Improving Science Education and Understanding through Editing Wikipedia

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> The public issues which preoccupy the political life of America today ... involv[e] the realms of information and ideas which are unfamiliar and unknown to the vast majority of the American people. Clearly, if the citizens of our country are to govern themselves wisely, and participate effectively in public discussion and decision, they must acquire a better understanding of science.
> Gerard Piel, 1953 *(1)*

The increasing impact of science and technology on daily life necessitates a general understanding of their fundamental principles. Internet accessibility and use has led to a greater ability to easily share information and can potentially improve the communication of science to the general public. Because most graduate curricula do not include training for future scientists on how to communicate advanced concepts to a general audience successfully, we have designed a graduate class project with that goal using Wikipedia.org, the free online encyclopedia that anyone can edit.

Wikipedia is a highly visible and open platform on the Internet for communicating information to both general and technical audiences. Founded in 2001, Wikipedia is now the seventh most-accessed site on the Internet *(2)*, containing over 3 million articles in English, with entries available in 270 languages. A recent study comparing science articles in Wikipedia and *Encyclopædia Britannica* showed that the examined content was similarly accurate *(3, 4)*. The format of Wikipedia is designed so that anyone can create or edit an entry with minimal instruction and entries can be readily interconnected through links. Furthermore, the edits for each entry are tracked, providing a history of all changes.

This paper describes a class project that enables students to explore advanced concepts in chemistry and learn how to communicate science to a diverse audience by collaboratively editing an entry in Wikipedia.org *(5)*. This project has been implemented in two different graduate-level chemistry courses at the University of Michigan: (i) In Fall 2008 and 2009, the project was used in Organic Principles (Chem 540), a graduate course focusing on physical organic chemistry; and (ii) In Winter 2009, the project was used in Macromolecules (Chem 538), a graduate course on the synthesis and properties of organic polymers.

Project Structure

The structure of the project over one semester included these milestones:

- *Week 1:* Students were divided into groups of two or three and assigned a group login name and password so that individual edits could be easily recognized and compiled.
- *Week 3:* Each student group submitted three potential topics that were related to the course material and were not already adequately described in Wikipedia. The students were asked to identify the strengths and weaknesses of current entries and propose changes and additions. The graduate student instructor and professor selected the final topic from each list. Topics were selected primarily based on their perceived importance and relevance to chemistry. Highest priority was given to those topics that had either no or minimal information on Wikipedia before the project. For example, in Fall 2009, several groups identified "strain" as an important concept in organic chemistry that had limited content on Wikipedia. Indeed, "strain" influences both a molecule's stability and reactivity, and thus, it was selected as a suitable topic for editing.
- *Week 5:* An outline of the group's proposed entry text was submitted for review and feedback.
- *Week 7:* An in-class demonstration on how to edit Wikipedia was presented. Students were provided with a handout highlighting (a) the important editing functions and examples of their use, and (b) instructions on how to create simple, yet high-quality artwork. (This handout is included in the online supporting information.)
- *Week 10:* Students submitted their proposed entry using the "sandbox" feature of Wikipedia. The students obtained feedback on the writing style, format, and the original figures. For example, each figure was evaluated in terms of the quality of the image and the extent to which it clarified and enhanced the key concepts of the entry. Students were then allowed to upload their entry to the main Wikipedia Web site.
- *Week 14:* The groups presented their final entry to the class, comparing the entry before and after the changes were made, showing relevance of the topic to the course, and suggesting future additions.

Project Assessment

Assessment was based on completing the assigned criteria within a group's entry, and the quality of the in-class presentation. The assigned criteria follow:

- A minimum of eight references must be added.
- A minimum of three sections must be added, including an introductory paragraph aimed at the general public.
- A minimum of three original figures or schemes that enhance explanations of the topic must be added.
- Hyperlinks must be included to the project's entry from other related entries, as well as links to related topics within the project's entry.

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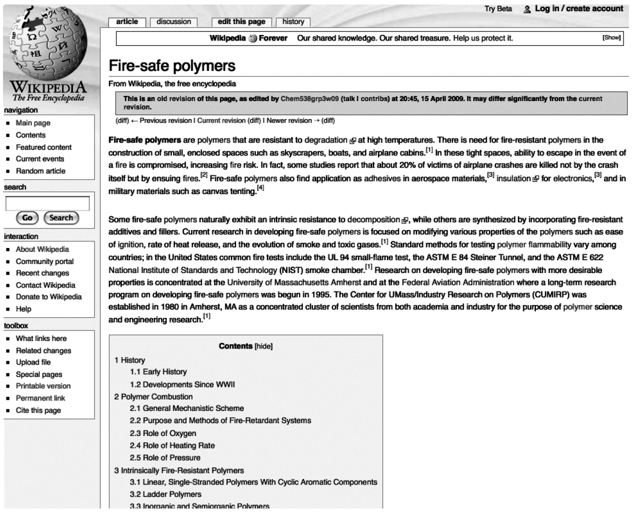
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Fire-safe polymers

From Wikipedia, the free encyclopedia

This is an old revision of this page, as edited by Chem538grp3w09 (talk I contribs) at 20:45, 15 April 2009. It may differ significantly from the current revision.

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Fire-safe polymers are polymers that are resistant to degradation at high temperatures. There is need for fire-resistant polymers in the construction of small, enclosed spaces such as skyscrapers, boats, and airplane cabins.[1] In these tight spaces, ability to escape in the event of a fire is compromised, increasing fire risk. In fact, some studies report that about 20% of victims of airplane crashes are killed not by the crash itself but by ensuing fires.[2] Fire-safe polymers also find application as adhesives in aerospace materials,[3] insulation for electronics,[3] and in military materials such as canvas tenting.[4]

Some fire-safe polymers naturally exhibit an intrinsic resistance to decomposition, while others are synthesized by incorporating fire-resistant additives and fillers. Current research in developing fire-safe polymers is focused on modifying various properties of the polymers such as ease of ignition, rate of heat release, and the evolution of smoke and toxic gases.[1] Standard methods for testing polymer flammability vary among countries; in the United States common fire tests include the UL 94 small-flame test, the ASTM E 84 Steiner Tunnel, and the ASTM E 622 National Institute of Standards and Technology (NIST) smoke chamber.[1] Research on developing fire-safe polymers with more desirable properties is concentrated at the University of Massachusetts Amherst and at the Federal Aviation Administration where a long-term research program on developing fire-safe polymers was begun in 1995. The Center for UMass/Industry Research on Polymers (CUMIRP) was established in 1980 in Amherst, MA as a concentrated cluster of scientists from both academia and industry for the purpose of polymer science and engineering research.[1]

Contents [hide]

1 History
1.1 Early History
1.2 Developments Since WWII
2 Polymer Combustion
2.1 General Mechanistic Scheme
2.2 Purpose and Methods of Fire-Retardant Systems
2.3 Role of Oxygen
2.4 Role of Heating Rate
2.5 Role of Pressure
3 Intrinsically Fire-Resistant Polymers
3.1 Linear, Single-Stranded Polymers With Cyclic Aromatic Components
3.2 Ladder Polymers
3.3 Inorganic and Semiorganic Polymers

Figure 1. Students in the Winter 2009 Chem 538 course created this new Wikipedia entry on fire-safe polymers *(6b)*. This version, posted in April 2009, is no longer the current version because other Wikipedians have since contributed to this entry. (The full version of this figure is provided in the online supporting information.).

The history of each entry is kept indefinitely; therefore, it was easy to assess the student group contributions to the page even when others in the Wikipedia community subsequently made changes. (The assigned group login names facilitated tracking these changes.) A partial screenshot of one of the newly created Wikipedia pages is provided in Figure 1. The full Wikipedia page is provided in the online supporting information.

Evaluation of the Project

The students were generally very excited to do the project and were motivated by the visibility of their efforts. On the basis of open-response written feedback at the conclusion of the project in Fall 2008, the students reported that they had gained a greater understanding of their topic and had learned how to communicate advanced concepts in science to the general public. Members of the public, and certainly the readership of this *Journal*, are welcome to examine the students' work *(6)*. The students were asked to list the benefits of doing this project; some representative responses follow:

- "Teaches us how to present theories in a manner that people who don't have prior knowledge can understand it."
- "It was good having the scientific responsibility to create/fix a Web site in which millions of people can access."
- "It encourages collaborative learning and betters the quality of scientific information available to the public."
- "Learned in depth about a particular topic in physical organic chemistry and to explore this topic for applications that I found most interesting."
- "It helped improve Wikipedia!"

In Fall 2009, a retrospective survey using student panels was implemented to evaluate whether the Wikipedia project significantly contributed to the learning objectives of the course, namely:

1. Learning advanced concepts in chemistry
2. Communicating science to a diverse and general audience
3. Identifying appropriate references and other resources for building an argument
4. Working collaboratively
5. Understanding how a well-researched explanation is constructed

We identified seven learning resources for the course: classroom lecture, the textbook, problem sets, literature papers, Wikipedia, working alone, working in groups.

In order to put the Wikipedia project in context, we implemented a survey that asked students two questions about all seven of the resources as they applied to the five learning goals. The questions and statements that students were asked to respond to were:

A. The [*first*] learning goal for Chem 540 was to [*explore and learn advanced concepts in chemistry*]. To what degree do you think that each of the following resources contributed to this goal?
B. Now, rank these seven according to their significance in getting you to [*explore and learn advanced concepts in chemistry*].

For Question A, respondents used a 7-point scale to rate how the resource contributed to achieving the goal, from 7−1 in which 7 indicated "extremely", 4 indicated "neutral", and 1 indicated "not at all". For Question B, respondents ranked each of the seven resources using a 7-point scale, from 1−7, in which 1 indicated "most significant", and 7 indicated "least significant", with no ties allowed. Note that the scale in Question B was inverted from Question A to intentionally differentiate the rating question from the ranking question. A copy of the survey is provided in the online supporting information.

We used student panels rather than individual student responses. Using student panels that discuss and come to consensus is the recommended strategy to overcome the intrinsic unreliability of retrospective self-assessment of learning gains *(7)*. The 30 Chem 540 students were divided into six panels, each with five students. The panels worked on their responses for an average of 45 min. Responses were anonymous. These results were compiled and analyzed by one of us (B.P.C.) who was external to the class after the grades were assigned and submitted.

The primary purpose of Question B, which asked for an absolute ranking of the usefulness of the resources, was to check the reliability of the responses to Question A. The inverted numerical scales make it particularly difficult for respondents to simply translate the rating responses from Question A to the rankings of Question B. We plotted the average score given by the panels across the range of resources with respect to each learning goal, predicting that the higher the rating score that a resource received from Question A, the more significant its ranking should be from Question B. We carried out a least-squares regression on the data from each of the five learning goals and observed r^2 correlation coefficients of 0.91−0.96, from which we conclude that the ratings given to Question A are highly reliable.

To evaluate whether or not a given resource was being deemed by the students to contribute significantly to the learning goal, intraresource comparisons are not useful. We wished to understand how far from "neutral" the students were rating the contribution of a resource to their learning for any given instructional goal. Consequently, the ratings for each resource were compared for their statistical difference from a hypothetical

Table 1. Average Scores of Ratings on the Contribution of Class Resources for Each Class Goal[a]

Resource	Learning Objectives and Ratings: Average Scores (*p*-Values)				
	1. Learn Advanced Concepts	2. Communicate Science to a General Audience	3. Identify Resources for Building an Argument	4. Work Collaboratively	5. Construct Well-Researched Explanations
Lecture	**6.33** (0.000)	4.83 (0.318)	**5.67** (0.000)	2.17 (0.012)	**6.67** (0.000)
Textbook	4.17 (0.599)	3.67 (0.651)	4.00 (1.000)	**1.33** (0.000)	3.83 (0.828)
Problem sets	**6.00** (0.000)	4.33 (0.145)	4.50 (0.270)	*5.33* (0.003)	**5.50** (0.000)
Literature papers	4.33 (0.515)	3.33 (0.373)	**5.67** (0.000)	2.67 (0.038)	**6.17** (0.000)
Wikipedia	3.33 (0.207)	**5.83** (0.000)	**6.50** (0.000)	**6.00** (0.000)	4.67 (0.304)
Working alone	**6.17** (0.000)	3.83 (0.845)	2.83 (0.128)	**1.33** (0.000)	3.67 (0.628)
Working in groups	*5.33* (0.003)	5.33 (0.038)	3.17 (0.318)	*5.50* (0.006)	3.83 (0.734)

[a] Scale for average scores ranges from 7, indicating the resource contributed "extremely" to meeting course goals, to 1, indicating the resource contributed "not at all" to meeting course goals. The reported *p*-values (statistical significance) were obtained relative to a purely neutral rating. Bold type indicates scores for which $p \leq 0.0005$; italics indicate scores in which $0.001 < p < 0.01$.

response set of all 4's (i.e., perfectly neutral), using a two-tailed type-2 *t*-test. Table 1 provides the results of this analysis, expressed as the average rating from the six student panels along with the *p*-value derived from comparing the student data set with the hypothetical response set.

We have used relatively conservative criteria to evaluate our results. We deemed $p \leq 0.0005$ as a statistical threshold for resources that the students report to contribute most significantly to their learning of a particular goal; *p*-values between 0.001 and 0.01 as marginally significant; and values of $p \geq 0.01$ as insignificant. The validity of the student responses is reflected, we believe, in their responses to the learning goal of "working collaboratively". The Wikipedia project was deemed to be the most useful, working on problem sets and studying with others were deemed useful, and using the textbook and studying alone were not useful.

Although interesting results emerge throughout Table 1, of particular interest to this paper is how students evaluated the Wikipedia project compared with other classroom resources in achieving the course learning goals. The Wikipedia project was the only resource with a significant contribution to "communicating science to a diverse and general audience", and it was the most significant resource for "identifying appropriate references and other resources for building an argument" and "working collaboratively". While no resource should or can carry the entire burden for the learning goals of any class, we do note that the Wikipedia project received the best ratings out of the seven resources (this project contributed significantly to three of the five learning goals, all with the highest resource score), just above the lecture, which also contributed to three of the five learning goals, with two out of three receiving the highest resource score.

Finally, we contacted a specialist in writing and rhetoric, Anne Gere, who holds joint appointments in the University of Michigan Department of English Language and Literature and the School of Education, and directs the Sweetland Writing Center, to comment on the writing and accessibility of the edited Wikipedia entries *(8)*. Gere compared three representative Wikipedia articles before and after the student editing had occurred. She concluded that the revisions were much more engaging to general readers because of the revisions' attention to real-world uses of substances (such as polymers) and clear explanations of the multiple forms of molecular strain. In addition, the inclusion of historical contexts and strategic use of graphic representations made the information accessible for nonspecialists.

Further Thoughts and Discussion

This project provides students with both the opportunity and platform to communicate advanced topics in science to the general public. One observation we made was that students appeared to assess the material they added to the chosen entry more critically compared to when they were simply studying for the class, perhaps because of the visible nature of Wikipedia. In general, this observation is consistent with Coleman's notion of students' developing a higher level of explanatory knowledge when they are explicitly aware of the need to engage in teaching *(9)*. Although Coleman studied direct instruction, it is reasonable to think that editing a Wikipedia entry carries a comparable, if not higher, awareness about a future teaching event while learning is taking place.

While implementing this project, we became aware of several aspects of the Wikipedia platform that should be specifically discussed with the students:

- Wikipedia has articulated style guidelines *(10)*; students should be given information on these at the start of the project to facilitate their planning of the Wikipedia entry.
- Students need to create their own figures and use a free license when uploading *(11)*.
- The references should come from a broad range of sources, not solely the primary scientific literature. In addition, if applicable, the digital object identifier (DOI) number should be included.
- Group accounts are not formally allowed in Wikipedia. However, the guidelines state that "If a rule prevents you from improving or maintaining Wikipedia, ignore it" *(12)*. Therefore, we created group accounts only for this project and terminated them at the conclusion of the project.
- A group of frequent contributors to the WikiProject Chemistry *(13)* seeks to improve the quality of chemistry-related articles on Wikipedia *(14)*. We found it helpful to correspond with these expert Wikipedians during the class project. There is also a WikiProject for educators to discuss how they are incorporating Wikipedia into their classrooms *(15)*.

We created a handbook entitled *Editing Wikipedia as a Class Project* to facilitate incorporation of this project into other courses at our institution and beyond. This handbook provides detailed and streamlined instructions for both the instructor and the students and is included in the online supporting information.

Planned modifications to the graduate course project include incorporating a peer-review component: the students will be asked to first identify the evaluation criteria and then apply those criteria to evaluate their peer's outlines and sandbox entries. The project's structure is flexible and a simpler version can also be adapted for undergraduate courses.

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Supporting Information Available

Panel survey; full version of Figure 1; handbook, Editing Wikipedia as a Class Project. This material is available via the Internet at http://pubs.acs.org.

