Chemical Information Media in the Chemistry Lecture Hall: A Comparative Assessment of Two Online Encyclopedias

Lukas Korosec[a], Peter Andreas Limacher[b], Hans Peter Lüthi[b], and Martin Paul Brändle*[a]

Abstract: The chemistry encyclopedia Römpp Online and the German universal encyclopedia Wikipedia were assessed by first-year university students on the basis of a set of 30 articles about chemical thermodynamics. Criteria with regard to both content and form were applied in the comparison; 619 ratings (48% participation rate) were returned. While both encyclopedias obtained very good marks and performed nearly equally with regard to their accuracy, the average overall mark for Wikipedia was better than for Römpp Online, which obtained lower marks with regard to completeness and length. Analysis of the results and participants' comments shows that students attach importance to completeness, length and comprehensibility rather than accuracy, and also attribute less value to the availability of sources which validate an encyclopedia article. Both encyclopedias can be promoted as a starting reference to access a topic in chemistry. However, it is recommended that instructors should insist that students do not rely solely on encyclopedia texts, but use and cite primary literature in their reports.

Keywords: Chemical information · Quality assessment · Römpp Online · Student survey · Wikipedia

Introduction

In research as well as in studies, the use of online media by graduate and undergraduate students is common practice. In the chemistry library, we observe that students regularly use online encyclopedias as a quick and easy path to chemical information, *e.g.* for substance information with structures, molecular formulas, safety information, physical properties, or for name reactions. Among the encyclopedias, Wikipedia is most popular. The success of Wikipedia can be attributed to the fact that its articles are freely available on the Web and are highly interlinked, which leads to a prominent ranking of its pages in search engine results. For example, if one does a search on google.ch for the German terms listed in Table 1 describing thermodynamic concepts or quantities, a Wikipedia entry appears as the first hit for all of them. Hence, students who carry out Google searches to find information that assists them in their assignments will come across Wikipedia articles very often. This,

Correspondence: Dr. M. P. Brändle[a]
Tel.: +41 44 632 29 48
Fax: +41 44 633 12 87
E-mail: braendle@chem.ethz.ch
[a]Chemistry Biology Pharmacy Information Center
ETH Zürich
Wolfgang-Pauli-Str. 10
CH-8093 Zürich
[b]Laboratory of Physical Chemistry
ETH Zürich

however, raises the question whether the chemical information in Wikipedia can be trusted, as freshman students without prior knowledge about the system of chemical literature, essential reference works, and databases in chemistry tend to do. How should chemistry lecturers and chemical information instructors respond?

The reliability and accuracy of Wikipedia articles is topic of an ongoing debate,[1–9] because they are the collaborative result of many volunteers, amateurs as well as experts. Wikipedia's easy-to-use interface allows anyone to write and make changes to articles. Authors can remain anonymous, and there is no formalized peer-review system in action. This openness, in the worst case, makes Wikipedia susceptible to vandalism.[1,2] The encyclopedia relies on its community to recognize and correct factual errors and to improve overall style and content of the articles. Smaller errors and apparent vandalism are rectified quickly, whereas errors introduced in the first edit may survive for quite a while before they are detected.[2]

Several studies have contrasted Wikipedia with traditional online and print universal encyclopedias such as the Britannica,[3a] Encarta,[4] and Brockhaus.[4,5a,6] Two of them concluded that the quality of selected Wikipedia articles is nearly equivalent for science articles[3a] or even better for popular science articles[6] than their counterparts. Notably the comparison with Britannica published in Nature gave rise to some controversy.[3b] In specialized scientific disciplines, only a few evaluations of Wikipedia versus reference works have been done, *e.g.*

for American history,[1,7] or pharmacology.[8] All came to the conclusion that the investigated reference works were more reliable than Wikipedia.

Regarding chemistry content, an extensive comparison between the renowned chemistry encyclopedia Römpp Online and German Wikipedia was done by Jana Sonnenstuhl in her magister thesis[9] that was accompanied by one of the authors (MB). Both quantitative comparisons regarding coverage, formal criteria (translations of headwords, number of sources, further reading, graphics, and links) and structural criteria (number of structure formulae, tables, chapter titles, and reaction equations) as well as an expert assessment of the content of randomly selected articles were carried out. While Römpp Online was judged to be superior to Wikipedia with respect to coverage and most of the formal and structural features, the quality assessment by experts from ETH Zürich and the Max Planck Society favored Wikipedia articles over those of Römpp Online. However, the results of the expert assessment must be taken as non-representative, since only about half of the 32 survey forms were returned. Furthermore, each article was rated only once, and the disciplines within chemistry and pharmaceutical sciences were covered rather unevenly.

We took the concept of this study as a starting point to repeat the assessment of Römpp Online and Wikipedia with a focus on a single discipline only and carried out by first-year university students. As discipline we chose chemical thermodynamics, because this topic is part of every chemis-

Table 1. Alphabetic list of examined headwords in thermodynamics

German headword	English translation
Absolute Temperatur	Absolute temperature
Absoluter Nullpunkt	Absolute zero
Adiabate	Adiabatic curve
Ausdehnungskoeffizient	Thermal expansion coefficient
Avogadrosches Gesetz	Avogadro's hypothesis
Carnotscher Kreisprozess	Carnot cycle
Clausius-Clapeyron-Gleichung	Clausius-Clapeyron equation
Dampf	Vapor
Dampfdruck	Vapor pressure
Druck	Pressure
Enthalpie	Enthalpy
Entropie	Entropy
Gibbs-Energie	Gibbs energy
Gibbssche Phasenregel	Phase rule
Hessscher Satz	Hess law
Isobare	Isobar
Isotherme	Isotherm
Kalorimetrie	Calorimetry
Kompressibilität	Compressibility
Kritischer Punkt	Critical point
Normalbedingungen	Standard conditions
Partialdruck	Partial pressure
Phasendiagramm	Phase diagram
Reaktionsenthalpie	Reaction enthalpy
Schmelzwärme	Heat of fusion
Spezifische Wärmekapazität	Specific heat (capacity)
Tripelpunkt	Triple point
Verdampfungswärme	Heat of vaporization
Volumenarbeit	Pressure-volume work
Wärme	Heat

try curriculum, well covered in textbooks, highly formalized and comes with a rich – and often confusing – terminology. Our study had several objectives. As a didactic measure, we set up the assessment as a written assignment during the thermodynamics course. We expected from this that students would actively apply and learn the subject matter and become better prepared for the exam by reading other sources in addition to the lecture manuscript and the recommended textbooks.[10,11] By providing the students with different assessment criteria, we hoped that they would learn to critically judge the quality of reference works and improve their information literacy. Furthermore, we expected to obtain recommendations for use of the chemistry encyclopedias as instructional materials in chemistry lectures and courses in chemical information. Also, we wanted to know to what extent the two encyclopedias are able to support the learning process and fulfill the requirements of being an introductory source. Students and experts may look at scientific texts in a different way: Which criteria do chemistry students regard as relevant to assess the quality and utility of an encyclopedia article? Finally, we wanted to learn from the students, which target groups the encyclopedia articles are suited for.

Only a few papers[12–14] or projects[15] exist that actively promote teaching with Wikipedia and other online encyclopedias, which shows that instructors are still reluctant about the use of these new media. We hope that by our contribution we can encourage other instructors to develop ideas on how to incorporate online encyclopedias in the classroom.

Römpp Online and Wikipedia

The Römpp Chemielexikon was founded in 1947 by chemistry teacher Hermann Römpp and is now published by Thieme. The 10th and last print edition dates 1996–1999 and covers six volumes on chemistry and five additional volumes on biochemistry and molecular biology, paints and printing inks, food chemistry, natural products, and environmental science. It is considered the standard reference work in German-speaking university chemistry libraries.[16,17] The eleven volumes were converted in 2002 to the Web-based encyclopedia Römpp Online,[18] which is updated semi-annually. The online version can only be accessed on the basis of an institutional subscription. Articles are authored by about 180 paid experts from academia, industry and the government in their respective fields. Authorship is credited in the article header if the author agrees. An editorial board consisting of 20 editors and the Römpp editorial office propose new encyclopedia entries and are also responsible for quality assurance. As of November 2007, Römpp Online contained about 57'000 headwords, of which 39% were redirects.[9]

The universal encyclopedia Wikipedia, founded 2001 by Jimmy Wales and funded by donations, is now the largest encyclopedia worldwide with more than 15 million articles, created by the collaborative work of about 91'000 active contributors in more than 270 languages (as of January 2010).[19] The German Wikipedia[20] with about 1.04 million articles is the second largest after the English edition. There is no editorial board or office as with Römpp. However, registered users who publish many articles may advance to members with higher administrative rights. For the German Wikipedia, a chemistry panel[21] of about 30 members who develop guidelines and style rules for chemistry articles[22] has been formed. Half of its members are chemistry enthusiasts, the other half are professional chemists including master students, PhD students, PhDs and even a professor of chemistry. As of November 2007, the German Wikipedia covered about 29'000 headwords in the field of chemistry, of which 42% were redirects.[9]

Method

Comparison of German Wikipedia and Römpp Online was carried out as one of twelve written assignments of the second semester thermodynamics course at ETH Zürich. This course is attended by students of chemistry, chemical engineering, and molecular biology. Participation in this survey was non-mandatory, since only ten of the written assignments had to be completed to obtain the credit points. The survey was handed out as one of the last assignments in the semester, so that it was safe to assume that the students already had acquired firm knowledge to respond in a competent manner. For the comparison, a Web-based survey form was installed. The survey form was available for a four-week period (23.4.–17.5.2009). Thirty lemmas (see Table 1) of thermodynamics topics taught in the lecture were available for rating. These were selected from a database-generated list of lemmas[9] in physical chemistry covered by both encyclopedias. After a student had selected a headword from the list, links to the correspond-

ing encyclopedia articles were presented. Students had to rate at least three lemmas from both encyclopedias (or six articles), but were free to select the topics from the list. This indicated to us which topics were preferred by the students. To check who completed the survey, the student had to submit his/her student ID.

The survey contained four criteria to be rated with regard to content and four criteria with regard to the form of the articles. The same criteria were used as in the survey of experts carried out in 2008.[9] Criteria with regard to content were *accuracy*, *completeness*, *length*, and *comprehensibility*. Two additional text fields allowed comments on mistakes and omissions in the selected article. Criteria with regard to form were availability and quality of literature *sources* the article is based on, references for *further reading*, *links* to external websites, and *images and graphics*, respectively. For these criteria, it was possible to assign a mark only after one had checked a tick mark to indicate that corresponding items exist in the article. In addition, an overall mark had to be attributed to the article. The available marks ranged from 1 (bad), 2 (insufficient), 3 (sufficient), 4 (good), to 5 (excellent). Finally, the survey asked the student to select one or more target groups that the article may be suited for. As target groups 'pupils of secondary school level 2', 'students', 'PhD students', 'PhDs and experts', and 'general public' could be chosen from a list. For each of the eight criteria and the target group, an additional text field allowed comments on the rating or the selection.

To stimulate the students' interest and commitment for the assignment, a 15 minute kick-off session was held during a lecture, giving more background and information on the purpose of the survey. The final results and the evaluation of the survey were then presented during the final lecture of the thermodynamics course.

Results

215 students registered for the thermodynamics course, so that in theory 1290 ratings could be expected. Of these, 99 students (46%) contributed 619 ratings (310 for Römpp Online and 309 for Wikipedia), which corresponds to a feedback rate of 48%. 91 students (42%) submitted five or more ratings. One diligent student even contributed as many as 11 ratings.

The favorite headwords were 'Absoluter Nullpunkt', rated 42 times for Römpp and 38 times for Wikipedia, followed by 'Absolute Temperatur', rated 19 times for Römpp and 20 times for Wikipedia, and 'Gibbs-Energie', rated 18 times for both encyclopedias. The most unpopular head-

Table 2. Average marks *m* for Römpp Online and Wikipedia, calculated by averaging the criterion marks over all articles, number *b* of articles that were rated better[a], and standard deviation *s*. Mark scale ranging from 1 (bad) to 5 (excellent). The superior values of *m* and *b* are indicated by bold printing.

Criterion	Römpp Online			Wikipedia		
	m	*b*	*s*	*m*	*b*	*s*
Accuracy	**4.44**	**16**	0.78	4.34	8	0.72
Completeness	3.43	6	1.14	**4.17**	**22**	0.82
Length	2.99	4	1.22	**3.91**	**24**	0.96
Comprehensibility	3.80	5	1.04	**4.29**	**22**	0.73
Sources	**3.64**	**14**	0.93	3.42	10	1.12
Further reading	3.56	9	1.01	**3.90**	**16**	0.88
Web links	3.22	3	1.01	**4.01**	**24**	0.91
Images and graphics	3.15	2	1.10	**3.96**	**25**	1.05
Average of criteria marks[b]	3.61	4	1.14	**4.07**	**21**	0.91
Average overall mark[c]	3.23	6	0.96	**3.95**	**23**	0.79

[a]Counted as better if the absolute value of the difference between marks was greater than 0.1, otherwise counted as equivalent; [b]Calculated as arithmetic mean over the marks for all criteria except the overall mark; [c]Average over overall marks supplied by students

words were 'Spezifische Wärmekapazität', rated twice, along with 'Kalorimetrie' and 'Avogadrosches Gesetz', which were both rated only once.

Table 2 compares the average marks of the eight criteria used for rating of the articles. Overall, Wikipedia obtained better marks than Römpp Online, with the exception of the criteria *accuracy* and *sources*. This trend is also reflected in the number of articles that were rated better in one encyclopedia compared to the other. For all criteria, the average mark over all headwords was at least 'sufficient' (3 or greater) for both encyclopedias.

Fig. 1 and Fig. 2 compare the average overall marks attributed to the individual articles of both encyclopedias. In Fig. 1, the headwords on the abscissa are sorted by decreasing average overall mark of the Römpp Online articles and in Fig. 2 of the Wikipedia articles, respectively. The average overall marks for Römpp Online articles are lower than the ones for the Wikipedia articles, ranging from 1.7 to 4.1 compared to 2.0–4.7, respectively. For 23 headwords (77%), the Wikipedia articles obtained a higher mark than the corresponding Römpp Online articles. One lemma was ranked equally, and six Römpp Online articles were ranked better than the corresponding Wikipedia article. Seven articles in Römpp Online and two articles in Wikipedia obtained an insufficient average overall mark (below 3).

For Römpp Online, the top three overall marks were given to articles 'Druck' (average mark 4.10, 10 ratings), 'Gibbssche Phasenregel' (4.08, 12 ratings), and 'Kalorimetrie' (4, 1 rating). Articles with the worst overall marks were 'Gibbs-En-

ergie' (2.17, 18 ratings), 'Reaktionsenthalpie' (2.00, 5 ratings), and 'Ausdehnungskoeffizient' (1.71, 7 ratings). The three worst-rated articles contained – at the time when the survey was carried out – only the minimum information by stating the definition of the respective quantity in one or two sentences only, which was criticized in the submitted comments. For Wikipedia, the three articles 'Verdampfungswärme' (4.67, 3 ratings), 'Normalbedingungen' (4.64, 11 ratings), and 'Ausdehnungskoeffizient' (4.57, 7 ratings) were ranked best, whereas 'Isotherme' (3.38, 16 ratings), 'Isobare' (2.71, 14 ratings), and 'Kalorimetrie' (2, 1 rating) obtained the lowest overall marks. While the article 'Isotherme' was rated as sufficient and also obtained favorable comments, 'Isobare' obtained insufficient marks with regard to *completeness*, *length*, and *sources*. In the comments to 'Isobare', the students often criticized that the article referred to meteorology rather than to thermodynamics; seven comments mentioned omissions such as heat and entropy change associated with an isobaric process which are described in the corresponding Römpp Online article. The single rating on article 'Kalorimetrie' gave insufficient marks (2) for *length* and *sources*, but a mark 3 for *accuracy* and *comprehensibility*. In the comment, the student mentioned that the topic was "not well explained at all".

To check whether the overall marks reflect the impression the participants gained from their rating of the individual criteria, we calculated an average from all marks that were attributed to the criteria. The deviation between the averaged marks over criteria and the students' overall marks,
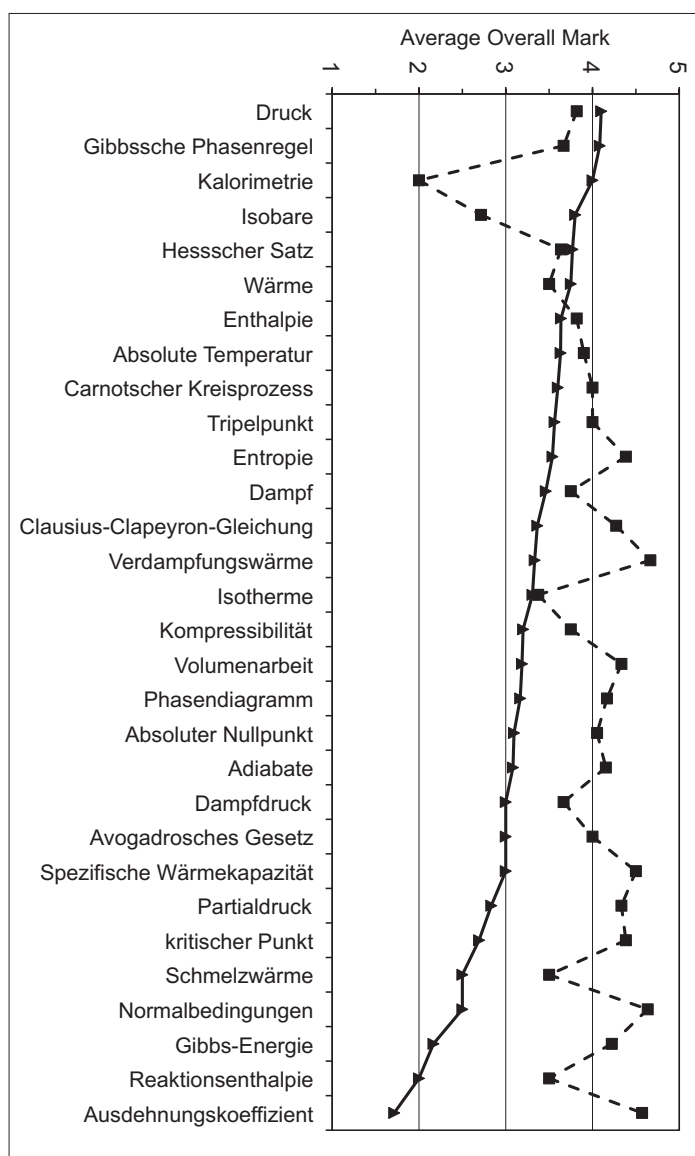
Fig. 1. Average overall marks given for individual headwords, sorted by decreasing value for articles in Römpp Online. Continuous line with triangles: Römpp Online, dashed line with squares: Wikipedia. Mark scale ranging from 1 (bad) to 5 (excellent).
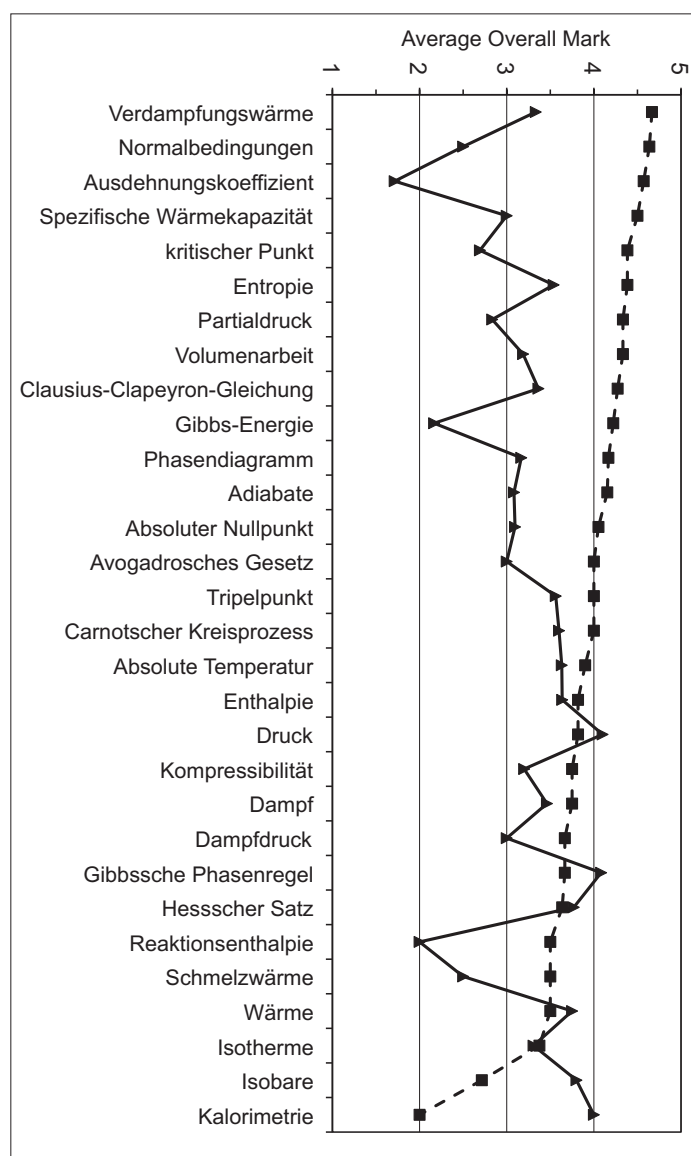

Fig. 2. Average overall marks given for individual headwords, sorted by decreasing values for articles in Wikipedia. Continuous line with triangles: Römpp Online, dashed line with squares: Wikipedia. Mark scale ranging from 1 (bad) to 5 (excellent).

both listed in Table 2, is small. The latter are only slightly lower by 0.38 for Römpp Online and 0.12 for Wikipedia. Average marks over criteria and overall marks for individual articles correlate well for both encyclopedias. For Römpp, the correlation coefficient is 0.77 and for Wikipedia 0.76, which indicates that the chosen criteria were relevant and other, unconsidered parameters such as *style* or *conciseness* would not have a significant influence on the overall assessment.

Table 3 displays correlation coefficients between ratings of different criteria with regard to content. There is only one strong correlation, namely between *length* and *completeness* for Römpp Online (0.70), which will be discussed below.

For both encyclopedias we wanted to find out to what extent the marks of the eight criteria enter into the overall mark. We assume that an overall mark o_j of a rating j can be described by the linear equation

$$\sum_{i=1}^{8} w_i c_{ij} - o_j = 0 \qquad (1)$$

with w_i = weight and c_{ij} = jth mark for criterion i, o_j = overall mark, and i running over all criteria. Since 310 ratings were obtained for Römpp Online articles and 309 ratings for Wikipedia articles, the system of linear equations is overdetermined, but optimum weights can be found by minimizing the sum of the squares

Table 3. Correlation coefficients between marks regarding content criteria.

	Completeness		Length		Comprehensibility	
	Römpp	Wikipedia	Römpp	Wikipedia	Römpp	Wikipedia
Accuracy	0.26	0.50	0.14	0.34	0.28	0.42
Completeness			0.70	0.48	0.16	0.32
Length					0.22	0.31

$$R = \sum_{j=1}^{n} \left(\sum_{i=1}^{8} w_i c_{ij} - o_j \right)^2 \qquad (2)$$

for the *n* rated articles of the respective encyclopedia. The optimization was carried out with the Microsoft Office Excel add-on Solver which uses the generalized reduced gradient algorithm. For different sets of initial guess values for w_i, always the same optimized values resulted after each run. The weights found for Römpp Online and Wikipedia (values in brackets) were 0.42 (0.36) for *completeness*, 0.24 (0.24) for *length*, 0.14 (0.10) for *comprehensibility*, 0.07 (0.19) for *accuracy*, 0.05 (0.06) for *sources*, 0.05 (0.03) for *images and graphics*, 0.03 (0.04) for *further reading*, and 0.00 (0.01) for *links*. Note that the weights are not normed – in the case of Wikipedia they add up to 1.03 – since the only boundary condition applied in the optimization was $w_i \geq 0$. The *R* value for Römpp Online is 86, for Wikipedia 67.9.

Fig. 3 shows the distribution of target groups for which the survey participants indicated articles are suited for. Note, since multiple selections per rated article were possible, the sum of the percentages exceeds 100%. Both encyclopedias were rated adequate for students as target group (Römpp 73%, Wikipedia 91%), with Römpp Online catering more to the expert and Wikipedia more to the general public.

Table 4 lists the participation of students in the survey and in the course exam, as well as the number of students who passed the exam. Of the 215 students who registered to the course, 181 (84%) took the exam. 86 of these (47.5%) passed the exam. Of the 84 students who took the exam and also completed the survey, 35 (42%) passed and 49 failed (58%). On the other side, 51 (53%) students of the 97 who did not participate in the survey passed the exam, but 46 (47%) failed. Given that the off-diagonal numbers (51 passed/not completed and 49 failed/completed) are larger than the diagonal values (35 passed/completed and 46 failed/not completed), one has to conclude that participation in the survey did not have any effect on success in the exam. This finding is also supported by the small, negative correlation coefficient of –0.11.

Discussion

The relationship between participation in the survey and success in the exam may come as a surprise. The main reason for this result is that the exam questions were not designed to test the knowledge which was imparted by the encyclopedia articles – definitions, examples, applications – but were problem solving questions only.
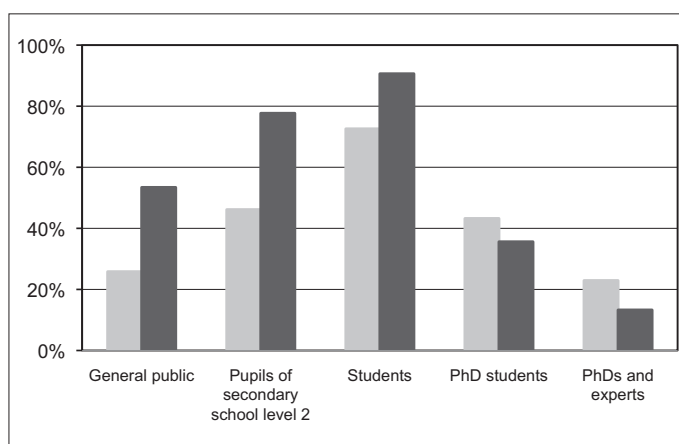

Fig. 3. Distribution of target groups named by students for encyclopedia articles. Multiple selections were allowed. Light bars: Römpp Online, dark bars: Wikipedia.

Table 4. Student participation in survey and exam. Values indicate number of students.

Survey	Exam			Total
	passed	failed	not adhered	
completed	35	49	7	91
not completed	51	46	27	124
Total	86	95	34	215

Therefore, one should have in mind to prepare one or two knowledge requests in case of a possible repetition of this survey in another discipline. One has to note also that this assignment was one among eleven other written assignments which covered problem solving questions and therefore were made to prepare for the exam.

The largest Wikipedia-Römpp differences between the marks in Table 2 can be found for the criteria *length* (0.92), *images and graphics* (0.81), *Web links* (0.79), and *completeness* (0.74). However, according to the results of our fit of weights described above, students attribute little significance to formal criteria such as *images and graphics* and *web links*, but high importance to the content criteria *completeness* and *length*. This is especially true for Römpp Online, for which we find that marks regarding *completeness* and *length* are correlated significantly. That *length* and *completeness* of the articles were key parameters for the students can also be seen from the number of comments they had submitted with their ratings. For Römpp Online, 142 (46%) comments on *length* were obtained. Two thirds (94) of these mentioned that the article was "too short" or consisted of "only one sentence", but only five (4%) said that it was too long. This trend is also reflected in the number of comments on *omissions*, for which 110 (35%) comments were returned for Römpp Online and only 38 (12%) for Wikipedia, but less so in the number of comments on *completeness* (89 Römpp versus 70 Wikipedia). Otherwise, Wikipedia articles ob-

tained 119 (39%) comments on *length*, of which 48 (40%) stated that the article was "too long" or "too elaborate", whereas only 17 (14%) comments mentioned that it was too short. Overall, the large number of comments indicates that the students took the written assignment seriously; also they expressed strong interest in the results presented by us in the last lecture.

Both encyclopedias obtained very good average marks for the *accuracy* of their articles. The difference between them is very small (0.10), which is also supported by the fact that only a few mistakes were reported, namely 15 factual errors for Römpp Online versus 18 for Wikipedia. If one adds also the factual errors reported in the comments for *accuracy*, one finds 25 factual errors for Römpp Online and 26 for Wikipedia (or for both in 8% of the ratings).

We found that some students were not familiar with the concepts *sources*, *further reading*, *weblinks*, *images and graphics*, since we observed for several articles that for example existence of *images and graphics* was checked with a tickmark, although there were none in the original article. Apparently, some took the mathematical formulas in the articles for graphics. Also, it was not clear to students how to treat *web links*, since internal links to other encyclopedia articles were counted as well as links to external webpages, although we had expected that only the latter should be counted. Similarly, the meaning of *sources* and *further reading* was intermingled. Therefore, we counted the existence of an item only if it was ticked by at least half

of the participants in their ratings. For the 30 articles, we found about equal use of *sources* (17 versus 19 as indicated by students) and *further reading* (both 16) in both Wikipedia and Römpp Online, but much higher use of *web links* (21 versus 4) and *images and graphics* (20 versus 5) in Wikipedia than in Römpp Online.

This is obviously related to the fact that, unlike Römpp Online, Wikipedia was designed as a Web medium from the very beginning. Römpp, as a former print medium, had to be considerate on space and therefore works with the minimum of graphical materials. This view is also supported by the results of Sonnenstuhl,[9] whereas, contrary to the results for the thermodynamic article set, she found for a set of 171 articles in 15 chemistry disciplines that Römpp Online cites more *sources* and *further reading* than Wikipedia.

The distribution of target groups in Fig. 3 shows its maximum for the target group of students, for which both Wikipedia and Römpp Online are suited. In fact, it was difficult for the participants to estimate from their level of experience what knowledge PhD students, PhDs and experts had acquired and would require and what type of encyclopedia content would therefore be adequate for those target groups. Hence, only the statements on the target groups general public, pupils and students are significant, whereas the higher suitability of Römpp Online for PhD students, PhDs and experts must be interpreted in the manner that students estimate the articles of Römpp Online as more complex and less comprehensible than those of Wikipedia.

Conclusions

In the eyes of first-year university students, both encyclopedias obtained very good ratings regarding their accuracy. However, in the overall rating, Römpp Online became victim of its terse and concise scientific writing style, because in their learning process, students attach importance rather to completeness and comprehensibility than to exactness and accuracy. Neither Römpp nor Wikipedia were originally designed with the student in mind and to support teaching and learning. The open concept of Wikipedia attracted with time authors such as chemistry students and professional chemists who like to impart their knowledge to others. Both encyclopedias are now written by peers for peers, Wikipedia mostly by non-experts for students, scholars, and the general public, Römpp Online by experts for experts.

Wikipedia articles are easier to understand because their content and language is more textbook-like.

In our chemical information courses for bachelor students, we promote Römpp Online and other commercial encyclopedias as an entrance to quickly obtain an overview, relevant sources and further literature. In many chemistry disciplines, Römpp Online does well for that purpose. However, to be more attractive to students, articles should be written with more focus on didactics.

Given the survey results, it is remarkable that students do not pay more attention to number, type and quality of sources cited in encyclopedia articles, and have a fuzzy understanding of their importance to support and validate the statements made. This is especially important in the case of Wikipedia where anyone can edit articles. Frequent use of Wikipedia articles by students is a fact; students do trust this information. Based on the findings of the present and the previous[9] assessment, both Wikipedia and Römpp Online can be recommended as a starting reference. However, chemistry lecturers, lab course assistants and chemical information instructors should insist that students do not stop at encyclopedia texts, but use and cite the primary literature and secondary references (handbooks, databases) in their reports, so that students become acquainted with the system of peer-reviewed chemistry literature as early as possible.

Supplementary material

The master evaluation, the detailed evaluations and comments made by students on the individual encyclopedia articles can be obtained on request from the corresponding author.

[1] R. Rosenzweig, *J. Am. Hist.* **2006**, *93*, 117; http://www.historycooperative.org/journals/jah/93.1/rosenzweig.html (28.3.2010).

[2] B. Luyt, T. C. H. Aaron, L. H. Thian, C. K. Hong, *J. Am. Soc. Inf. Sci. Technol.* **2008**, *59*, 318; doi: 10.1002/asi.20755

[3] a) J. Giles, *Nature* **2005**, *438(7070)*, 900; doi: 10.1038/438900a; b) Links to Britannica's objections, Nature's responses to Encyclopedia Britannica and supplementary material available on http://www.nature.com/nature/britannica/index.html (28.3.2010).

[4] C. Schlieker, 'Wissen auf wikipedia.org: Explorative Untersuchung von Wissen in kollektiven Hypertexten', Version 1.01, Diplomarbeit, Univ. Bremen, **2005**; http://www-user.uni-bremen.de/~chrof/wissen_auf_wikipedia.pdf (7.4.2010).

[5] a) R. Hammwöhner, K.-P. Fuchs, M. Kattenbeck, C. Sax, in 'Open Innovation', Ed. A. Osswald, M. Stempfhuber, C. Wolff, Proc. 10. Internationales Symposium für Informationswissenschaft, Konstanz, **2007**; b) R. Hammwöhner, in 'Wikis: Diskurse, Theorie und Anwendungen', Ed. C. Stegbauer, J. Schmidt, K. Schönberger, kommunikation@ gesellschaft **2007**, *8*, Beitrag 3; http://www.soz.uni-frankfurt.de/K.G/B3_2007_Hammwoehner.pdf (7.4.2010).

[6] H. Güntheroth, U. Schönert, *Stern: das deutsche Magazin* **2007**, *50*, 31; http://www.stern.de/digital/online/wikipedia-wissen-fuer-alle-606048.html (28.3.2010).

[7] L. H. Rector, *Ref. Serv. Rev.* **2008**, *36*, 7; doi: 10.1108/00907320810851998

[8] K. A. Clauson, H. H. Polen, M. N. Kamel Boulos, J. H. Dzenowagis, *Ann. Pharmacother.* **2008**, *42*, 1814; doi: 10.1345/aph.1L474

[9] J. Sonnenstuhl, 'Römpp Online versus Wikipedia: ein formaler und inhaltlicher Vergleich zwischen einer lizenzpflichtigen und einer freien Online-Enzyklopädie', Magister Thesis, Humboldt University, Berlin, **2008**.

[10] P. W. Atkins, J. de Paula, 'Physikalische Chemie', 4. Aufl., Wiley-VCH, Weinheim, **2006**.

[11] K. Denbigh, 'The Principles of Chemical Equilibrium: With Applications in Chemistry and Chemical Engineering', 4th ed., Cambridge University Press, Cambridge, **1981**.

[12] P. Konieczny, *Int. J. Instructional Technol. Distance Learn.* **2007**, *4*, 15; http://www.itdl.org/Journal/Jan_07/article02.htm (26.3.**2010**).

[13] D. Murley, *Law Libr. J.* **2008**, *100*, 593; http://www.aallnet.org/products/pub_llj_v100n03/2008-29.pdf (27.3.**2010**).

[14] K. Wannemacher, in 'Advances in Web Based Learning – ICWL 2009', Ed. M. Spaniol, Q. Li, R. Klamma, R. W. H. Lau, *Lect. Notes Comput. Sci.* **2009**, *5686*, 434; doi: 10.1007/978-3-642-03426-8_52

[15] Wikipedia, Wikipedia:School and university projects, http://en.wikipedia.org/wiki/Wikipedia: SUP (7.4.**2010**).

[16] M. Mücke, 'Die Chemische Literatur: Ihre Erschliessung und Benutzung', Verlag Chemie, Weinheim, **1982**.

[17] R. Keese, 'Grundoperationen der präparativen organischen Chemie: Eine Einführung', 6. Aufl., Univ. Bern, **2003**.

[18] Thieme Chemistry – Römpp, http://www.roempp.com/ (25.3.2010).

[19] Wikipedia, Help:About, http://en.wikipedia.org/wiki/Help:About (29.3.2010).

[20] Wikipedia – Die freie Enzyklopädie, http://de.wikipedia.org/ (1.4.2010).

[21] Wikipedia, Wikipedia:Redaktion Chemie, http://de.wikipedia.org/wiki/Wikipedia:Redaktion_Chemie (25.3.2010).

[22] Wikipedia, Wikipedia:Richtlinien Chemie, http://de.wikipedia.org/wiki/Wikipedia:Richtlinien_Chemie (25.3.2010).