

## **Wikis as a Technology Fostering Knowledge Maturing: What We Can Learn from Wikipedia**

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**Abstract:** The knowledge maturing theory opens an important macro perspective within the new paradigm of work-integrated learning. Especially wikis are interesting socio-technical systems to foster maturing activities by overcoming typical barriers. But so far, the theory has been mainly based on anecdotal evidence collected from various projects and observations. In this paper, we want to present the results of a qualitative and quantitative study of Wikipedia with respect to maturing phenomena, identifying instruments and measures indicating maturity. The findings, generalized to enterprise wikis, open the perspective on what promotes maturing on a method level and what can be used to spot maturing processes on a technology level.

**Keywords:** wiki, knowledge maturing, work-integrated learning

**Categories:** H.3.5, H.3.7, H.4.0, J.4

### **1 Introduction**

Current research approaches to supporting workplace learning have shifted their attention from provision of learning material towards supporting the active contribution of the learner and the collaboration with others. Working and learning are increasingly conceived as embedded into, interwoven with, and even indistinguishable from everyday work processes. On the one hand, learning support is increasingly seen as work performance support; on the other hand, collaborative activities are increasingly understood as collaborative learning activities.

One important element of this new perspective is that individual learning processes are no longer seen as isolated one-way processes, but rather as interlinked with others and loosely coordinated by organizational goals. The theory of the knowledge maturing process (as introduced in [Schmidt 05]) provides a conceptual model for this interlinkage and the corresponding change in the quality of involved knowledge. The model uses the metaphor of maturing and is structured into several phases: from (1) emergence of ideas, via (2) distribution in community, (3) formalization up to (4) ad hoc training and (5) formal training. Along this process, the characteristics of knowledge change: implicit contextualization decreases, explicit linkage increases as well as hardness, legitimation, and teachability [Maier & Schmidt 07]. Furthermore, the theory identifies typical barriers in maturing, such as between

phases (2) and (3) where knowledge usually is detached from its originator and (3) and (4) as the typical barrier between knowledge management and e-learning.

Wikis have been identified in [Maier & Schmidt 07] as a promising technology fostering knowledge maturing because it allows for the coexistence of and smooth transition between different maturing phases. They can capture initial ideas in a similar way as didactically prepared learning material, and there are no technical barriers between the different maturity phases. Maturing can emerge as part of the social interaction, producing explicit or implicit conventions.

This sounds plausible from everyday observation, but in this paper, we want to go one step further and actually validate this view, i.e., the hypotheses that (1) knowledge maturing as described in [Maier & Schmidt 07] actually takes place in wikis and (2) that socio-technical wiki systems have brought forth instruments overcoming barriers in the maturing processes. In order to be able to rely on a large body of data, we have conducted a qualitative (which problems and mechanisms for maturing have emerged) and quantitative study (which measures can be used to describe maturing) on Wikipedia (primarily focused on the German Wikipedia), which we consider the largest social experiment on knowledge maturing. We will also analyze the transferability of these results to enterprise wiki systems.

## 2 Qualitative Analysis of Wikipedia: Three Layers of Maturing

Our initial step to analyze Wikipedia in terms of knowledge maturing was to identify instruments within Wikipedia that affect maturing. The first insight gained from that qualitative analysis was that the majority of such instruments is not technically implemented at all in the underlying MediaWiki system or has been only successively implemented over time as a response to pressing needs to codify social rules. That is also reflected in a varying list of (more or less) official principles and guidelines. The second insight was that we need a more differentiated view on maturing in order to describe and relate the instruments with the knowledge maturing theory. The phenomenon of maturing can be divided into three layers:

**Artefact Layer.** The most obvious layer is concerned with the artefacts that are produced in the course of communicating with others about certain knowledge elements. In the case of wikis, these artefacts are the wiki pages. The most obvious instruments of Wikipedia on the artefact level are the predicates that are given to certain articles, which represent the legitimation by the Wikipedia community. They indicate their level of quality like good article (“lesenswert”), featured article (“exzellente Artikel”), but also “stub” and “needs review”. Wikipedia has also developed definitions for the level of quality, which correlate with the notion of maturity. Closely linked with these predicates are candidate lists implementing a limited and very loose form of transition workflow. These lists encourage maturing of articles by creating awareness for them: typically other authors become aware of the existence and the need for improvement of these articles.

**Knowledge Layer.** As artefacts are usually only a medium for communicating knowledge between individuals and communities, these do not accurately reflect the individual knowledge. Even when knowledge is mature, artefacts like Wikipedia articles usually start at an immature status. This does not deny the coupling between artefact and knowledge layer: producing mature artefacts requires a certain level of

maturity on the knowledge layer, and this production process usually implies a construction process on the knowledge layer. Wikipedia offers also instruments on the knowledge layer: the use of categories to organize articles, links among articles that are not directly tied to the occurrence of the article name, and disambiguation pages. All of these instruments contribute to improving the decontextualization process (and the explicit linking as an inverse criterion): knowledge is organized from a more global perspective, abstracting away the creation context.

**Social Layer.** As knowledge maturing is an inherently collaborative activity, it also requires social “meta competencies”, i.e., a socialization process in which conventions and adherence to rules are learnt. Besides the “Wikiquote”, which comprises some principles of etiquette on how to work together, these instruments target at organizing, moderating, and improving the social interaction process, but also at the individual’s motivation to engage in collaboration:

- Discussion pages give space to complex negotiation processes among potentially conflicting viewpoints (which can also be seen on the knowledge layer as it often leads to a more holistic view on the subject).
- Changes are visible in a global (e.g. on the special page “recent changes”) as well as in a local change log (each page has a version history allowing for tracking all changes and offering the possibility to roll back in case of destructive behaviour). This transparency also helps to socialize new community members by showing them how collaboration actually works and which form of behavior is acceptable.
- Users can have a user identity (with a user page for self-portrayal, e.g., listing contributions, or as elected administrator with extended rights, or as mentor), and watchlists that support the responsibility for certain articles. These promote the feeling of social esteem and allegiance to the Wikipedia community and mission, important for user motivation (e.g. [Schroer 07]).
- Wikipedia also limits activities by technical means in order to cope with problems where different opinions don’t converge naturally and result in so-called edit wars. Featured articles are write-protected (only the German Wikipedia), and the English Wikipedia has introduced the “3-revert-rule”.

As a summary, Wikipedia instruments are primarily – as to be expected – on the artefact level: they indicate and promote the maturity of articles. But a significant number of instruments also address the social layer, developing the wikipedians’ social competency to contribute collaboratively to maturing processes.

### 3 Quantitative Analysis of Wikipedia: Maturity Metrics

In our second step we have focused on a quantitative analysis of Wikipedia to find measures for maturity at the artefact level; i.e. the maturity of articles. As maturing is a process, it is in particular interesting to observe the development of the articles over the time and not just snapshots. Wikipedia provides a rich data set of articles with their detailed version history. The articles characterized as featured articles are furthermore interesting as it is the highest available distinction within Wikipedia.

### 3.1 Existing quantitative studies on Wikipedia

A number of quantitative studies for assessing the quality of Wikipedia articles have been conducted. These focused in particular on the growth of Wikipedia (e.g. [Buriol 06] or [Voss 05]) or the number of edits and editors (e.g. [Wilkinson & Huberman 07] or [Kittur 07]) in order to make some assessments. [Lih 04] focused on content construction and use processes from the perspective of participatory journalism. He proposed the total number of edits (rigor) and the total number of unique editors (diversity) as metrics for quality. [Emigh & Herring 05] studied the formality of language and compared Wikipedia articles with the traditional Comlumbia Encyclopaedia and with the also community-based Everything2 based on frequency of parts of speech measurement. [Stvilia 05] studied the English Wikipedia and applied readability metrics by Flesch and Kincaid (cf. [Flesch 48]). He has shown that the readability for featured articles is better than median values for readability of random articles.

The studies of [Viégas 04] and [Buriol 06] are the only ones taking into account temporal aspects. [Viégas 04] developed a tool called “History Flow” for visualizing the version history of articles. With this tool they could reveal collaboration patterns like *mass deletion*, *offensive copy*, *phony copy*, *phony redirect*, *idiosyncratic copy*. Against expectations, the length of articles does not stabilize over time. Instead, articles with more than 100 edits are continuously growing.

[Buriol 06] made a temporal analysis of the Wikigraph. They examined in- and outgoing links from articles within the Wikipedia, but they did not considered broken internal links, that means links referring to not yet existent entries (highlighted in Wikipedia as red links). They generated webgraphs based on 17 snapshots. They found out that newer articles grow slower than older ones and older articles get more edits, which they interpret as maturity of coverage but not of depth. Concerning the linkage, they could state a power-law distribution of the ingoing and the outgoing links with an increase of outgoing links from 7 to 16 over the observed period.

### 3.2 Measures and Metrics

For the purpose of our study, we have developed three metrics used as simple measure for maturity. These are prototypical indicators for estimating the maturity level of articles over time.

- **Readability**<sup>1</sup>. The assumption is that the more an article matures the better it is readable and understandable. As indicated by [Stvilia 05], featured (i.e. more mature) articles have a higher readability score. We revert to Flesch’s Reading Ease Score (RES) adjusted to the German language by [Amstad 78]:  $RES(\text{German}) = 180 - (\#words/\#sentences) - 58.5 * (\#syllables/\#words)$
- **Presentation and Format**. A good and mature article is not only characterized by its content at word level but also by its presentation and format. Articles are structured by and by; i.e. an article is parted in sections, headings are introduced and images for illustration are added. Therefore, we are looking at the number of words per headline and the number of words per image.

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<sup>1</sup> Stvilia specified readability as *complexity*

- **Linkage.** The more knowledge matures the better it can be embedded into different contexts. If users extend articles and add contents, cross references can be set. These can be links to other Wikipedia pages but also to articles outside Wikipedia. Here, we are regarding the number of words per internal link as well as the link density comprising internal and external links.

### 3.3 Results

The basis of our analysis is the German Wikipedia. We are using the full XML dump generated on 2007-01-24, containing all article pages with their complete version history and corresponding discussion pages (also with history) as well as pages beyond the articles' name space (e.g. user profiles). Due to time constraints, the following results refer to the first 68854 pages within the XML dump. As the order within the dump is only semi-alphabetical, the obtained articles range from A to Z. Of 68854, we filtered 19245 pages containing user profiles, discussion pages and lists. Because of the abolition of the explicit "stub" tag for articles within the German Wikipedia in 12/2005, we defined stubs as articles with less than 200 words. Thus, we received 19852 "stub" articles, 612 good articles, 343 featured articles and 28763 "normal" articles without any markup.

	<b>Stub</b>	<b>Normal</b>	<b>Good</b>	<b>Featured</b>
<b>#articles</b>	19852	28763	612	343
<b>#words per article</b>	43 (4) 60	1196 (753) 1359	5386 (4580) 3428	6689 (5952) 3561
<b>RES per article</b>	35 (41) 32	50 (53) 35	55 (55) 7	54 (54) 6
<b>#headlines p. art.</b>	0 (0) 1	7 (5) 8	21 (18) 13	24 (22) 14
<b>#images per article</b>	0 (0) 0	2 (0) 6	8 (6) 10	11 (8) 13
<b>#words p. headline</b>	105 (96) 50	198 (157) 198	391 (229) 880	438 (249) 883
<b>#words per image</b>	132 (138) 45	747 (493) 827	1289 (722) 1897	1181 (647) 1633
<b>#(unique) internal links</b>	6 (1) 9 6 (1) 9	75 (55) 71 82 (58) 87	212 (170) 144 238 (188) 171	240 (213) 137 272 (233) 169
<b>#words p. int. link</b>	5 (3) 5	16 (13) 17	29 (21) 25	31 (24) 26
<b>link density (%)</b>	31 (33) 16	9 (8) 4	5 (5) 2	4 (4) 2

Table 1: Comparison of article quality classes (mean (median)  $\sigma$ )

In a first run, we compared the four article quality classes by applying the measures on the last versions of the articles (cf. Table 1). In total, the mean and median results correlate to the maturing process. As expected, the number of headlines and images per article increases on average from stub to normal and good to featured articles; as well as in the case of the linkage. Whereas the increase from stub to normal and from normal to good is evident, the difference between good and featured articles is not as big anymore. This can be traced back to the fact that there is no clear definition of the

differences between good and featured articles and the non-obligatory tagging of featured articles as good. However, the standard deviations are severe and do not decrease as expected; except for the RES where the differences between normal, good and featured are only small but the standard deviation decreases obviously.

These results are further confirmed regarding the evolution of featured articles (cf. Figure 1). In a second run, we analyzed the set of 343 featured articles and their history and looked at the measures' development over the time. Therefore, we applied the measures to every version of an article and uniformly aggregated the versions to an interval of 100 discrete scores. It is interesting that, contrary to the first comparison, the median RES is higher in the early phases and then decreases and stabilizes on a value of 54 (cf. Figure 1a). The words per headline, images and internal link develop as expected (cf. Figure 1 b-d). Although articles are always growing, the words per headline converge to about 250-300 words. There is no significant difference between the featured articles tagged as good beforehand and the ones directly tagged as featured. Regarding the standard deviations, they increase similarly unexpectedly high (except for the RES). Thus, on average maturing can be observed in the development of Wikipedia articles, but these simple measures do not allow the automated classification of a single article.

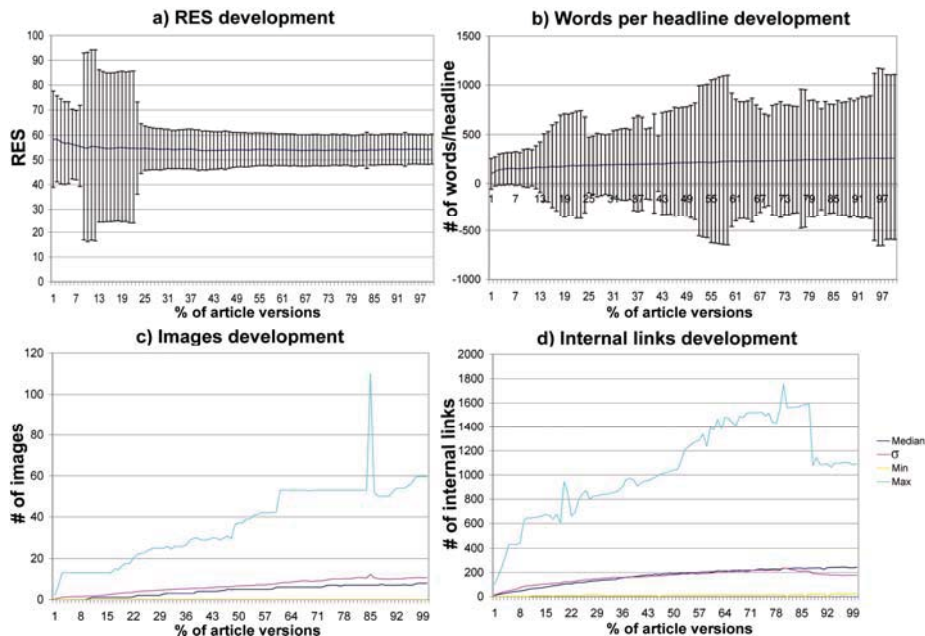


Figure 1: Measures development over the version history of featured articles

#### 4 Wikipedia vs. Enterprise Wiki Systems

While Wikipedia as a large and transparent social experiment is ideal for empirical analysis, it should be clear that results from analyzing Wikipedia cannot be mapped

one to one on knowledge maturing phenomena in enterprise wikis. Concerning knowledge maturing, the most important difference lies in the systematic bias of Wikipedia to more mature knowledge: The criteria qualifying an article for inclusion in Wikipedia clearly favour more mature knowledge elements. On the other hand, enterprise wikis are mostly used to improve informal learning of immature elements, which are often still highly contextualized. Thus, the maturing focus of Wikipedia is clearly on the artefact level, whereas of enterprise wikis, being part of knowledge management initiatives, it is more on the knowledge level. Table 2 summarizes these and some more differences between the two. Still, the patterns of interaction remain the same: collaborative improvement and enrichment of content and socially negotiated interaction protocols. So results of our qualitative and quantitative study can also be applied to enterprise wiki systems, which is planned to be confirmed by specific enterprise wiki studies in the future.

	<b>Wikipedia</b>	<b>Enterprise wikis</b>
<b>Size of community</b>	large numbers	limited to (parts of) the organization
<b>Goal</b>	general public encyclopaedia	persistence and exchange of experiences
<b>Type of knowledge</b>	rather mature knowledge (at least ad-hoc training)	immature knowledge (mostly distribution in communities and formalization, up to ad-hoc-training)
<b>Maturing focus</b>	artefact level (knowledge is considered to be sufficiently mature)	knowledge level (artefacts are considered to be facilitating the collaboration and exchange)
<b>Motivation</b>	idealism and identification with Wikipedia goals, quest for social esteem	work process needs, professional esteem, organizational goals

Table 2: Differences between Wikipedia and enterprise wikis

## 5 Conclusions and Outlook

Our Wikipedia study has confirmed that maturing actually takes place in wiki systems and that social negotiation processes have brought forth a set of mechanisms that foster maturing. Furthermore, starting from the criteria developed in [Maier & Schmidt 07], a quantitative analysis has shown that there are measures indicating maturing of artifacts. But individual differences between articles (diagnosed by the high standard deviation) do not allow for determining maturity of artefacts in an automated way based on these simple measures. The results suggest that we need to go beyond artefact measures and rather consider creation and usage contexts.

We are aware that Wikipedia and enterprise wiki systems have several differences; most notably the difference in magnitudes of its user community and the systematic Wikipedia bias towards artefacts communicating more mature knowledge. We still argue that the mechanisms of Wikipedia and the identified measures can also be applied to enterprise wiki systems. Of course, this will be validated in a future study of an enterprise wiki system.

For improving knowledge maturing processes, we can derive from this study that we need to consider all layers of maturing (artefact, knowledge and social). These are mutually dependent – a fact which has often been neglected by systems focusing merely on the artefact level (i.e., on documents). Especially motivational aspects need to be taken into account: community members engage in maturing activities not only because it is useful (or they expect a future benefit), but also because they identify themselves with the socio-technical system as whole and specific parts of it (e.g., as caretakers). Apart from motivation, awareness of activities plays a key role (cf. [Lih 04]): only if others are aware of what's going on, what's there and what needs to be done, they will invest time in it. This social layer has to be analyzed in more depth.

From a technological point of view, an important lesson is that the instruments should not be the result of technical design, but rather of social negotiation. Technical systems should constrain collaboration processes as little as possible.

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