Editing Wikipedia as a Strategy to Promote Learning

Anne McNeil (associate professor)

Literature, Science and Arts, Chemistry

Origin of the innovation:
In 2008, I began developing a class project that tasks students with editing science content on Wikipedia to (i) enhance student learning and understanding of the course material, (ii) build collaborative skills, and (iii) improve the quality and quantity of scientific information available to the public. This project is a modern adaptation of the traditional student-generated "literature review" that has been utilized in education for decades, with the added benefit that the collated information is now accessible to a much broader audience.

Wikipedia is a highly visible platform for communicating science to both general and technical audiences, and is now the sixth most accessed site on the Internet, containing nearly 4 million articles in English. The impact of this project was expected to be broad considering that an average of 14% of global Internet users visit Wikipedia each day. Wikipedia has become a trustworthy first source of information for both the general public and scientists. Because anyone can create or edit a Wikipedia entry with minimal instruction and the edits for each entry are tracked, it is an ideal platform both for students to contribute new content and for faculty to evaluate their contributions.

This project was first implemented in a graduate-level course I taught on Physical Organic Chemistry (CHEM 540) in Fall 2008. One of the challenges of this course is that the enrollment includes students from a number of different PhD programs. One benefit of this project is that the students can explore a particular course concept in more detail and relate it to their field of study. Briefly, the students worked in groups of two or three and were asked to select a topic related to the course that was inadequately covered on Wikipedia and modify (or create) the site. The groups were assigned and each group consisted of members from different PhD programs. Throughout the semester the students submitted an outline and draft website for peer review. Peer review is an effective strategy for engaging students in the analysis of their scientific writing and it has been demonstrated to provide students with valuable insights about their own work. The culmination of the project involved posting the revised sites online, which included: (i) new references, (ii) three new sections, including a general, introductory paragraph for non-scientists, (iii) three new, original figures that enhance explanations of the topic, and (iv) hyperlinks to/from their entry to other related entries.

Scalability of the innovation:
Over the next five years, I continued to revise the project based on open-response feedback from the students. The website: http://www.umich.edu/~ajmlab/wiki.html contains a comprehensive list of all the Wikipedia sites revised by my students in these courses. Throughout this time there have been minor changes to the project framework and major changes in the support network. These changes in support have greatly improved its accessibility to other instructors and enabled its implementation in a wide range of courses across campus (see impact section). To understand the change in support, some context about a parallel movement that was occurring at the national level with using Wikipedia in classroom. In 2008, the Wikimedia Foundation became aware of my project and asked me to advise them on how to help implement similar projects at other universities. From these discussions emerged the Wikipedia Ambassador Program and the Wikipedia Education Program.

The central goal of the Wikipedia Ambassador Program is to have local, experienced Wikipedia editors on each campus to support the instructional goals of the faculty. At U-Michigan, Ye Li (Science

Librarian) volunteered to get trained as a Wikipedia Ambassador. Ye has developed a 45 min in-class presentation that not only trains students on how to edit Wikipedia, but also covers the nuances of copyright infringement, uploading original figures, identifying a diverse list of resources, and following community etiquette. Ye also holds office hours throughout the term so that students can get their Wikipedia-related questions answered as they arise. She monitors the student progress and provides comments on their draft sites. At the end of the term, Ye returns to class to help the students "move" their new content onto the live Wikipedia site. Ye has become an invaluable resource for this project and has enabled many other instructors across campus to easily incorporate this project (see impact section). The Wikipedia Education Program is a massive online community that actively supports the incorporation of Wikipedia editing in the classroom setting. It is primarily a web interface that facilitates communication between the faculty and students in the course and with the broader Wikipedia community. The Wikipedia Education Program also houses a vast series of instructional videos and handouts on how to incorporate Wikipedia in the classroom (including some from my courses).

Impact of the innovation:
Through both informal discussions and public seminars by Ye and myself, this project gained the attention of other faculty at UM and has resulted in several other courses adopting it. For example, I presented a CRLT Seminar (Fall 2010) and at the Provost's Seminar on Teaching (Fall 2012). Within the Chemistry department, the following courses have used Wikipedia editing: CHEM 511 (Fall 2009/2010/2011/2012, Prof. Banaszak Holl and Prof. Laine), CHEM 507 (Fall 2009/2010/2013, Profs. Bartlett, Szymczak and Pecoraro), CHEM 505 (Fall 2012/2013, Prof. Walter), and CHEM 528 (Winter 2013/2014, Prof. Fierke). Across campus, other faculty have worked with either Ye or myself, including: AMCULT 204 (Spring 2012, Prof. Kelderman), ASTRO 533 (Fall 2010, Prof. Bell), ENVIRON 320 (Fall 2012/Winter 2013, Prof. Askari), ENVIRON 367 (Fall 2011/2013, Prof. Xu), MATSCI 440 (Winter 2014, Prof. Laine), SI 110 (Winter 2014, Prof. MacKie-Mason), and SW 697 (Winter 2013/Winter 2014, Prof. Patton).

To more broadly disseminate this project idea, we published a manuscript describing its implementation in the Journal of Chemical Education in 2010. My project was highlighted as a "case study" on the Wikipedia Global Education Program website and all of my course materials are freely available through this website. In 2011, my graduate student presented some of this work at the International Wikimania Conference in Haifa, Israel. Since then, I have been contacted by faculty from across the globe, soliciting advice and feedback on how to implement related projects.

There is a broader impact of this project that extends well beyond the classroom setting and the individual student's learning process. Sixty science-based Wikipedia sites have been edited (or created) by the students in my courses. The sheer amount of scientific information that is now freely accessible to anyone with an Internet connection is simply astounding. As a representative example, if search "physical organic chemistry" in Google, the first hit is Wikipedia. This Wikipedia site was substantially edited last term as part of my CHEM 540 course. We proactively promoted the new content by nominating this site for the "Did You Know" feature on the front page of Wikipedia. During the four hour window that it was highlighted on the front page, it garnered over 1300 hits. It now averages somewhere between 40-60 hits/day. Since early December, over 5,900 people have viewed the site. It is statistics like these that motivate the students (and myself) to be involved in this project.

Relevant Teaching Materials:

and

Evidence of Impact on Student Learning:

follow

Editing Wikipedia as a Strategy to Promote Learning

Supporting Materials for the
Provost's Teaching Innovation Prize

Anne J. McNeil
Associate Professor of Chemistry
and Macromolecular Science and Engineering Program

Contents

Course Materials Given to Students

Chem 538 Syllabus Winter 2014

Organic Chemistry of Macromolecules

Prof Anne McNeil
2817 Chemistry
ajmcneil@umich.edu
Office Hr: Mon 10–11 am (or by appt)

Amy Bondy
Science Learning Center
albondy@umich.edu
Office Hr: Wed 12–1 pm (or by appt)

Class: MWF; 11 am–12 pm in 1210.

Text: *Polymers: Chemistry and Physics of Modern Materials* by J.M.G. Cowie, 3rd edition

Supplemental: *Principles of Polymerization* by Odian, 4th edition
Polymer Chemistry by Stevens, 3rd edition
Original research papers on the CTools site

Requirements: Your grade will be based on a midterm, five problem sets, two projects, and a final.

Grading:

Midterm (Mon. February 24, 2014; 7–9 pm; TBD)	26.6% of final grade (200 pts)
Final (Wed. April 30, 2014; 4–6 pm; Rm 1210)	33.3% of final grade (250 pts)

Grading System: The exams will be graded using the 0-5-10 system. For example, if a question is worth 10 points, you can get a 0, 5, or 10. *We round to the closest number*.

Problem Sets: Problem sets (5) will be graded *based on effort* with an S (20 pts) or U (0 pts). It is your responsibility to check the answer key to check the accuracy of your answers. These problems are representative of ones you will see on the exams. 13.3% of final grade (100 pts).

Wikipedia Project: You will work in groups to create or edit a polymer-focused Wikipedia site. The final Wikipedia site is due March 14. More details will come. 13.3% of final grade (100 pts).

Proposal Project: You will write an independent research proposal regarding the synthesis of a new polymer for a specific application. The final proposal is due April 25. More details will come. 13.3% of final grade (100 pts).

Course Outline: The course will cover chapters 1-7, 9 and 16 of your textbook.

Refresher: If it has been awhile since you have taken an organic chemistry course, you should refresh your memory of the standard functional groups and their reactivity. In addition, you should be able to draw an arrow-pushing mechanism for these basic transformations: S_N1, S_N2, transesterifications, amide formation, alcohol additions to isocyanates, acid/ester condensations, free radical reactions with alkenes, electrophilic additions to alkenes, alkene and alkyne metathesis reactions, cross-coupling reactions.

WIKIPEDIA PROJECT - DESCRIPTION

Overview: You and your partner will either create or substantially improve a Wikipedia site on a specific polymer, class of polymers or famous polymer chemist.

Why: Wikipedia is written for the general public, so you will gain practice communicating advanced topics to a non-specialized audience. It will enable you to gain a deeper understanding (than what can be done in lecture) of polymeric materials. You will gain skills in critically analyzing the literature. You will gain experience in working collaboratively with other people. The broader impact of your efforts is enormous!

Groups: You will select your partner from the class!

Peer Review: Each of you will be individually assigned another group to peer review. You will be graded on the quality of your peer review

Grading: The Wiki site will be graded on three aspects:

(a) Content: A minimum of 4 sections must be added to the site, including an introductory paragraph aimed at the general public. The quality of the added content will be evaluated.

(b) Figures: A minimum of 4 original figures and/or schemes must be added to the site. Again, the quality will be evaluated.

(c) *References*: A minimum of 10 references must be added to the site. The quality and appropriateness of these references will be evaluated. Note that references should come from all sources, including textbooks, primary literature, review articles, etc.

WIKIPEDIA PROJECT – TIMELINE

Jan 10	In-class discussion of project; teams assembled
Jan 17	List of two potential topics is due
Jan 22	Topics will be assigned to each group
Jan 24	In-class editing tutorial by Ye Li (Chemistry Librarian)
Feb 14	Sandbox version of site due
Feb 26	Peer review of sandbox version due
Mar 14	Wikipedia sites go live and are graded!

WIKIPEDIA PROJECT – GRADING

Sandbox version – 20 pts

Peer review – 20 pts

Wikipedia site (with response to reviewers) – 60 pts

(Note: Missing any deadline is an automatic 5 pt deduction.)

WIKIPEDIA PROJECT – PEER REVIEW

Read the current Wikipedia site on the topic (if there is one).

Read at least one review or reference article related to the topic.

Consider each of the following general questions and write a response in paragraph form.

Content

- Is the introductory section accessible for non-experts?
- Do the contents of each section justify its length?
- Are all the important terms/concepts linked to their respective Wikipedia pages for further reference?
- Are the highlighted examples appropriate?
- Is the content duplicative of any other content already on Wikipedia?

Figures

- Are the figures original and of high quality?
- Are the figures informative and add to the text?
- Are the Chemdraw structures chemically accurate, aligned, and easy to read?

References

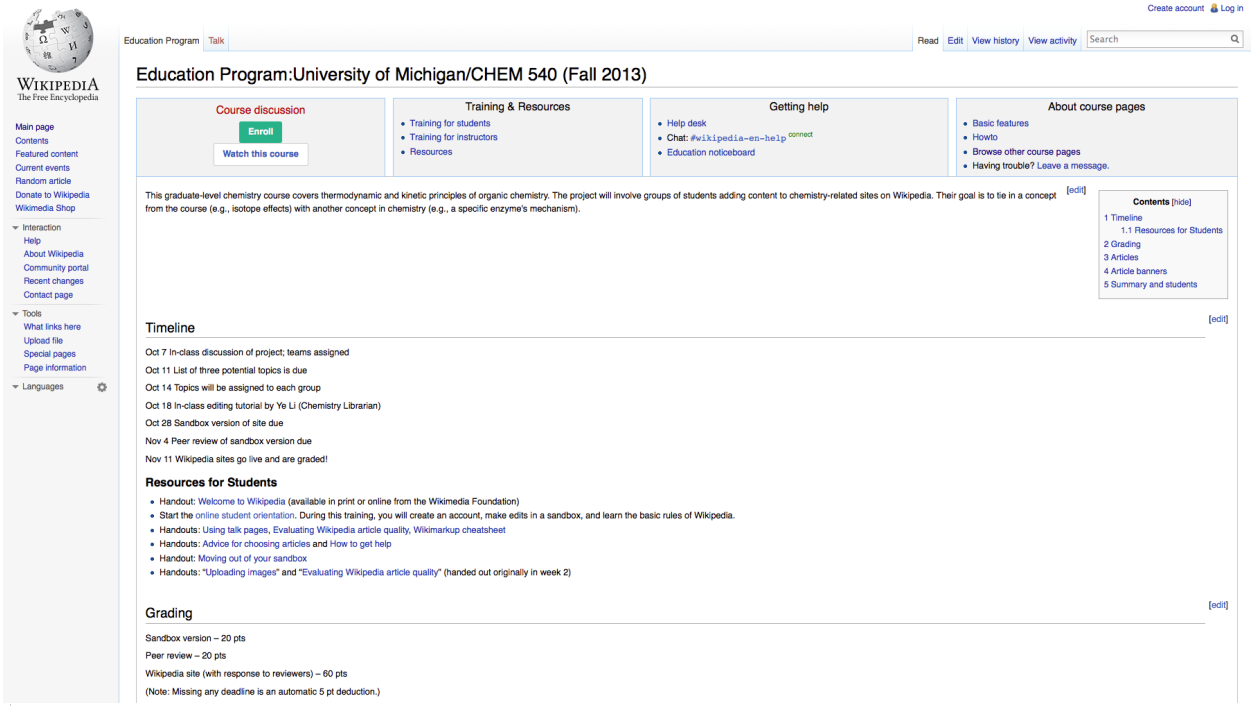
- Are the references complete (≥ 10)?
- Are the references inclusive of non-journal sources?

Overall Presentation

- Provide a short summary of the entire content/figures/references, highlighting both what the group did well and well as what still needs to be improved.

Snapshots of a Course Page on the Wikipedia Education Program Site

https://en.wikipedia.org/wiki/Education_Program:University_of_Michigan/CHEM_540_%28Fall_2013%29



Education Program:University of Michigan/CHEM 540 (Fall 2013)

Course discussion — Enroll — Watch this course

Training & Resources
- Training for students
- Training for instructors
- Resources

Getting help
- Help desk
- Chat: #wikipedia-en-help connect
- Education noticeboard

About course pages
- Basic features
- Howto
- Browse other course pages
- Having trouble? Leave a message.

This graduate-level chemistry course covers thermodynamic and kinetic principles of organic chemistry. The project will involve groups of students adding content to chemistry-related sites on Wikipedia. Their goal is to tie in a concept from the course (e.g., isotope effects) with another concept in chemistry (e.g., a specific enzyme's mechanism).

Contents [hide]
1 Timeline
1.1 Resources for Students
2 Grading
3 Articles
4 Article banners
5 Summary and students

Timeline

Oct 7 In-class discussion of project; teams assigned
Oct 11 List of three potential topics is due
Oct 14 Topics will be assigned to each group
Oct 18 In-class editing tutorial by Ye Li (Chemistry Librarian)
Oct 28 Sandbox version of site due
Nov 4 Peer review of sandbox version due
Nov 11 Wikipedia sites go live and are graded!

Resources for Students

- Handout: Welcome to Wikipedia (available in print or online from the Wikimedia Foundation)
- Start the online student orientation. During this training, you will create an account, make edits in a sandbox, and learn the basic rules of Wikipedia.
- Handouts: Using talk pages, Evaluating Wikipedia article quality, Wikimarkup cheatsheet
- Handouts: Advice for choosing articles and How to get help
- Handout: Moving out of your sandbox
- Handouts: "Uploading images" and "Evaluating Wikipedia article quality" (handed out originally in week 2)

Grading

Sandbox version – 20 pts
Peer review – 20 pts
Wikipedia site (with response to reviewers) – 60 pts
(Note: Missing any deadline is an automatic 5 pt deduction.)

Articles

This table will list the articles which the students will be working on. Please input the topic you selected to edit and sign your username (3~) next to your topic. And create a link to the Sandbox where you draft your article. If a page already exist in Wikipedia on the topic you are working on, please post a link in the Current page column. Otherwise, write N/A there.

Topic	Current page	Students	Sandbox	Reviewers	Starting page (Before editing)	After editing
Example: Strain	Strain (chemistry)	ChemLibrarian (talk)	Sandbox for Strain	UMChemProfessor (talk)	Strain(chemistry) (Before editing)	Strain(chemistry) (After editing)
Water-gas shift reaction	Water-gas shift reaction	Zwickipedia (talk) ajc540 (talk)	Sandbox for Water-gas shift	Physorg 2013 (talk) GoBlue18 (talk)	Water-gas shift reaction (Before editing)	Water-gas shift reaction (After editing)
Suzuki reaction	Suzuki reaction	Educatefreechemistry (talk) Organic_Chemist_19 (talk)	Sandbox for Suzuki reaction	ajc540 (Talk) AviMole602 (Talk)	Suzuki reaction (Before editing)	Suzuki reaction(after editing)
Synergistic catalysis	Synergistic catalysis	Tiraxxis (talk) Tayrochemie (talk)	Sandbox for Synergistic Catalysis	Biomedchemist (talk) Zwickipedia (talk)	Synergistic Catalysis (Before Edit)	Synergistic Catalysis (After Edit)
Van 't Hoff equation	Van 't Hoff equation	Sjsteiner77 (talk) CarboJoule (talk)	Sandbox for Van't Hoff equation	Mr.Holmium(talk) Educatefreechemistry (talk)	Van 't Hoff equation (Before editing)	Van 't Hoff equation (After editing)
Transition state analog	Transition state analog	Kschemumich13 (talk) Trcum (talk)	Sandbox for Transition state analog	Organic_Chemist_19 (talk) UMMedChemStudent (talk)	Transition State analog (Before editing)	Transition State analog (After editing)
Captodative effect	Captodative effect	dgsinUM (talk) genger14 (talk)	Sandbox for Captodative effect Sandbox for Captodative Effect (Intro and Kinetics)	Tiraxxis (talk) Chemumich (talk)	(Before editing)	Captodative effect (after editing)
Energy profile (chemistry)	Energy profile (chemistry)	AimNature (talk) Charco0917 (talk)	Sandbox for Energy Profile	Tayrochemie (talk) DGH91 (talk)	Energy Profile (Before editing)	Energy Profile (After editing)
Hydroamination	Hydroamination	Yvonnedep (talk) 5402013SD (talk)	Sandbox for Hydroamination	CarboJoule (talk) RLM0518 (talk)	Hydroamination(Before editing)	Hydroamination (After editing)
Antiaromaticity	Antiaromaticity	P org 2013 (talk) Physorg 2013 (talk)	Sandbox for Antiaromaticity	Sjsteiner77 (talk) Terbium4 (talk)	Antiaromaticity(Before Editing)	Antiaromaticity (After Editing)
Noncovalent bonding	Noncovalent bonding	AviMole602 (talk) GoBlue18 (talk)	Sandbox for Non-covalent Interactions	Trcum (talk) Bisoxo (talk)	Noncovalent bonding (Before Editing)	Non-covalent interactions (After Editing)
Foldamer	Foldamer	Terbidium(talk) Biomedchemist (talk)	Sandbox for Foldamer	Paracelsus22 (talk) Kschemumich13 (talk)	Foldamer (Before Editing)	Foldamer (After Editing)
Physical organic chemistry	Physical organic chemistry	RLM0518 (talk) Bisoxo (talk)	Sandbox for Physical Organic Chemistry	Physchem 13 (talk) genger14 (talk)	Phys. Org. Chem. (Before editing)	Phys. Org. Chem. (After Editing)
E1cB-elimination reaction	E1cB-elimination reaction	Physchem 13 (talk) Paracelsus22 (talk)	Sandbox for E1cB-elimination reaction	dgsinUM(talk) mechem13(talk)	(Before Edits)	(After Edits)
Borylation	Borylation	Iridium (talk) Ybs.Umich (talk)	Sandbox for Borylation	Charco0917 (talk) physorgchem13 (talk)	(Before Edits)	(Final page)
Atropisomer	Atropisomer	Mechem13 (talk) Chemumich (talk)	Sandbox for Atropisomer	AimNature (talk) kmk982013 (talk)	(Before Editing)	Atropisomer (Final page)
Conformational isomerism	Conformational isomerism	Mr.Holmium (talk) UMMedChemStudent (talk)	Conformational Analysis Sandbox	yvonnedep (talk) Ybs.Umich (talk)	Conformational Isomerism (Before Editing)	Conformational Isomerism (After editing)
Anomeric effect	Anomeric effect	Physorgchem13 (talk) Kmk982013 (talk) DGH91 (talk)	Sandbox for anomeric effect	5402013SD (talk) p_org_2013 (talk) Iridium (talk)	[anomeric effect (previous page)]	[anomeric effect (current page)]

Article banners

To mark each article the subject of a student project, add the {{course assignment}} template at the top of the talk page for each article: {{ course assignment | course = Education Program:University of Michigan/CHEM 540 (Fall 2013) | term = Fall 2013 }} That will result in the following banner (which lets other editors know that you're working on it):

This article is/was the subject of an educational assignment in Fall 2013. Further details are available **on the course page**.

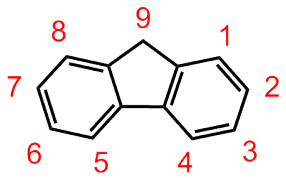
Summary and students

Summary	[collapse]
Institution	University of Michigan
Term	Fall
Start	7 October 2013
End	11 November 2013
Student count	32
Status	Ended
Instructors	• UMChemProfessor (talk I contribs I sandboxes)
Online volunteers	• Graeme Bartlett (talk I contribs I sandboxes) • JMathewson (WMF) (talk I contribs I sandboxes)
Campus volunteers	• ChemLibrarian (talk I contribs I sandboxes)

Representative Example of Student Work
(For a comprehensive list, see: http://www.umich.edu/~ajmlab/wiki.html)

"Polyfluorene" Wikipedia page **BEFORE** student editing.
(http://en.wikipedia.org/w/index.php?title=Polyfluorene&oldid=408917333)

Polyfluorene

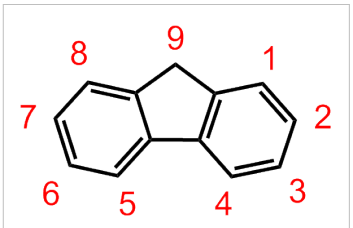
Polyfluorene	
	
Identifiers	
CAS number	95270-88-5 [1]
Properties	
Molecular formula	$(C_{13}H_{10})_x$
Except where noted otherwise, data are given for materials in their standard state (at 25 °C (77 °F), 100 kPa)	
Infobox references	

Polyfluorene (PFO) is a polymer that emits light by electroluminescence.

The building block of the polymer is the fluorene unit. Polyfluorenes are electroactive and photoactive materials with exceptional electrooptical characteristics which are used for the production of light-emitting diodes. Polyfluorenes can emit colors over the whole visible range.

The first blue light emitting polymer diode was produced with a substituted polyfluorene (poly(9,9-dihexylfluorene)).

An interesting use of Polyfluorene, together with lasers, provides a valuable explosives detection technology. Please see http://news.bbc.co.uk/1/hi/science_and_environment/10257425.stm for details.



For polyfluorene the fluorene molecules are connected at the 2 and 7 positions

References

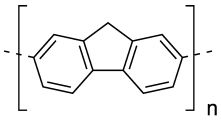
[1] http://www.commonchemistry.org/ChemicalDetail.aspx?ref=95270-88-5

- Bernius MT, Inbasekaran M, O'Brien J (2000). "Progress with Light-Emitting Polymers". *Advanced Materials* **12** (23): 1737–1750. doi: 10.1002/1521-4095(200012)12:23<1737::AID-ADMA1737>3.0.CO;2-N (http://dx.doi.org/10.1002/1521-4095(200012)12:23<1737::AID-ADMA1737>3.0.CO;2-N).
- Andrew C. Grimsdale and Klaus Müllen (2006). "Polyphenylene-type emissive materials: Poly(para-phenylene)s, polyfluorenes, and ladder polymers". *Emissive Materials Nanomaterials* **199**: 1–82. doi: 10.1007/11611967 (http://dx.doi.org/10.1007/11611967).
- D. Y. Kim, H. N. Cho and C. Y. Kim (2000). "Blue light emitting polymers". *Progress in Polymer Science* **25** (8): 1089–1139. doi: 10.1016/S0079-6700(00)00034-4 (http://dx.doi.org/10.1016/S0079-6700(00)00034-4).

"Polyfluorene" Wikipedia page **AFTER** student editing.
(http://en.wikipedia.org/w/index.php?title=Polyfluorene&oldid=423537166)

*Note: For some reason the full reference list and some images are not printing to the PDF – please see actual page for the best depiction of the student's work.

Polyfluorene

Polyfluorene	
	
Identifiers	
CAS number	95270-88-5 [1] ✓
Properties	
Molecular formula	$(C_{13}H_8)_n$
Molar mass	Variable
✓ (verify) [2] (what is: ✓/✗?) Except where noted otherwise, data are given for materials in their standard state (at 25 °C (77 °F), 100 kPa)	
Infobox references	

Polyfluorenes are an important class of polymeric materials. They are relevant to both academic and industrial research because of their optical and electrical properties. Furthermore they are a prototypical conjugated polymer which can be used to discuss property tuning; polyfluorenes are the only class of conjugated polymers which can be tuned to emit light throughout the entire visible region. They are not a naturally occurring material, but rather, they are designed and synthesized for their applications. Modern chemistry has enabled adaptable synthesis and control over polyfluorenes, which has facilitated use in many organic electronic applications. Polyfluorenes are primarily interesting because of the optoelectronic properties imbued by their chromophoric constituents and their extended conjugation. The design of polyfluorene derivatives relies on the character and properties of their monomers. Thus, the discovery and development of these polymeric repeat units has had a profound influence on the development of polyfluorenes.

Fluorene-based polymers are of great interest to industrial researchers because of their ability to act as electro and photoactive materials. As with many conjugated polymers, researchers have always been interested in using polyfluorenes in light-emitting diodes, field-effect transistors (FET), and plastic solar cells. As stated previously polyfluorenes gave high photoluminescence quantum yields, this along with their excellent solubility and the ability to control their properties by substituting different groups at the 9,9 position of the fluorene monomer has motivated researchers to use polyfluorenes as blue light emitters in polymer light-emitting diodes.

History of polyfluorenes

Fluorene, a principal repeat unit in polyfluorene derivatives, was isolated from coal tar and discovered by Marcellin Berthelot prior to 1883. So-named due to its interesting fluorescence, fluorene became the subject of chemical-structure related color variation (visible rather than luminescent), among other things, throughout the early to mid-20th century. Since it was an interesting chromophore researchers wanted to understand which parts of the molecule were chemically reactive, and how substituting these sites influenced the color. For instance, by adding various electron donating or electron accepting moieties to fluorene, and by reacting with bases, researchers were able to change the color of the molecule.

The physical properties of the fluorene molecule were recognizably desirable for polymers; as early as the 1970s researchers began incorporating this moiety into polymers. For instance, because of fluorene's rigid, planar shape a

polymer containing fluorene was shown to exhibit enhanced thermo-mechanical stability. Perhaps more interesting, however, was the promise of integrating the optoelectronic properties of fluorene into a polymer. Reports of the oxidative polymerization of fluorene (into a fully conjugated form) exist from at least 1972. However, it was not until after the highly publicized high conductivity of doped polyacetylene, presented in 1977 by Heeger, MacDiarmid and Shirakawa, that substantial interest in the electronic properties of conjugated polymers was aroused.

As interest in conducting plastics grew, fluorene again found application. The aromatic nature of fluorene makes it an excellent candidate component of a conducting polymer because it can stabilize and conduct a charge; in the early 1980s fluorene was electropolymerized into conjugated polymer films with conductivities of 10^{-4} S cm^{-1}. Additionally, the optical properties (such as variable luminescence and visible light absorption) that accompany the extended conjugation in polymers of fluorene have become increasingly attractive for device applications. Throughout the 1990s and into the 2000s, many devices such as OLEDs, organic solar cells., organic thin film transistors, and biosensors have all taken advantage of the luminescent, electronic and absorptive properties of polyfluorenes.

Properties of polyfluorenes

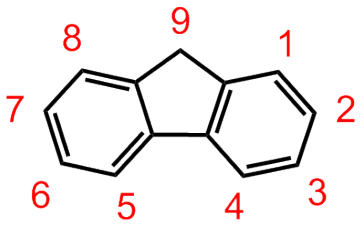


Figure 1. The fluorene molecule is most commonly linked at the 2 and 7 positions in polyfluorene derivatives. Also, the 9 position is typically where side chains are attached.

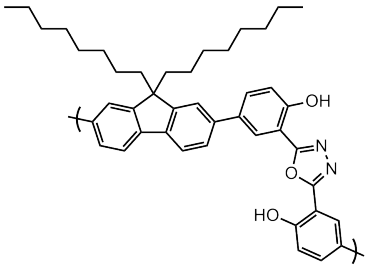


Figure 3. This polyfluorene derivative has a structure similar to that in Figure 6, except that the alcohol side chains can participate in ESIPT with the neighboring oxadiazole nitrogens causing a red-shifted emission. The meta-linkages in the backbone impart solubility in lieu of multiple side chains.

Polyfluorenes encompass an important class of polymers which have the potential to act as both electroactive and photoactive materials. This is partly due to the shape of fluorene. Fluorene is mostly planar; p-orbital overlap at the linkage between its two benzene rings results in conjugation across the molecule. This in turn allows for a reduced band gap due to the delocalized excited state molecular orbitals. Furthermore, since the degree of delocalization and the spatial location of the orbitals on the molecule is influenced by the electron donating (or withdrawing) character of its substituents, the band gap energy can be varied. This chemical control over the band gap directly dictates the color of the molecule by limiting the energies of light which it absorbs.

Interest in polyfluorene derivatives has increased because of their high photoluminescence quantum efficiency, high thermal stability, and also because of their facile color tunability, which can be obtained by introducing low-band-gap co-monomers. Research in this field has increased significantly due to potential application in organic light-emitting diodes (OLEDs). In this application, polyfluorenes are desirable because they are the only family of conjugated polymers that can emit colors spanning the entire visible range with high efficiency and low operating voltage. Furthermore, polyfluorenes are relatively soluble in most solvents, which makes them ideal for general applications.

Another important quality of polyfluorenes is their thermotropic liquid crystallinity which allows the polymers to be used on rubbed polyimide layers. Thermotropic liquid crystallinity refers to the polymers ability to exhibit a phase transition into the liquid

crystal phase as the temperature is changed. This is very important to the development of LCD's (liquid crystal display) because the synthesis of liquid crystal displays requires that the liquid-crystal molecules at the two glass surfaces of the cell be aligned parallel to the two polarizer foils. This can only be done by coating the inner-surfaces of the cell with a thin, transparent film of polyamide which is then rubbed with a velvet cloth. Microscopic grooves are then generated in the polyamide layer and the liquid crystal in contact with the polyamide, which is polyfluorene, can align in the rubbing direction. In addition to LCDs, polyfluorene can also be used to synthesize LEDs. By using polyfluorene, LEDs have been synthesized that can emit polarized light with polarization ratios of more than 20 and with brightness of 100 cd m^{-2}. Even though this is very impressive it is not sufficient for general applications.

Challenges associated with polyfluorenes

Researchers have encountered several issues with polyfluorenes which inhibit their use in many general applications. Polyfluorenes often show both excimer and aggregate formation upon thermal annealing or when current is passed through them. Excimer formation involves the generation of dimerized units of the polymer which emit light at lower energies than the polymer itself. This hinders the use of polyfluorenes for most applications, including light-emitting diodes (LED). When excimer or aggregate formation occurs this lowers the efficiency of the LEDs by decreasing the efficiency of charge carrier recombination. Excimer formation also causes a red shift in the emission spectrum.

In addition to excimer and aggregate formation, polyfluorenes can also undergo decomposition. There are two known ways in which decomposition can occur; the first involves the oxidation of the polymer which leads to the formation of an aromatic ketone. This carbonyl group that is formed quenches the fluorescence. The second process results in aggregation formation, which then leads to a red-shifted fluorescence and reduced intensity, be exciton migration and relaxation through excimers.

Researchers have attempted to eliminate excimer formation and enhance the efficiency of polyfluorenes by copolymerizing polyfluorene with anthracene and end-capping polyfluorenes with bulky groups which could sterically hinder excimer formation. Additionally, researchers have tried adding large substituents at the ninth position of the fluorine in order to inhibit excimer and aggregate formation. Furthermore, researchers have tried to improve LEDs by synthesizing fluorene-triarylamine copolymers and other multilayer devices that are based on polyfluorenes that can be cross-linked. These have been found to have high brightness and reasonable efficiencies.

Aggregation has also been combated through chemical structure variation. For example, when conjugated polymers aggregate (as they have a natural tendency to do in the solid state), their emission can be self-quenched, reducing luminescent quantum yields and reducing luminescent device performance. In opposition to this tendency, researchers have used tri-functional monomers to create highly branched polyfluorenes which resist aggregation due to their bulkiness. This design strategy has achieved luminescent quantum yields of 42% in the solid state. Unfortunately, this solution reduces the ease of processability of the material because branched polymers have increased chain entanglement.

Another problem commonly encountered by polyfluorenes is a commonly observed broad green, parasitic emission which detracts from the color purity and efficiency needed for an OLED. Initially attributed to excimer emission, this green emission has been shown to be due to the formation of ketone defects along the fluorene polymer backbone (oxidation of the 9 position on the monomer in Figure 1) at incompletely substituted 9 positions of the fluorene monomer. Routes to combat this involve ensuring full substitution of the monomer's active site, or including aromatic substituents. These solutions may present sub-optimal structures (in terms of bulkiness) or may be synthetically difficult.

Synthesis and design of polyfluorenes

One of the reasons that conjugated polymers, polyfluorene included, are such a versatile class of material is because of the variability of relevant properties that molecular design and synthesis afford. Polyfluorenes are designed and synthesized for their applications, usually requiring appropriate luminescent emission, appropriate absorption wavelengths and processability, among other properties. As mentioned above, the color of conjugated molecules can be designed through control over the electron donating or withdrawing character of the substituents on fluorene or similarly, of the comonomers in polyfluorene (as in Figure 4). Processability, on the other hand, is primarily the result of the solubility of the polymers because solution state processing is very common. Since conjugated polymers, with their planar structure, tend to aggregate bulky side chains are added (to the 9 position of fluorene) to prevent this and to instill solubility. With these concepts in mind, an understanding of the synthesis of polyfluorenes can be developed.

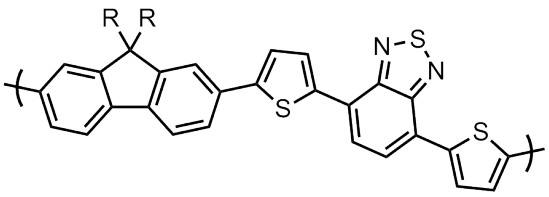


Figure 4. This is the structure of a common low band-gap polyflourene derivative. It has electron donating fluorene (left) and electron withdrawing benzothiadiazole (mid right between two thiophenes) monomers which allow for a reduced band gap due to charge transfer absorption.

Oxidative polymerization

The earliest polymerizations of fluorene were oxidative polymerization with $AlCl_3$ or $FeCl_3$, and more commonly electropolymerization. Electropolymerization is an easy route to obtain thin, insoluble conducting polymer films. Unfortunately it does not provide easy control over the site on the monomer from which chain growth occurs and since the polymer is insoluble, processing and characterization are difficult. Oxidative polymerization produces a similarly poor site-selectivity on the monomer for chain growth resulting in poor control over the regularity of the polymers structure, especially for asymmetric monomers. However, oxidative polymerization does produce soluble polymers (from side-chain containing monomers) which are more easily characterized with nuclear magnetic resonance (NMR).

Cross coupling polymerizations

The design of polymeric properties requires great control over the structure of the polymer. For instance, low band gap polymers require regularly alternating electron donating and electron accepting monomers (such as that in Figure 4 with fluorene on the left and benzothiadiazole on the mid-right). More recently, many popular cross-coupling chemistries have been applied to polyfluorenes and have enabled controlled polymerization; Palladium catalyzed cross couplings such as Suzuki coupling , Heck coupling , etc., as well as nickel catalyzed Yamamoto and Grignard coupling reactions have been applied to polymerization of fluorene derivatives. Such routes have enabled excellent control over the properties of polyfluorenes; the polymer in Figure 4, with a band gap of 1.78 eV when the side chains are alkoxy, appears blue because it is absorbing in the red wavelengths.

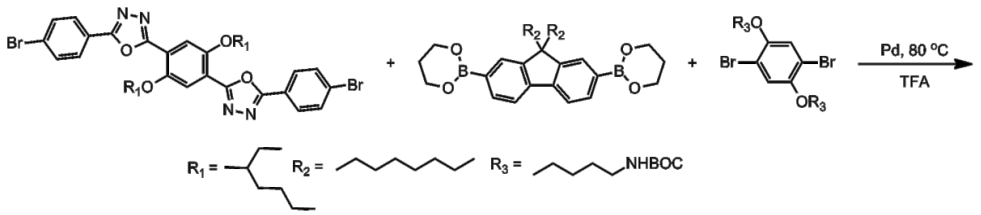


Figure 5. These are the monomers used to obtain the complex polyfluorene derivative in Figure 6. This Suzuki polymerization utilizes a palladium cross coupling between monomers with halogens and boronic esters.

Design of polyfluorenes

Modern coupling chemistries allow other properties of polyfluorenes to be controlled through implementation of complex molecular designs. For instance, using Suzuki coupling (Figure 5) the complicated polymer in Figure 6 was produced. It has excellent (94%, solution in chloroform) photoluminescent quantum yields, partly due to its fluorene monomer, excellent stability, due to its oxadiazole comonomer, good solubility, due to its many and branched alkyl side chains, and has an amine functionalized side chain for tethering to other molecules or to a substrate. The luminescent color of polyfluorenes can be changed, for example, (from blue to green-yellow in Figure 2) by adding functional groups which participate in excited state intramolecular proton transfer (ESIPT). Exchanging the alkoxy side chains for alcohol side groups (Figure 3) allows for energy dissipation (and a red-shift in emission) through reversible transfer of a proton from the alcohol to the nitrogen (on the oxadiazole). These complicated molecular structures were engineered to have these properties and were only able to be realized through careful control of their ordering and side group functionality through polymerization chemistry.

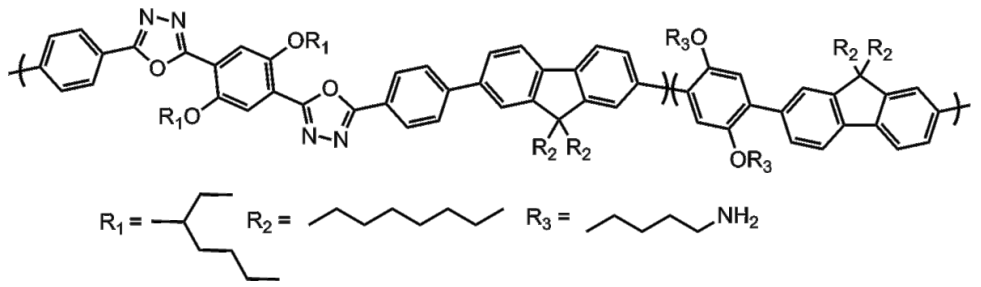


Figure 6. This is the structure of a complex polyflourene derivative. It contains multiple monomers, including fluorene on the far right, which give it desirable characteristics

Industrial uses of polyfluorene

OLEDs

In recent years many industrial efforts have been focused on tuning color using polyfluorenes. It was found that by doping green or red emitting materials into polyfluorenes one could tune the color emitted by the polymers. Since polyfluorene homopolymers emit higher energy blue light, they can transfer energy via FRET to lower energy emitters. In addition to doping, it was found that one could tune the color of polyfluorenes by copolymerizing the fluorene monomers with other low band gap monomers. Researchers at the Dow Chemical Company synthesized several fluorene-based copolymers by alternating copolymerization using 5,5-dibromo-2,2-bithiophene which showed yellow emission and 4,7-dibromo-2,1,3-benzothiadiazole, which showed green emission. Other

copolymerizations are also suitable; researchers at IBM performed random copolymerization of fluorene with 3,9(10)-dibromoperylene,4,4-dibromo-R-cyanostilbene, and 1,4-bis(2-(4-bromophenyl)-1-cyanovinyl)-2-(2-ethylhexyl)-5-methoxybenzene. Only a small amount of the co-monomer, approximately 5%, was needed to tune the emission of the polyfluorene from blue to yellow. This example further illustrates that by introducing monomers that have a lower band gap than the fluorene monomer, one can tune the color that is emitted by the polymer.

Substitution at the ninth position with various moieties has also been examined as a means to control the color emitted by polyfluorene. In the past researchers have tried putting alkyl substituents on the ninth position, however it has been found that by putting bulkier groups, such as alkoxyphenyl groups, the polymers had enhanced blue emission stability and superior polymer light-emitting diode performance (compared to polymers which have alkyl substituents at the ninth position).

Polymer solar cells

Polyfluorenes are also used in polymer solar cells (as in Figure 7) because of their affinity for property tuning. Copolymerization of fluorene with other monomers allows researchers to optimize the absorption and electronic energy levels as a means to increase the photovoltaic performance. For instance, by lowering the band gap of polyfluorenes, the absorption spectrum of the polymer can be adjusted to coincide with the maximum photon flux region of the solar spectrum. This helps the solar cell absorb more of the suns energy and to increase its energy conversion efficiency; donor-acceptor structured copolymers of fluorene have achieved efficiencies above 4% when their absorption edge was pushed to 700 nm.

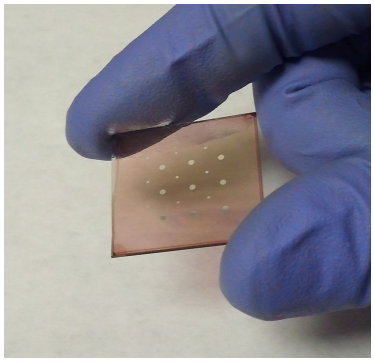


Figure 7. This is a laboratory scale polymer:PCBM blend solar cell. Polyfluorenes are utilized in similar devices.

The voltage of polymer solar cells has also been increased through the design of polyfluorenes. These devices are typically produced by blending electron accepting and electron donating molecules which help separate charge to produce power. In polymer blend solar cells, the voltage produced by the device is determined by the difference between the electron donating polymer's highest occupied molecular orbital (HOMO) energy level and the electron accepting molecules lowest unoccupied molecular orbital energy level. By adding electron withdrawing pendant molecules to conjugated polymers, their HOMO energy level can be lowered. For instance by adding electronegative groups on the end of conjugated side chains, researchers lowered the HOMO of a polyfluorene copolymer to -5.30 eV and increased the voltage of a solar cell to 0.99 V.

Typical polymer solar cells utilize fullerene molecules as electron acceptors because of their low LUMO energy level (high electron affinity). However the tunability of polyfluorenes allows their LUMO to be lowered to a level appropriate for use as an electron acceptor. Thus, polyfluorene copolymers have also been used in polymer:polymer blend solar cells, where their electron accepting, electron conducting and light absorbing properties enhance device performance.

References

[1] http://www.commonchemistry.org/ChemicalDetail.aspx?ref=95270-88-5
[2] http://en.wikipedia.org/w/index.php?title=Special:ComparePages&rev1=414599462&page2=Polyfluorene

Further reading

- Barford, William (2005). *Electronic and Optical Properties of Conjugated Polymers* (http://www.oup.com/us/catalog/general/subject/Physics/MaterialsScience/?view=usa&ci=9780198526803). Oxford University Press. ISBN 0198526806.
- Hamilton, Michael (2005). "Polyfluorene-based organic field-effect transistors" (http://gradworks.umi.com/31/92/3192650.html). *Thesis dissertation*. ISBN 0542364948.
- Hong, Meng; Li, Zhigang (2007). *Organic Light-emitting Materials and Devices* (http://books.google.com/books?id=m8D-dHddKywC&printsec=frontcover&dq=Organic+light-emitting+materials+and+devices&source=bl&ots=sQBxj8vhrr&sig=MqEzmNdTYtzlSa4-gNE4GoeiGKw&hl=en&ei=6AuaTcqpMc_TgQeDiuWxCA&sa=X&oi=book_result&ct=result&resnum=3&ved=0CDUQ6AEwAg#v=onepage&q&f=false). CRC Press. ISBN 9781574445749.
- Lee, Shu-Jen (2004). "Organic Polymer Light-emitting Devices: Optical Modeling, Engineering and Evaluation of Opto-electronic Properties" (http://gradworks.umi.com/31/50/3150130.html). *Thesis dissertation*. ISBN 9780496090549.

Peer Reviews of the "Polyfluorene" Wikipedia Page

See: http://en.wikipedia.org/wiki/Talk:Polyfluorene

Polyfluorene Class Peer Review [edit]

*The following discussion is closed. **Please do not modify it.** Subsequent comments should be made in a new section.*

The current site has basic information, but has some sources that could be useful. It's explanation of the basic polymer backbone with the monomer units is simple and to the point with a good image to enforce this detail. This site however is not very detailed and I agree that it needs attention and is a worthy subject to work with. Review read: Source 17 on sandbox: J. POLYM. SCI. PART A: POLYM. CHEM 39: 2867-2873

Section 1. [edit]

- The objectives are clear and original, since they would expand the current site and add many new ideas, with historical, synthetic and application sections. There does not appear to be any sites with duplicate information. It would be recommended that the site contain links to the Wikipedia fluorene site, which will explain some basic properties of the monomer, although this site itself is not very thorough. Other useful related links could be the electroluminescence page, conjugated systems page, quantum efficiency page, and the OLED page. Many others could also be used. The suggested length of the page is definitely feasible for a semester long project and would add more than the requirements for the assignment to the site.

Section 2. [edit]

- The length of the work seems to be appropriate. There is not more being added to the site than can be handled by a two -person team. I don't think that splitting any of the sections would be useful, but some small things could be added, such as how defects/doping affect the properties. How do different R groups on the fluorene change the properties? Be sure to explain briefly what each of the properties mean and link to respective sites if there are any. Since the original site is very limited, any work on the site would compliment the limited original site with its basic fluorene unit and some basic properties. It would definitely build it into a better page, with much more background, synthetic and application information. This section does meet the stated objectives well and should give people a clear understanding of basics of polyfluorene. One thing that could be changed is the "Industrial Uses of Polyfluorene" to just "Applications of Polyfluorene." Maybe it sounds friendlier. It may be useful to mention stability based on repeated excitation events or cyclic voltametry tests if the data exists. How much does this affect degradation?

Images. [edit]

- It is not clear from the structure given on the page, which part of that monomer unit is the actual polyfluorene molecule. So it could be difficult to know what they are looking at without reading through the text. This molecules take home message seems to be that this is an example of some repeat unit, however a brief description of its specific properties may give it a stronger message. It may just be helpful to show the polyfluorene by itself like it is on the original page. The image looks good for the site and is a legible size, with good resolution. From the looks of the image, the appropriate Chemdraw settings were used. More images would definitely be useful, possibly even a picture of the fluorescence occuring or a table of repeat polymer units.

Section 3. [edit]

- The references need to be diversified; nearly every reference is a journal article that the majority of the public would not have access. Also add DOI numbers. Here are a few books that may be useful as sources: "Advances in Polymer Science: Polyfluorenes" by Ullrich Scherf 2008, this book gives information about applications in OLED's, focus on emissive defects, electroluminescence efficiency, band gap tuning, and the incorporation of charge-transfer substituents in the context of hole and electron injection. "Organic light-emitting materials and devices" by Hong Meng pg's 159 and 122, 2007, contains a few short sections also. I also found an interesting short article out of Popular Science that uses polyfluorenes as sensors. (Laser Sensor Can See Explosives' Vapor Trails Even at Extremely Low Concentrations, posted 6/7/10 by: Clay Dillow. Also check C&EN "Better blue for polyfluorene OLED's". These would all be good articles with simpler understanding for the average person. Also check out Scientific American and Popular Mechanics to see if additional lay-person articles exist. Your list of resources is very extensive and has many good review articles. I found the original articles out of the 1800's quite interesting and I believe this is a very excellent way to start the historical background.

Overall. [edit]

- I believe that you have the start of what will become a nice site. The sections you decided to mention as well as your objectives seem well within the realm of the scope of the project, and polyfluorenes seem to be relevant compounds in today's market. My research this semester has sort of been based on these kinds of properties. Your images look very nice, and you have a great number of primary source materials. I like the historical background back the 1880's. I would recommend adding more alternative sources such as books and magazines to your resource repertoire. This would allow more people to access this information. I would also recommend putting strong emphasis on these compounds have emission over the entire visible range; which is probably one of the most important properties. Be sure to add more images and tables as mentioned above. Good Start!

JFSK538MM (talk) 01:45, 18 February 2011 (UTC)

*The above discussion is preserved as an archive. **Please do not modify it.** Subsequent comments should be made in a new section.*

Class Peer Review: Polyfluorene [edit]

*The following discussion is closed. **Please do not modify it.** Subsequent comments should be made in a new section.*

Section 1 [edit]

The objectives described for the new polyfluorene site are clear and also appropriate for Wikipedia. No duplicated information was found during a search of other sites. The topics proposed in the objectives and outline will provide good coverage of the subject and give a much-needed update to the current site. Judging from the objectives and outline, the article will be of a feasible length for both a course project and a Wikipedia article. The following is a suggestion of sites that could be linked to from this site: fluorene, luminophore, electroluminescence, photoluminescence, and polymer light-emitting diodes.

Section 2 [edit]

The topics listed in the outline seem as though they will provide a discussion that meets the goals stated in the objectives. The sections are organized well and ordered appropriately. The length seems like it will be appropriate for providing a good overview of polyfluorene/s while still being a manageable length for a course project. The proposed additions to the site will be complementary to the current site, adding important information which the current site lacks.

In terms of merging or splitting sections, I would be cautious when writing the section on "Discovery of Polyfluorenes and their Interesting Properties." It seems that a lot of information will be covered in this section, so I advise to keep it well organized to make it clear for the reader. You might even want to consider splitting the section into one about discovery and one about properties for better organization. If you decide to keep it as one section, I suggest re-phrasing the section title, perhaps to something along the lines of "Discovery and Properties" (something doesn't sound quite right with the current phrasing).

There is one concept which I did want to mention: from what I have seen in the literature, unwanted green emission has been a challenge associated with blue-emitting polyfluorene LEDs. It is unclear from the outline whether this will be discussed in the new site, but I think it is an important challenge to address. I see that your reference by Lin *et al.* (2010) discusses this unwanted emission. Another article you can refer to is by Romaner *et al.* in *Adv. Funct. Mater.* **2003**, *13*, 8 (link to article n/). The topic of this unwanted green emission would probably work in either "Polyfluorenes as electroactive polymers" or "Industrial Uses of Polyfluorene," depending on the discussion at hand.

Images [edit]

The image included with the outline looks very nice; it is clearly drawn and of a good size. The image also appears to follow the appropriate ChemDraw settings. Further, the image makes sense on its own and has a clear caption. Since the image is a supplement to a topic explained in the text, the figure will serve to clarify the discussion by providing an example for the reader.

The site would definitely benefit from a good selection of images. I think it would be a good idea to include an image of the basic polyfluorene repeat unit like the one featured on the current site. Also, many eye-catching and colorful images could be provided for the discussion on industrial applications.

Section 3 [edit]

You have chosen a great selection of articles to reference, however your reference list is not very diverse. It would be a good idea to include other sources, such as websites and/or books (especially since not everyone has ready access to journal articles). There are a few books which discuss polyfluorenes that are available for full online access via the U of M library website, such as *Polyfluorenes* by Ullrich Scherf and Dieter Neher (2008). Also, I noticed that your references are not formatted uniformly. You may want to change this to have the references look more consistent. After a brief literature search, I do not see any key references missing from your list.

Overall Comments [edit]

The objectives and outline for the new site look very promising. The current site desperately needs an upgrade, so I think it is great that you are taking on this project. The topics addressed in the outline will provide a good overview of polyfluorenes. The proposed sections are organized well and cover key concepts. I would definitely link to other sites from this page in order to provide supplementary information for the reader. It would also be a good idea to add some diversity to your references by including websites and books. I think you could have a lot of fun with the images you pick for the site considering your topic. Overall, this is a great start to the project, and I look forward to reading the completed product! Good luck to you!

Pharmscistudent (talk) 05:05, 18 February 2011 (UTC)

*The above discussion is preserved as an archive. **Please do not modify it.** Subsequent comments should be made in a new section.*

Evidence of Impact on Student Learning and Attitudes

Assessment. An evaluation was given at the end of the first term to gauge the effectiveness of the project. When asked to list the benefits of doing the project, some representative responses were: (a) “It was good having the scientific responsibility to create/fix a website in which millions of people can access.” (b) “[It] teaches us how to present theories in a manner that people who don’t have prior knowledge can understand it.” The students also reported a greater understanding of the course material, which is consistent with the observation that students develop a higher level of explanatory knowledge when they are explicitly aware of the need to engage in teaching.

After the second implementation, a more quantitative evaluation was performed in collaboration with Prof. Brian Coppola. Specifically, a retrospective survey using student panels was used to evaluate whether the project significantly contributed to the learning objectives of the course. We 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. Of particular interest 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.” Each subsequent term I have collected feedback on the project using open-response evaluations. Some of those comments are provided in the supplemental information.

Anonymous Comments from End-of-term Evaluations

“The Wikipedia project is certainly a great thing to have in the upper-level chem classes!! I wish that all the departments would do this to help Wikipedia become more useful for educated levels.”

“I feel the Wikipedia project is a good idea and is a nice way of getting students to not only think about a concept but also including examples which is a useful skill if one plans of teaching in the future.”

“This project is great for exploring a specific topic in-depth. Because it is published on Wikipedia, it forces us to be able to present the material to the general public, which helps us learn the material better. It is a big project but the due dates throughout the semester made it very manageable.”

“I appreciate the contribution that I have made to both the lay as well as academic communities through the Wikipedia project.”

“I think this helped me to be better at doing literature research.”

“I did learn something new-ish and helped improve skills in writing about science for a general audience.”

“I thought that the Wikipedia project was really cool and pretty fun to do.”

Improving Science Education and Understanding through Editing Wikipedia

Cheryl L. Moy, Jonas R. Locke, Brian P. Coppola, and Anne J. McNeil*
Department of Chemistry and Macromolecular Science and Engineering Program, University of Michigan, Ann Arbor, Michigan 48109-1055
*ajmcneil@umich.edu

> 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.

10.1021/ed100367v Published on Web 08/23/2010

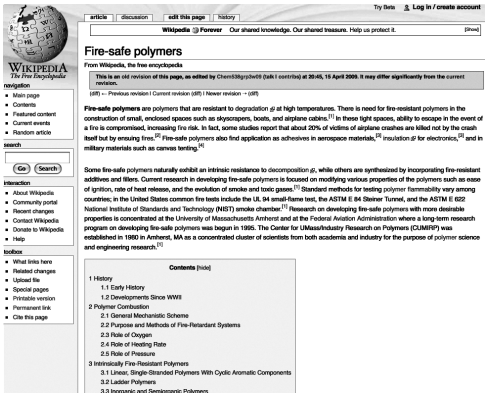


Figure 1. Students in the Winter 2009 Chem 538 course created this new Wikipedia entry on fire-safe polymers *(6b)*. This version, posted in April 2009, is no longer the current version because other Wikipedians have since contributed to this entry. (The full version of this figure is provided in the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

	Learning Objectives and Ratings: Average Scores (*p*-Values)				
Resource	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.

Acknowledgment

C.L.M. thanks the University of Michigan IDEA Institute (http://ideainstitute.umich.edu/; accessed Aug 2010) and GAANN (US-DOE 055384) for a fellowship to support this effort. The authors thank the entire Organic Principles class (Chem 540) from Fall 2008 and Fall 2009 and the Organic Chemistry of Macromolecules class (Chem 538) from Winter 2009 for their participation and feedback on this project. A.J.M. thanks Brian Coppola's Post-Secondary Education class (Chem 720) from Winter 2008, and particularly Rebecca Lahti, for discussing their Wikipedia class project, which inspired this work.

Literature Cited

1. Piel, G. *J. Chem. Educ.* 1954, *31*, 20−23.
2. Home Page of Alexa. http://www.alexa.com/ (accessed Aug 2010).
3. Giles, J. *Nature* 2005, *438*, 900−901. See also : http://www.nature.com/nature/journal/v438/n7070/full/438900a.html (accessed Aug 2010).
4. *Encyclopædia Britannica* has disputed these claims. For more information, see: Fatally Flawed: Refuting the Recent Study on Encyclopedic Accuracy by the Journal *Nature*. *Encyclopædia Britannica*; March 2006.
5. Kovac, J.; Sherwood, D. W. *J. Chem. Educ.* **1999**, *76*, 1399–1403.
6. (a) Web Page of the Asymmetric Induction Entry at Wikipedia; http://en.wikipedia.org/wiki/Asymmetric_induction (accessed Aug 2010). (b) Web Page of the Fire-Safe Polymers Entry at Wikipedia. http://en.wikipedia.org/wiki/Fire-safe_polymers (accessed Aug 2010).
7. (a) Finney, H. C. *Eval. Rev.* **1981**, *5*, 207–229. (b) Poggio, J. P.; Miller, M. D.; Glasnapp, D. R. *Educ. Psychol. Meas.* **1987**, *47*, 783–793.
8. Gere, A. R. University of Michigan, Ann Arbor, MI. Personal communication, 2009.
9. (a) Coleman, E. B.; Brown, A. L.; Rivkin, I. D. *J. Learn. Sci.* **1997**, *6*, 347–365. (b) Coleman, E. B. *J. Learn. Sci.* **1998**, *7*, 387–427.
10. Main Page of the English-Language Wikipedia's Manual of Style. http://en.wikipedia.org/wiki/Wikipedia:Manual_of_Style (accessed Aug 2010).
11. Wikimedia Commons Page for File Uploading. http://commons.wikimedia.org/wiki/Commons:Upload (accessed Aug 2010).
12. English Wikipedia Policy Page. http://en.wikipedia.org/wiki/Wikipedia:Ignore_all_rules (accessed Aug 2010).
13. Wikipedia:WikiProject Chemistry Home Page. http://en.wikipedia.org/wiki/Wikipedia:WikiProject_Chemistry (accessed Aug 2010).
14. For information on a related WikiProject for RNA, see: Daub, J.; Gardner, P. P.; Tate, J.; Ramsköld, D.; Manske, M.; Scott, W. G.; Weinberg, Z.; Griffiths-Jones, S.; Bateman, A. *RNA* **2008**, *14*, 2462–2464.
15. Wikipedia Schools and University Projects Policy Statement. http://en.wikipedia.org/wiki/Schools_and_universities_project (accessed Aug 2010).

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.

Center for Research on Learning & Teaching
University of Michigan
1071 Palmer Commons
100 Washtenaw Ave.
Ann Arbor, MI 48109-2218
provostTIP@umich.edu

Dear Provost's TIP Selection Committee:

It is my pleasure to write a letter in support of the innovative Wikipedia project developed by Dr. Anne McNeil submitted for the Provost's Teaching Innovation Prize for 2014 at the Center for Research on Learning & Teaching.

Over the last year, I have been enrolled in two courses taught by Dr. McNeil into which the Wikipedia project was incorporated (one of which is still in progress). In both courses, I felt that the support my partner and I received was vital to the success of the pages we edited. This support was provided by Dr. McNeil and the respective GSI, Ye Li (the Wikipedia ambassador for the University of Michigan), and two of my classmates through a peer review process.

The completed page from last semester, titled "non-covalent interactions", was completed over a 3-4 week period. The first two weeks were dedicated to researching the topic and creating the page. The latter weeks were dedicated to peer reviewing another team's page, and reviewing our own page's reviews and editing the draft of our page accordingly. The timeframe of the project aligned well with the course material, as a portion of the page was required to contain or relate to course material. During the project timeline, there was sufficient material taught in lecture to complete this task for our page. However, a great deal of material on the page was learned by our research of the material, an amount that could not have been taught in the proper timeline of the course. In my opinion, this project expanded my knowledge of the topic past what we learned in the course. I also learned to explain the material to non-experts searching on Wikipedia. Since conveying scientific material to a general audience is an essential life skill often overlooked in traditional curricula, this project provides a great opportunity for STEM students to practice this skill by publishing peer-reviewed work to the general public.

Overall, I fully support Dr. Anne McNeil's nomination for the Provost's Teaching Innovation Prize for her project in expanding the classroom to Wikipedia. Through this project, I feel that I have had exceptional practice in writing about chemistry to the general public – a challenge many scientists have admitted difficulty accomplishing successfully. The logistics and timeline of the project were well organized, and the project goals established to best expand student learning past the classroom. I feel this project can be easily incorporated to other branches of chemistry, as well as other fields in the sciences and beyond, with many of the necessary resources established and provided by Dr. McNeil.

Please feel free to contact me via email if you have any other questions at slesarey@umich.edu.

Sincerely,

Samuel L. Esarey
Graduate Student Instructor
Department of Chemistry
University of Michigan
Ann Arbor, MI 48109-1055

Dear Provost Pollack and Members of the Selection Committee,

I am delighted to support the nomination of Professor Anne McNeil for the Provost's Teaching Innovation Prize. In the past five years, Anne's creativity and dedication have led to many accomplishments in both teaching and research. My letter will focus on her contribution to Wikipedia editing in classroom at the University of Michigan, which has inspired me and many other instructors on our campus and beyond. As the Librarian for Chemistry, I feel very fortunate that I have been able to collaborate with Anne on Wikipedia-related innovative projects to enrich our teaching and learning environment.

Professor Anne McNeil is one of the first few professors around the world who introduced Wikipedia editing into the classroom. As the Chemistry Librarian, I was first inspired by her work back in 2010. I learned about the effort led by Anne from a presentation by her graduate student Cheryl Moy at the American Chemical Society (ACS) National Meeting. I was immediately attracted by the potential of the project and sought for the opportunity to support the project as an information specialist. Since then, I have been working with Anne and other professors for using Wikipedia editing to enhance students' understanding of subject materials as well as improve their information literacy, peer review, and communication skills. Anne's work enabled students to contribute to public good using what they learned in class and interact with other Wikipedians who share the same scientific interest worldwide.

Anne has been proactively sharing her valuable experiences on Wikipedia projects on campus and nationwide via publications, conference talks, and individual communications. Her article (DOI: 10.1021/ed100367v) published in the Journal of Chemical Education in 2010 comprehensively introduced the project from implementation to assessment and was highlighted in the Science magazine as Editor's Choice for Education[1]. She was invited to share her strategies through a CRLT seminar "*Editing Wikipedia to Improve Writing to a General Audience*" and a panel discussion in which I also participated as a part of the supporting team. She also generously shared her teaching materials for a couple of courses through Open.Michigan and reached out to individual colleagues who expressed interest to the project.

Anne's initiatives inspired librarians of the University Library, education specialists from CRLT and Open.Michigan, faculty and students from the School of Information, and many undergraduates to join her in promoting Wikipedia editing as a teaching and learning strategy. We have hosted many workshops and "edit-a-thons" to help instructors and students. With our joint effort, many professors across Chemistry, Material Science, Environmental Science, American Culture, Information Science, and Social Work have built upon Anne's project design and adopted the Wikipedia editing project for different levels of courses from freshmen to graduate level. We have supported their classes through providing in-class workshops and consultations after class. Having helped many instructors in various disciplines, I clearly see the success of the project in Anne's

[1] Melissa McCartney, Wikipedia Goes to Grad School, *Science* **2010**, *330*, 891

courses attributes to her in-depth understanding of Wikipedia community and her determination to deliver the best of our students' work to more people through the public accessible platform.

The Wikipedia community also values Anne's work. One of the classes she taught was used as an example case in a Wikipedia Education Program publication to demonstrate how to teach with Wikipedia to instructors around the world. Several articles written or expanded by students from her classes were featured on Wikipedia homepage and drew thousands of clicks within one day (e.g. entry Physical Organic Chemistry). Other Wikipedia editors posted many positive feedbacks for our students' contribution. For example, in a comment for Water-gas shift reaction article, students' contribution was evaluated as an "outstanding improvement" which had made the article "both informed and accessible". The positive impact of Anne and her students' work truly demonstrated the value of students' contribution to Wikipedia and influenced the Wikipedia community to be more open to edits from students as their class projects.

Anne also supported her graduate student to initiate the very first student Wikipedia club worldwide, Michigan Wikipedians, which has been helping many undergraduate students on campus contribute to Wikipedia in a variety of topics based on what they learned within and outside the classroom at U-M. Once students learned how to edit Wikipedia properly, they also learned to critically evaluate what they read from Wikipedia and consult a variety of trustworthy resources before jumping into conclusion.

From an information professional's perspective, I appreciate the opportunity to work with Anne on all these fronts related to Wikipedia in education. These impact–driven projects are innovative because they push the boundary between learning in the "Ivory Towers" and fulfilling real-world needs of accurate and accessible scientific information; because they challenge students to develop fundamental understanding of concepts by finding, digesting, and synthesizing relevant information with general public as the audience in mind; and because it's a lot of fun for students to "publish" their work conveniently and engage in global conversations on their topics. Professor Anne McNeil's initiative and leadership have been crucial for our involvement in this exploration. I fully support her nomination for the Provost's Teaching Innovation Prize.

Thank you! Please feel free to contact me if you have any questions. I am honored to provide this letter of support as Professor Anne McNeil's colleague.

Sincerely,

Ye Li, Ph.D. MLIS
Chemistry Librarian
3162 Shapiro Library
University of Michigan
liye@umich.edu (734)615-5694

Dear Selection Committee,

I am writing in support of Professor Anne McNeil to receive the Provost's Teaching Innovation Prize for her Wikipedia project. This project is exceptionally beneficial for not only the students to better understand the material and learn how to communicate it, but also it globally and daily helps people as Wikipedia has become an integral part of learning. Professor McNeil has created an impactful project deserving of this prize.

I would like to explain how each step of Professor McNeil's Wikipedia project teaches students a unique lesson. First, students select topics with the only restriction being that it must be related to the class. This gives students the opportunity to learn more about something they are interested in, which makes projects enjoyable, and I also feel creates a situation where students are more likely to excel. Students then work in small groups to either improve a Wikipedia page or create a completely new one. The team aspect helps students prepare for real world experiences where collaboration is very important, especially amongst scientists. The project also requires that students add a certain amount of new content including text, figures, and references. These requirements help teach students how to communicate chemistry to anyone that seeks information on Wikipedia, which ranges from the general public to professional chemists. Additionally, it helps students with their writing skills, an extremely important aspect in their careers. The figures also teach students how to clearly summarize and supplement the text in a way that will draw a viewer into the article. The references that the students add are arguably the most important part of this project. University of Michigan students have access to numerous great resources and know how to sort through the information. By referencing the material covered in the Wikipedia page, we give the viewers proof that the material is accurate and also, a place where they can find more information if desired.

After creating or editing the article, the students then have a series of final steps before the new information becomes available to the public. A round of peer reviews takes place where classmates verify the new content for accuracy and clarity. This is a great opportunity for classmates to learn how to critique one another in a productive way, give and receive feedback, and view a topic matter from a different perspective. A final set of editing takes place, before the page goes live on Wikipedia.

I touched on the general impacts of the Wikipedia project, and I would now like to discuss some of my personal viewpoints. I greatly enjoyed the Wikipedia project when taking CHEM 538, last semester, and CHEM 540, this semester. Both times I felt that I gained a great deal of chemistry knowledge about topics that I initially knew little about, but found very interesting. The information I gained was extremely useful, but more importantly, I feel much more confident communicating difficult chemistry topics to non-chemists. Professor McNeil's Wikipedia projects are certainly one of the most rewarding and useful things I have done in graduate school.

Professor McNeil has proven to be an extremely valuable asset to the University of Michigan. She is exceptionally organized and dedicated to her students, their success, and learning in general. This can be seen through her continual efforts to improve Wikipedia through the Wikipedia project, which reaches from the classroom to all over the world. In closing, Professor Anne McNeil deserves the Provost's Teaching Innovation Prize.

Sincerely,
Danielle Samblanet

31) Title of Teaching Innovation: Improving Science Education and Understanding through Editing Wikipedia

Nominee Name: Anne McNeil (associate professor)
Unit/Dept: LSA, Chemistry

Description:
Prof. McNeil has improved student learning by developing an innovative class project centered on editing scientific content in Wikipedia.

Project Description: Wikipedia is a highly visible platform for communicating science to general and technical audiences as it is currently the sixth most accessed site on the Internet. 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. The goals of McNeil's project are to (i) enhance student learning, (ii) build collaborative skills, and (iii) improve the quality and quantity of scientific information available to the public. Briefly, the students work in small groups to edit a site on a topic that is related to the course material and not already adequately described in Wikipedia. The students submit a draft version for peer review and feedback.

The culmination of the project involves posting the revised site online, including: (i) ten new references; (ii) four new sections (including a general introductory paragraph for non-scientists); (iii) four new figures or schemes that enhance explanations of the topic; and (iv) hyperlinks to related Wikipedia entries and topics.

Implementations: This project was initiated in 2008 for a graduate-level Chemistry course and is now being implemented in upper-level courses across campus, in part due to the high visibility of this project. Prof. McNeil has been active in presenting this work at various venues on campus, including a CRLT-sponsored Seminar and a Provost Teaching Seminar that was recorded and recently highlighted on the front page of CTools. To facilitate new implementations of this project, Prof. McNeil has made available her project outline, timelines, grading rubrics and other instructional documents. In addition, she has recruited Ye Li, one of the UM science librarians, to serve as a Wikipedia Ambassador and co-facilitator. As a result, the barrier to implementing this project in a new course is minimal. As evidence, recently this project has been utilized in courses in Chemistry, Astrophysics, Environmental Health, and the School of Social Work.

Assessment: Overall, the students report great enthusiasm for this project and quantitative studies have shown that it has improved student learning. The students reported the development of a greater understanding of the course material, along with interpersonal skills. For details of these studies, see J. Chem. Educ. 2010, 87, 1159-1162 with McNeil as the senior author.

Some representative student responses about the benefits of this project were:

> "It was good having the scientific responsibility to create/fix a website in which millions of people can access."
>
> "[It] teaches us how to present theories in a manner that people who don't have prior knowledge can understand it."

"The Wikipedia project is certainly a great thing to have in the upper-level chem classes!! I wish that all the departments would do this to help Wikipedia become more useful for educated levels."

"I feel the Wikipedia project is a good idea and is a nice way of getting students to not only think about a concept but also including examples which is a useful skill if one plans of teaching in the future."

"This project is great for exploring a specific topic in-depth. Because it is published on Wikipedia, it forces us to be able to present the material to the general public, which helps us learn the material better. It is a big project but the due dates throughout the semester made it very manageable."

"I appreciate the contribution that I have made to both the lay as well as academic communities through the Wikipedia project."

Broader Impacts: The impact of this work extends beyond the University. The Wikimedia Foundation, the non-profit organization that runs Wikipedia, took notice of Dr. McNeil's project and invited her to present the project to their Education and Outreach Program Coordinators. The Foundation modeled their first education program (the Public Policy Initiative) based on Prof. McNeil's experiences. The success of this program led to the now expanded Global Education Program. (https://en.wikipedia.org/wiki/Wikipedia:Education_program/Educators). Prof. McNeil's instructional materials are highlighted and available for downloading at this site (https://outreach.wikimedia.org/wiki/Education/Case_Studies/content). There are currently >50 courses across the US that are engaged in editing Wikipedia this term, including three at the University of Michigan.

In summary, Dr. McNeil's innovative Wikipedia project has had a large impact on education at the University of Michigan and other institutions across the country. This project has enormous potential for growth, and my colleagues and I feel that Dr. McNeil is a highly deserving candidate for this award.

Nominator Name: *Wolfe, John*
Status: *Faculty*
Unit/Dept: *LSA, Chemistry, Associate Chair for Undergraduate Education*