiki wiki" meaning "fast" or "quick". A Wiki is essentially a collection of Web sites connected via hyperlinks. While there is a wide range of Wiki systems available (e.g. MediaWiki, MoinMoin, TWiki) with different purposes and audiences, all of them share the following common properties:

Editing via Browser. Content is usually edited via a simple browser interface that can be used without installing any additional (expensive) software. This makes editing simple and allows to modify pages from everywhere in the world with only minimal technical requirements. As a consequence, content creators can access and update the Wiki from wherever they are, e.g. at work, at home, at conferences, nowadays even while travelling.

Simplified Wiki Syntax. Content is usually expressed in a simplified hypertext format ("Wiki syntax") that is much easier to use for non-technical users than e.g. HTML. Formatting thus does not require knowledge of HTML.

Rollback Mechanism. Changes to the content of a Wiki are *versioned* each time they are stored, i.e. previous versions of pages are kept. This allows to revert to earlier versions of a page e.g. in case important parts have been accidentally deleted or undesirable modifications have been made by someone else. Also, most Wiki systems allow to compare two versions of a page, making it possible to identify changes between edits quickly.

Strong Linking. Pages in a Wiki are usually strongly linked with each other using hyperlinks. The reason for this is that the simplified Wiki syntax makes it very easy to define a link to another page in the Wiki. For example, in many Wikis a link is defined by enclosing a word in square brackets, or by using a so-called "CamelCase" where a word contains several upper-case letters. Links to non-existing pages are usually rendered in a different colour. If a user clicks on such a link, the system redirects him to a view where he can create the non-existing page. In many Wikis, this is even the only way to create a page.

Links in a Wiki are the most important tool for navigation. Therefore, many systems allow not only to follow links in the direction they are defined but also in reverse direction ("back-links").

Unrestricted Access. In most Wiki systems, access is completely unrestricted – i.e. anyone can correct, modify, complete, or even delete anything. While this might seem strange, and even dangerous, from a traditional perspective, practice shows that the system works: on the one hand, ill-meaning users are rather rare; on the other hand, all changes can easily be undone using the rollback mechanism. Note that some Wikis still allow to apply further access restrictions using users and groups as found in traditional content management systems.

Collaborative Editing. The above-mentioned properties combined make Wikis an ideal tool for collaborative editing. As soon as someone creates content, others can contribute to it, extend it, correct it, etc. Many Wiki systems provide further support for collaborative editing, e.g. by means of discussion forums, summaries of changes, and list of last updates.

Unlike other groupware or content management tools, a Wiki gives users almost complete freedom over the content development process without rigid workflow, access restrictions, or predefined structures. Users need not adapt their practice to the "dictate of the system", but can allow their own practice to define the structure. This is important, because different domains often have – or even require – different kinds of workflow.

As a recent survey on the popular technology site *Slashdot* showed[1], Wiki systems are currently used for a wide variety of purposes, including:

- *encyclopaedia systems:* collect information in a certain area (e.g. Wikitravel) or unrestricted (e.g. Wikipedia) in a community effort with contributions from a wide range of users

[1] http://ask.slashdot.org/article.pl?sid=06/01/21/1958244

– *software development:* collaboratively create documentation, collect ideas, track bugs; most of today's high-profile Open Source projects (e.g. Apache, Mozilla, OpenOffice) use Wikis for coordination
– *project knowledge management:* project tracking, brainstorming and exchange of ideas, coordination of activities, agenda tool for collecting topics of meetings, project notes repository, knowledge base, staff directory
– *personal knowledge management:* sketchpad to collect and elaborate personal ideas, addresses, dates, tasks, bookmarks, etc. [3]
– *collaborative writing:* authors work collectively on a writing (short story, novel, etc.) which is immediately accessible by readers for their enjoyment
– *CMS:* collect and connect content, simple publication tool

2.2 Semantic Wiki Systems

A "Semantic Wiki" extends a Wiki by "semantic technologies" like RDF, OWL, Topic Maps, or Conceptual Graphs. The main idea is to make the inherent structure of a Wiki – given by the strong linking between pages – accessible to machines (agents, services) beyond mere navigation. This is generally done by annotating existing navigational links with symbols that describe their meaning. A link from *Mozart* to *Salzburg* could e.g. be annotated with *lived in* or *born in*.

Such annotations are useful for many purposes, e.g. for enhanced presentation by displaying contextual information, enhanced navigation by giving easy access to relevant related information, and enhanced "semantic" search that respects the context in addition to the content. Note that presentation, navigation, and search can be done in a rather generic manner, but often profit greatly from an adaptation to the represented context.

Semantic Wikis exist in many different flavours (e.g. Semantic MediaWiki [2], SemWiki [3], IkeWiki [6], PlatypusWiki [1]). Some systems are still primarily focused on the page content and see annotations as optional "added value". For others, the semantic annotations are in the foreground and sometimes even more important than the actual content. Different systems serve different purposes, e.g. extending existing content by annotations to allow for better navigation, collaborative ontology engineering, etc. Commonly found features are:

Typing/Annotating of Links. Virtually all Semantic Wikis allow to annotate links by giving them certain types. The idea behind this is that every link carries meaning beyond mere navigation, as given in the example in the beginning of this section. The way link annotations are edited differs from system to system. Some Semantic Wikis include the annotations as part of the Wiki syntax (e.g. *Semantic MediaWiki* [2]), while others provide a separate editor for adding annotations (e.g. *IkeWiki*).

Context-Aware Presentation. Many Semantic Wikis can change the way content is presented based on semantic annotations. This can include enriching

pages by displaying of semantically related pages in a separate link box, displaying of information that can be derived from the underlying knowledge base (e.g. a box with a graphical tree presentation, license information), or even rendering its content of a page in a different manner that is more suitable for the context (e.g. multimedia content vs. text content).

Semantic Navigation. Whereas a traditional Wiki only allows to follow a link, a semantic Wiki offers additional information on the relation the link describes. Such information can be used to offer additional or more sophisticated navigation. For instance, links are more independent from the textual context and can be displayed e.g. in a separate "related information" box. The page describing Mozart could e.g. offer a separate box with references categorised by "lived in", "composed", etc.

Semantic Search. Most Semantic Wikis allow a "semantic search" on the underlying knowledge base. Usually, queries are expressed in the language SPARQL [**?**], an RDF query language recently proposed by the W3C. Using "semantic search", users can ask queries like "retrieve all pieces composed by Mozart" or "retrieve all documents where the license permits derivative works".

Reasoning Support. Reasoning means deriving additional, implicit information from the facts entered into the system using predefined or user-defined rules in the knowledge base. For example, from the fact that "Mozart" composed "Die Zauberflöte", a system capable of reasoning could deduce that "Mozart" is a "Composer". Although reasoning is an important feature, it is only supported by few Wikis. Reasons might be that it is time-consuming, memory intensive, and can yield results that are not expected and/or traceable by the user.

3 Learning with Semantic Wikis

In this section, we characterise the potential and relevance of traditional and Semantic Wikis in learning environments. Furthermore we aim to give a short overview about the possibilities and advantages of Wikis in practical use. The use of Wikis in learning environments has only recently attracted attention and is rapidly gaining interest. We begin this section with a brief introduction into learning concepts aimed at the technical reader. We then introduce the current use of (traditional) Wikis in learning environments. We conclude with a discussion of possible benefits of Semantic Wikis over traditional Wikis.

3.1 Learning Concepts

Everyone has an informal notion of what learning "means", but different disciplines and traditions have developed their own understandings and perspectives. Before describing the potential of Wikis for learning, we briefly summarise the concepts that have been developed in recent years and are now widely accepted.

Different Perspectives. Learning is a natural, birth-given ability. Psychologists define learning as "a process that results in relatively consistent change in behaviour, or behaviour potential, and is based on experience" [8]. From the neuro-scientific and cognitive perspective, learning is a process of modification of cognitive structures (thinking). In the pedagogical perspective, these changes should be "good" in a normative way: after learning, the learner should have improved his skills or competencies, extended or corrected his knowledge, etc. Philosophers discuss the epistemological preconditions for knowledge and learning.

Learning: State-of-the-Art. In the understanding developed in the last 20 years, *learning* means to construct one's own understanding of the world, i.e. (in a cognitivist view) we interpret new information with the help of prior knowledge and experience. Learners interact with the environment, select and transform information, and construct their own knowledge. Learning is (in a constructivist view) a recursive, self-referential process and needs the stimulus and challenge through others [9].

It is nowadays commonly accepted that the possibilities of *teaching* are limited: depending on prior knowledge, biography, learning abilities, motivation, emotional arousal, interest, understanding, etc., pedagogical goals might be achieved, but success is not guaranteed. Teachers can not directly transfer their knowledge. Instead, they should act as facilitators, encouraging students to discover principles on their own.

3.2 Wikis in Self-directed Learning

Most learning takes place outside the formal boundaries of a class room or learning system. We learn e.g. by searching for information on the Internet, by reading newspapers, books, articles, by trying to solve problems on the job, etc. Such learning is called *self-directed* or *informal* learning. Malcolm Knowles [10] describes self-directed learning as a process "in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" (p. 18).

Reflection. Writing text requires taking different views and perspectives on knowledge in order to make it explicit and understandable for readers, e.g. by integrating with contextual information and telling "a story". This results in additional reflection about the knowledge and thus learning. While this aspect is not specific to Wikis, the possibility to repeatedly update the content and structure gives success quickly and allows refinements later on. Furthermore, Wikis support the constructive process by allowing to embed content in a larger context using hyperlinks, and by considerably simplifying the restructuring of content. The hypertext structure of Wikis can also reflect and promote network thinking of the learners.

Stimulative Nature. A significant difference between a normal HTML page and a Wiki page is the possibility to directly change content. Even more so, most Wikis *invite* readers to edit the content. This possibility – when communicated rightly to readers – *challenges* the readers to question and rethink some or even all the content of a page ("is the author right? – what is my view? – is something missing? – can the text be improved?"), and thus mobilises critical thinking, which in turn initiates learning. Also, the dissociation from others and their perspectives on a topic is part of the (constructivist) learning process ("learning as experience of differences", [9]).

Additionally, as links to non-existent pages are usually rendered differently, Wikis also challenge readers to contribute to pages that do not yet exist, leading to active construction of knowledge and additional reflection about the content.

Personal Learning and Knowledge Tool. Self-directed learning also involves personal knowledge management: taking personal notes, collecting references, ideas, etc. The usefulness of Wikis for knowledge management has been investigated [3,11], so we do not go into details here.

3.3 Wikis in Educational Environments

Formal Learning describes learning activities that happen in an organised way, e.g. in schools, in university, in adult education centres, etc. Wikis can be used in different ways in formal learning situations. One use is as a knowledge repository for students to search in (see above). More interesting, however, is the use of an initially "empty" Wiki that is filled by the students themselves.

Wikis can play an important role both in blended learning (which combines traditional presence learning with technology-supported learning) and in "pure" eLearning. A particular advantage over other tools is that – prepared with the knowledge about a Web browser – the necessary technical knowledge can be acquired quickly. In the following, we describe different approaches to modelling the learning environment and show how Wikis can be supportive within these approaches.

Cognitive Apprenticeship [12] is based on the knowledge and skill transfer in the traditional master-apprentice education. In cognitive apprenticeship, learning is always situated in the context and happens via interaction with the environment and other individuals. The apprentice learns by working closely together with the master on real-world problems of the respective craft. The master acts as an archetype for the learner by doing work instead of trying to make explicit his knowledge.

Wikis provide an important benefit in this learning model: their collaborative features allow teachers and students to work closely together on a topic, e.g. writing a text or article, collecting information on a topic, etc. – regardless of the whereabouts of students and teachers. They thus aid in an important learning task of the emerging knowledge society.

Cooperative Learning differs from traditional curriculum-driven education in that students work in purposely heterogeneous groups to support the learning of their individuals. Important aspects of cooperative learning are positive interdependence of group members, individual accountability, face-to-face interaction, appropriate use of collaborative skills, and regular self-assessment of team functioning [13]. In cooperative learning, learners gain a realistic self-perception by looking at the other group members.

The collaborative features (collaborative editing, versioning, discussion next to the content) of Wikis make them particularly well-suited for cooperative learning environments, with no corresponding tool in traditional learning. Whereas collaborative working with twenty people using traditional methods – e.g. a chalk board, brainstorming sessions, etc. – is not viable because it takes a lot of time, is tiresome, and causes many learners to withdraw, collaborative working using a Wiki can easily function with hundreds or even thousands of people (cf. Wikipedia). Wikis are already used for a number of different tasks in cooperative learning. Examples are:

Communities of Practice are groups of persons pursuing common goals and interacting with other individuals [14]. In communities of practice, learning is a collaborative process of a group. Rather than looking to learning as the acquisition of certain forms of knowledge, communities of practice define learning as a situated process through the participation in the community. In order to fully participate in the community, members need to adopt to the communities shared knowledge and practices.

Wikis can serve as a knowledge platform for a community of practice where members of the community can share their knowledge with the group, put up interesting pieces of information, work together, discuss issues, etc. New members can use the Wiki for learning about the community and its practices. In a sense, even Wikis like Wikipedia can be considered as (large) communities of practice.

Project-Based Learning. Projects play a large role in the context of educational environments. Whether project weeks, project days, class-independent annual topics or smaller projects, the project method applies nearly everywhere. Project classes correspond to the general education programme of schools. The project method is seen as a way to reach the education goals. Wikis can represent – in case a project encloses many individuals or several classes – a very effective tool for project planning and documentation.[2]

Collaborative Story Writing. Wikis give learners completely new possibilities for creative writing. A Wiki can be seen as an interactive writing book, where students write together on an essay or story. The story does not necessarily have only one end; it can branch out like a tree or even graph with a lot of different

[2] Example: Planning of a musical project: http://www.prowiki2.org/glarnerschulen/wiki.cgi?OrdnerMusical

paths and ends. Talented students also have the possibility of supplementing illustrative figures or photographs to the story.[3]

Interdisciplinary and Intercultural Learning. The collaboration features and independence of Wikis from the actual whereabouts of the learners make them well-suited for interdisciplinary and intercultural learning, bringing together learners with different cultural and educational backgrounds. For example, religion can be discussed among christian, muslim, and hindu students, languages can be learned from other students with different mother tongues, etc.

3.4 Wikis as ePortfolios

Learning in general implies two different processes: on the one hand, one has to collect artefacts and pieces of information; on the other hand, these artefacts need to be integrated with ones existing knowledge space by "reflecting" the learning / knowledge building process on a meta-level. The sum of documentation and reflection illustrates the learning process as a whole and can therefore be used as an process oriented ePortfolio.

ePortfolios in general are a "structured personal digital collection of information describing and illustrating a person's learning, career, experience, and achievements."[4] Depending on the purpose, ePortfolios cover 3 major processes: *collection and presentation* (presentation portfolio), *reflection and communication* (learning- and process portfolio), and *evaluation* (assessment portfolio).

Wikis (in a learning context) can on the one hand obviously be used as a supportive technology for *collection and presentation* processes. These processes can support both, self-directed learning or community learning. On the other hand, *reflection and communication* purposes are covered by Wikis in terms of using the history function and the discussion function.

History function: a community, working together on one topic might investigate on a similar topic and find different aspects of an issue. By editing earlier versions of an item or a topic on the Wiki, the development process can be documented and reconstructed easily by the system itself. By using the *discussion feature* of a Wiki, the process of collaborative content generation combines the *collection and presentation* issues of ePortfolio work, the discussion function coveres the *reflection and communication* aspects.

The value of ePortfolios can be seen not only in the collection and presentation of artefacts. Too much information gets lost by only reproducing results of learning processes without documenting the meta-level, described in the development process in a holistic way. Wikis can support this process, but should be part of a bigger framework, dealing with personnel development / learning documentation and reflectional processes of this documentation.

[3] Example: Creative and Cooperative Writing with Wiki – Geschichtenwald: http://www.wikiservice.at/buecher/wiki.cgi?GeschichtenWald

[4] Definition by National Learning Infrastructure Initiative of EDUCAUSE, 2003

3.5 Possible Benefits of Semantic Wikis

In the following, we describe a number of benefits that Semantic Wikis may provide over traditional Wikis in the context of learning that go beyond those frequently mentioned for knowledge management (cf. e.g. [3,6]). The benefits are categorised in *Learning Process* and *Content Creation and Reuse*.

Learning Process. Semantic Wikis can participate in many ways in a learning process. In the following, we mention three possibilities:

Semantic Annotations lead to Reflection about Knowledge. The possibility to add semantic annotations in a Semantic Wiki and create a background model has a stimulating effect for reflecting about the learning content. Constructing a formal model requires structuring the content thoroughly. Hence, the learner needs to reconsider and possibly reorganise the content in the Wiki, leading to improved reflection about the content. The result of structuring the content and the changes history can additionally be used by the coach to assess the learner's progress.[5]

Sharing of Perspectives. Semantic Wikis also offer the possibility to share formal models between teachers and students and among students, and to participate in the collaborative building of a common model within a group. Sharing of knowledge gives learners the possibility to benefit from different perspectives stemming from different cultural, social, or educational backgrounds. This is particularly true in an open learning environment like the Web.

Reasoning Provides Additional Insight. Reasoning and inference capabilities of Semantic Web technologies can lead to unexpected interesting results that provide additional insight without requiring active search by the user. For example, a link from *Die Zauberflöte* to *Mozart* annotated with *composedBy* could instantly lead the user to the information that *Eine Kleine Nachtmusik* was also composed by *Mozart*, a piece of information possibly entered by someone else.

Content Creation and Reuse. Learning comprises not only the actual learning process but also the actual outcome of the learning process. This can include content objects represented traditionally as text oriented document (e.g. thesis, project report, paper, article), enriched with figures, images and some hierarchical structure.

Typing of links adds value to content creation process. Apart from its collaborative aspects, the hypertext and the Wiki paradigm added another layer of "structure": multiple paths/links within documents. However, these entities are fairly complex to maintain within a learning process, because the semantics of

[5] Note that currently existing Semantic Wikis do not support versioning of metadata.

the paths/links are not explicit. Semantic technologies support the formalisation of links by allowing to type objects and associations between them. This adds an additional dimension to the content creation process and allows further exploitation.

Reusability of Learning Content. Using Semantic Web technologies, learning content can be annotated using standardised knowledge models like IMS Learning Design[6] or Learning Objects Metadata (LOM)[7]. Semantically annotated content allows the designers of a curriculum to more easily reuse and combine existing content to create new course material. A Semantic Wiki provides an intelligent way for content creators to add and use such metadata.

Interoperability. A "learning environment" consists of a plethora of "tools" ranging from traditional classrooms and chalk boards over ePortfolios, Weblogs, and Wikis to sophisticated learning management systems. Naturally, there is a desire that such tools are widely interoperable to share information between them. The Semantic Web technologies used by Semantic Wikis provide the chance to re-use significant parts of the gained knowledge model within other applications, e.g. to export a specific knowledge model built for within the Wiki as the background model for the own competency portfolio within a specific domain, or to interact with a learning management system.

4 IkeWiki

A number of Semantic Wiki systems are currently under development.[8] In the following, we introduce our own system called *IkeWiki*. We believe that IkeWiki has many of the features desirable for Wiki use in learning environments.

4.1 Design Principles

Although now also considered in different settings, IkeWiki has originally been developed as a prototype tool to support knowledge workers in collaboratively formalising knowledge [6]. Although holding in other areas as well, IkeWiki's design principles are influenced by this idea:

Easy to Use, Interactive Interface. IkeWikis interface (Figure 2) resembles as closely as possible the Wikipedia interface which people are familiar with. Furthermore, IkeWiki offers an interactive WYSIWYG[9] editor (using AJAX[10]

[6] http://www.imsglobal.org/learningdesign/index.html
[7] http://ltsc.ieee.org/wg12/
[8] http://wiki.ontoworld.org/index.php/Semantic_Wiki_State_Of_The_Art
[9] WYSIWYG: "what you see is what you get"
[10] AJAX: "asynchronous JavaScript and XML" – used for interactive web applications

technology to communicate with the server backend) in addition to the traditional structured text editor, as WYSIWYG editors generally have a better acceptance among non-technical users.

The WYSIWYG editor also supports interactive typing of links and resources. The interface is designed in a way that users are invited to annotate their content with semantic annotations, instead of hiding them in the syntax. We consider this an important aspect, particularly in learning environments.

Immediate Exploitation of Semantic Annotations. An important motivating aspect of Wiki systems is that content is immediately available to the public when a user clicks on "save". Similarly, IkeWiki allows immediate exploitation of semantic annotations for enhanced editing, presentation, navigation, and searching, even if the knowledge base is not yet fully formalised.

Support for Different Levels of Experience. IkeWiki is designed as a tool for collaborative working. In such a process, it is common that non-technical people (e.g. learners) work together with experts (e.g. teachers). Therefore, IkeWiki supports all levels of experience. This means that certain advanced functionalities can be hidden from novice users but are available to experienced users.

Support for Different Levels of Formalisation. Different application areas need different levels of formalisation [6], and as Jim Hendler said:[11] "a little semantics goes a long way". One of the goals of IkeWiki is thus to support formalisation of knowledge all the way from informal texts to formal ontologies. Also, this means that parts of the knowledge base might be more formalised than others, and that formal knowledge is in constant evolution.

Support for Reasoning. Unlike most other Semantic Wikis, IkeWiki supports reasoning on the knowledge base. Reasoning is important as it allows to derive knowledge that is not explicit; it is thus the true power of Semantic Web technology. At the moment, IkeWiki supports only OWL-RDFS reasoning, but an extension with a user-accessible rule engine is planned. As mentioned earlier, reasoning can be an important supportive service in learning environments.

Compatibility with Semantic Web standards. To be able to exchange data with other applications (e.g. other Wikis, learning management systems, ePortfolio systems, Web services), IkeWiki is based on existing Semantic Web standards like XML, RDF and OWL. Note that other knowledge representation formats like conceptual graphs are conceivable but not investigated at this point.

[11] as conference chair in the opening speech of the 2003 International Semantic Web Conference; Sanibel Island, Florida, USA, October 2003

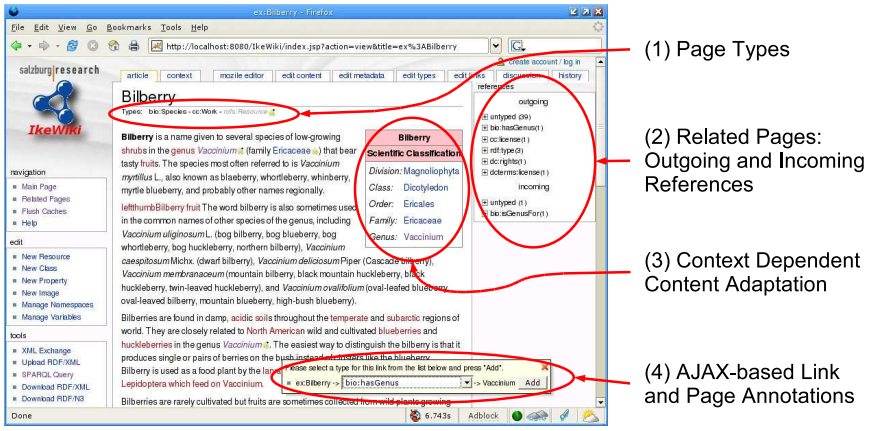

Fig. 2. Sample page in IkeWiki; type information below the title (1); incoming and outgoing links are displayed in a box on the right (2); context-dependent rendering: automatically generated taxonomy box (3); interactive editing (4).

Compatibility with Wikipedia/MediaWiki. A significant amount of information is available in Wikipedia. To reuse it, IkeWiki supports the Wikipedia syntax. This allows users to import existing content from Wikipedia into IkeWiki (e.g. via simple copy and paste) and directly begin working.

4.2 Interface

IkeWiki uses a purely browser-based interface (cf. Figure 2). The current implementation only supports the Mozilla browser family due to its standards compliance and free availability.

Page View. A sample page view is shown in Figure 2. In the figure, you can see a sample article (copied from Wikipedia) about the "Bilberry". Type information is shown below the page title (1). Links to (semantically) related pages are displayed in a separate "references box" on the right hand side (2). The taxonomy box (3) showing the biological classification of the described plant is automatically generated from existing semantic annotations (i.e. Bilberry *hasGenus* Vaccinium) and is an example for context adaptation. Finally, (4) shows interactive typing of links using AJAX technology.

Content Editor. The content editor is available in two flavours: as a traditional structured text editor and as a WYSIWYG editor. The structured text editor is aimed at expert users that are familiar with other wiki systems, and allows to directly copy content from Wikipedia. The WYSIWYG editor is aimed at novice users creating new content. The WYSIWYG editor interacts with the

server backend: links are automatically recognised and verified, and semantic annotations can be done directly in the editor (as also shown in Figure 2, (4)).

Semantic Annotations Editor. Semantic annotations are separated into three editors: the *metadata editor* allows to fill in textual metadata related to a page (like Dublin Core metadata or RDF comments). The *type editor* allows to associate one or more of the types available in the system with a page. The *link editor* allows to annotate outgoing and incoming links with type information. In the editors, available annotations are determined by the reasoner based on the page and link types; for example, if a link from "Mozart" to "Die Zauberflöte" is annotated by "composerOf", the system will automatically associate the type "Composer" with the page describing "Mozart".

5 Related Work

A number of studies investigating the use of (traditional) wikis in learning environments is available. A good survey over the use of wikis in teaching is given in [15]. A recent study by Beat Döbeli Honegger [16] investigated the use of wikis in schools and provided interesting results regarding the stimulative nature of wikis. The study conducted a project to create hypertext on Greek mythology and observed the effects on student learning. A visualisation of the content was done via TouchGraph technology. The EduCause fact sheet [17] further provides a very concise overview over the potential of wikis for learning.

To the best of our knowledge, this article is the first to consider Semantic Wikis as a tool for learning, as existing related work is mostly concerned with knowledge management [3,4] and knowledge engineering [6].

6 Perspectives and Conclusion

We investigated the use of Semantic Wikis as a tool in learning environments. The potential of using wikis, especially Semantic Wikis, in learning environments appear to be significant, but they have not yet been proven in real learning environments and – although well-founded – only reflect our own considerations. In the near future, we will therefore develop learning scenarios involving Semantic Wikis and try them in real-world settings. In addition, we will investigate the possible integration of Semantic Wikis with other learning tools like ePortfolios and learning management systems.

The prototype system IkeWiki also presented in this article is under active development. Plans for the near future are a more efficient reasoning support and improvements of the user interface. On the long term, we would like to implement a Semantic Wiki system with enhanced collaboration and editing features like synchronous editing, improved WYSIWYG editing, and a tighter integration of content and metadata editing.

IkeWiki is available as OpenSource software licensed under the GNU General Public License at `http://ikewiki.salzburgresearch.at`.

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