AC 2008-1627: WIKI-BASED LEARNING IN THE MECHANICAL ENGINEERING CLASSROOM

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Wiki-Based Learning in the Mechanical Engineering Classroom

1. Introduction

A wiki (derived from the Hawaiian word for quick) is a type of website that provides a framework for users to interactively and collaboratively build a database of interrelated information quickly and easily. Wikipedia[1], currently featuring more than two million articles in English alone, is the most well known wiki, but wikis can also be targeted to smaller audiences, such as an engineering class. Lamb[2], Parker and Chao[3], and Elgort[4] discuss the use of wikis in an academic environment. They provide an overview of the wiki concept, address common concerns about wikis (e.g., copyright issues, vandalism), and present some of the associated pedagogical challenges.

Our objective in this paper is to describe our specific experiences with wikis and teaching mechanical engineering classes. We will discuss our use of wikis in teaching a capstone senior design course and graduate courses in design optimization and small scale heat transfer. In all three courses, a wiki provides (i) logistical benefits to the instructor compared to a traditional web page, and (ii) an interactive and collaborative online-environment in which students can drive their own learning experience. In all three courses, the wiki is designed to grow in subsequent offerings, providing a basis and standard for future students. In addition to discussing the benefits of course wikis to both instructors and students, we will also describe the process of setting up and maintaining a wiki on a web server.

In keeping with the theme of wiki use for teaching and collaborative writing, this article was originally written by the authors on Professor Michalek's Design Decisions Wiki prior to publication with ASEE[5]. Other instructors with experience using wikis for teaching are welcomed and encouraged to contribute to this page, which will remain an active, dynamic resource for sharing experiences of wiki-based learning in the classroom.

Professor Michalek's Design Decisions Wiki (DDWiki) is located at http://ddl.me.cmu.edu/ddwiki. Professor McGaughey's Nanoscale Transport Phenomena Wiki (NTPWiki) is located at http://ntpl.me.cmu.edu/ntpwiki.

2. Wiki software

Most wiki software is open source code, and numerous wiki engines are available at no cost. The most popular one is MediaWiki[6], the same engine used for Wikipedia. MediaWiki is written in the hypertext scripting language PHP[7], incorporating a database management system. We choose and also recommend using MediaWiki to setup a classroom wiki for several reasons:

1. It has large-scale database capabilities and high operational reliability;
2. the installation and maintenance processes are simple and friendly;

3. MediaWiki has its own wiki, offering users comprehensive instructions about installation, maintenance, and updating; and
4. MediaWiki offers an integrated math-formula display function similar to the LaTeX math syntax. This important feature, especially for scientific and engineering courses, provides a convenient protocol to display mathematical symbols and formulations on a wiki page.

Wiki content is organized in a “flat” structure, meaning that all pages and images are saved in the same directory. This means that all content pages and images should have titles that are specific to their application. For example, Professor Michalek uses his Design Decisions Wiki for research as well as teaching several courses. Thus, it would be a poor choice to name a new page "course schedule", since there may be several courses that have schedules. Instead, the page can be named "24-441 course schedule" or can be added to the main page for the course. The wiki creator must decide whether to keep material relevant to a course aggregated onto a single page or how much to distribute it onto separate pages. We have found that keeping most material on a single page reduces problems with naming conventions, lost pages, and student confusion.

Additionally, if students add pages of their own, the preferred naming convention should be made clear to them. For example, in the capstone design course, students write project reports as wiki pages. In this course, Professor Michalek assigns a page name to each team representing the team's project (for example: "windshield wiper assembly"). The team can then work on that page, using the title as a preface to any new pages added (such as "windshield wiper assembly redesign"). Additionally, it is possible to define categories. Pages can be assigned to categories simply by including the text [[category:category name]] on the page. For example, by adding the category "design studies" to all student project pages, it is easy to navigate current and prior student work.

Linux is recommended for the operating system platform of a wiki because it is open source and has strong security features. Prior to installing the main wiki program, the PHP interpreter, HTTP server (e.g. Apache web server[8]), and database server (e.g. MySQL[9]) should be installed. Detailed installation procedures can be found on the corresponding websites.

A well-designed wiki program should be easy to maintain by the administrator. From our experiences, the maintenance responsibilities for a class wiki include:

1. user account management,
2. wiki page management,
3. database and file backups,
4. system updating, and
5. security issue handing.

MediaWiki provides a well-designed web interface for wiki administration. Backups and updates can be performed by following the procedures from the MediaWiki website. If security is not a problem, the wiki may be set as open access, such that any user can edit

any page simply by defining a user name and password. Security issues require an additional tool. A plug-in program called reCAPTCHA[10], developed at Carnegie Mellon University, is recommended. reCAPTCHA can effectively block malicious automatic registrations and spam by requiring users to read and interpret short distorted text graphics that are difficult for computer programs to read prior to making changes that contain external links.

The learning curve for wiki use is not steep, and the resulting instructor workload is comparable to that of maintaining a normal webpage. Editing a wiki page is simple and straightforward. The majority of graduate and undergraduate students in our experience have worked with wikis outside of class, and they are able to begin editing immediately without special instruction. “Advanced” topics such as formatting of tables or writing equations generally require a reference, but using MediaWiki means that all of these items are identical to Wikipedia, and therefore Wikipedia pages can be referenced for advanced information. Furthermore, Wikipedia text falls under the GNU Free Documentation License[11]; therefore, any Wikipedia page can be copied into a new wiki, so long as the Wikipedia source is identified.

In addition, each user is able to select her own settings to define how she would like to view wiki content. For example, headings can be numbered in outline format (section 1.1, etc.) or can be shown without numbers; a table of contents can be automatically added for pages with several headings; and each user can select which aesthetic "skin" to use.

To reduce the risk of plagiarism, it is advised to require students to complete a tutorial defining what constitutes plagiarism.[12] In our experience, most students do not arrive at university with detailed knowledge of what constitutes plagiarism.

3. Educational aspects: Course management

Wiki-based learning provides several advantages for course management including

1. efficient and customized options for information dissemination;
2. an enhanced ability to construct course notes that are modular, layered, and interlinking;
3. an enhanced ability to monitor student progress and contributions;
4. scheduling and team formation; and
5. collaborative writing for co-instruction.

We will examine each of these items in turn.

3.1 Information dissemination

For the course instructor, the wiki provides a web environment in which to disseminate information about the class. Like a regular website, the course schedule, policies, homework assignments, and important documents can be made available. In addition, the wiki encourages links to related pages. For example, the class schedule may include a list

of topics that will be discussed in each lecture. For those topics that have a related wiki page or course notes on the wiki, links can be made simply by surrounding the text with [[double square brackets]].

The wiki interface provides a convenient way to update and modify information, as the editing can be performed directly from a web browser with no need for specialized or external software. The wiki can be updated from any computer with internet access and has many convenient built-in features (e.g., tables, equations, etc.). The "preview" feature allows the author to see her changes before submitting them formally on the wiki. From the student perspective, information dissemination from the instructor through the wiki is the same as it would be on a regular web page, except that students may also subscribe to receive email alerts and/or RSS feeds to monitor updates and changes to course material in whatever customized format the student prefers. This feature can be particularly useful for students to monitor changes made to the course schedule or assignment due dates throughout the semester.

Wikis can be set up to restrict read or write access to an approved list of editors; however, we have not found this to be necessary. By allowing anyone to edit the wiki simply by choosing a user name and password, administrative work is minimized. Further, if the instructor signs up for email alerts and adds the course page to her watch list, she will receive an email immediately if the page is ever edited by anyone other than herself. In the even of vandalism, reverting the page to a prior version is as easy as clicking a button; however, the authors have not experienced any problems with vandalism or any need to police the pages.

Finally, a wiki-based course website can also be used to provide prospective students, fellow educators, or corporate sponsors with layered information about course content, organization, and past student contributions.

3.2 Course notes

Course notes, particularly if they are prepared using LaTeX, can readily be placed on the wiki. These pages can then be made open to students, where they can add questions, make changes, and initiate discussion of points that are not clear to them. In this way, the instructor can get feedback from students after they have had time to digest material, helping them to plan out future lectures. Students will also be able to catch errors or ask critical-thinking questions, and the instructor can even set up a reward system for insightful student input. Thus, the notes will be in a dynamic state throughout the semester, and they can be updated and reused in future course offerings or even for other courses with overlapping material. Course notes can also easily be linked off of the main course schedule, and connections among topics can be emphasized by linking key words to related pages of course notes.

3.3 Monitoring student progress

When students are given assignments to contribute new material to the wiki, instructors can monitor student progress in real time, foresee potential problems in time to offer corrections, and have access to a full history of team member contributions to support individualized feedback and grading of team projects. This is particularly useful for team-based courses or projects: Students can be asked to submit team reports as wiki pages, and the instructor is able to monitor contributions to the page in real time while retaining a full history of individual student contributions to support fair individual grading of team projects.

3.4 Scheduling and team formation

The wiki also supports efficient scheduling and team formation activities. For example, if it is necessary to schedule an activity outside of class time (such as selecting office hours that work best for most students), the instructor can post a table of alternative times, and each student can add an entry to the table to specify her availability or preference. Management of such a setup is far easier and more transparent than receiving email from students. Additionally, team formation for course projects is facilitated by giving the students a space to post comments, ideas, project interests, and questions. The instructor can also create a first-come-first-serve team creation space by allowing students to self organize and declare team and project selection preferences on the wiki.

3.5 Course co-development

The wiki can be a very helpful tool for courses that are co-designed and co-taught. Providing version-control and allowing all instructors to continuously have access to the most recent version of the course page with a quick and simple interface for editing can facilitate course development, negotiation, and decision-making. Professor Michalek is currently co-teaching a new Decision Tools for Engineering Design and Entrepreneurship Course at Carnegie Mellon that was co-developed with Professor Erica Fuchs. The course is a merger of two older courses taught separately by the instructors, and it involved substantial redesign. Using the wiki to edit one another's work in course development, continuously move lectures, homework assignments, and other items on the schedule, and come to agreements on course policies was invaluable. The wiki enabled both of the busy instructors to contribute at times most convenient to each of them while being immediately alerted to updates made by the other and having access to a full history of course design and development. It is also possible to use the “talk” page to write questions or comments to one another about potential changes to the page without editing the page itself. In this particular case, the textbooks used in the course both have online versions available, so readings and homework assignments could be easily linked directly from the course schedule on the main page, reducing any possible student confusion.

In future offerings, the course page from the prior offering can be used as a starting point in developing the revised offering. If multiple instructors teach the course, each instructor may choose to start with material from the last offering or search the page history for the

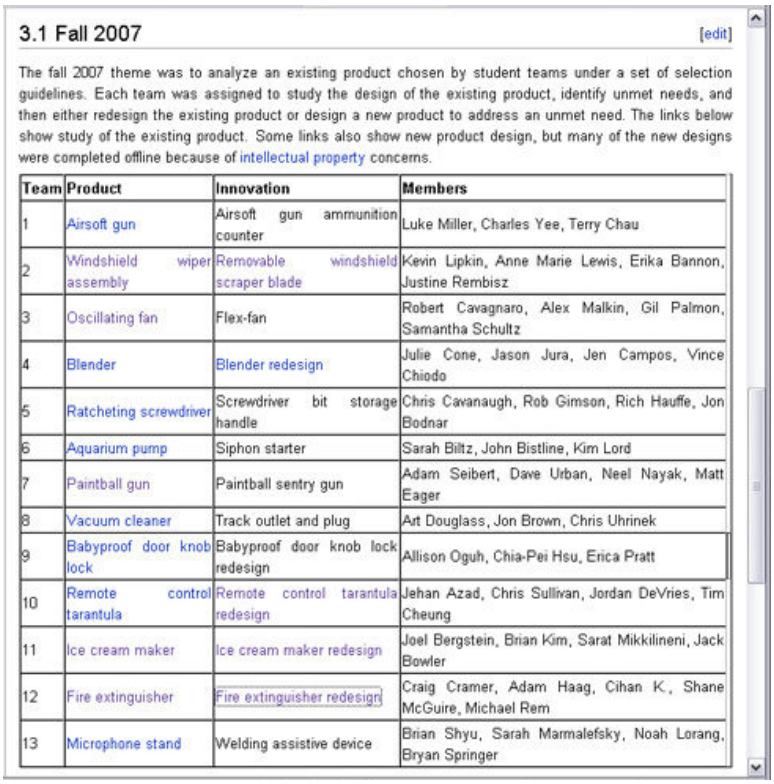
last version of the course taught by a particular instructor and use that page as the starting point. Thus the wiki setup provides a very flexible and efficient framework for dynamic course development over multiple offerings with multiple instructors.

4. Educational aspects: Student interaction

The active learning experience that a wiki offers to students is its strongest feature. We will illustrate this feature through discussion of three courses in which we have used wikis: an undergraduate project-based course in design, a graduate course in small-scale heat transfer, and a graduate course in quantitative modeling for product development.

4.1 Undergraduate project-based course experience

In the mechanical engineering senior capstone design course, students used the wiki in teams to collaboratively write design project reports, including pictures and videos to document use and functionality. The course website,[13] contains links to notes on many of the course topics as well as a history of prior student design reports that new students can use as references. The course involved a design project that began by students forming teams and selecting a mechanical system of interest to dissect and study. Following in-class activities, students formed teams based on member skills, diversity, and project interests. The wiki facilitated team formation by allowing students to find others with similar interests and form teams. Figure 1 shows a screen shot of the teams that formed.



3.1 Fall 2007 [edit]

The fall 2007 theme was to analyze an existing product chosen by student teams under a set of selection guidelines. Each team was assigned to study the design of the existing product, identify unmet needs, and then either redesign the existing product or design a new product to address an unmet need. The links below show study of the existing product. Some links also show new product design, but many of the new designs were completed offline because of intellectual property concerns.

Team	Product	Innovation	Members
1	Airsoft gun	Airsoft gun ammunition counter	Luke Miller, Charles Yee, Terry Chau
2	Windshield wiper assembly	Removable windshield scraper blade	Kevin Lipkin, Anne Marie Lewis, Erika Bannon, Justine Rembisz
3	Oscillating fan	Flex-fan	Robert Cavagnaro, Alex Malkin, Gil Palmon, Samantha Schultz
4	Blender	Blender redesign	Julie Cone, Jason Jura, Jen Campos, Vince Chiodo
5	Ratcheting screwdriver	Screwdriver bit storage handle	Chris Cavanaugh, Rob Gimson, Rich Hauffe, Jon Bodnar
6	Aquarium pump	Siphon starter	Sarah Biltz, John Bistline, Kim Lord
7	Paintball gun	Paintball sentry gun	Adam Seibert, Dave Urban, Neel Nayak, Matt Eager
8	Vacuum cleaner	Track outlet and plug	Art Douglass, Jon Brown, Chris Uhrinek
9	Babyproof door knob lock	Babyproof door knob lock redesign	Allison Oguh, Chia-Pei Hsu, Erica Pratt
10	Remote control tarantula	Remote control tarantula redesign	Jehan Azad, Chris Sullivan, Jordan DeVries, Tim Cheung
11	Ice cream maker	Ice cream maker redesign	Joel Bergstein, Brian Kim, Sarat Mikkilineni, Jack Bowler
12	Fire extinguisher	Fire extinguisher redesign	Craig Cramer, Adam Haag, Cihan K., Shane McGuire, Michael Rem
13	Microphone stand	Welding assistive device	Brian Shyu, Sarah Marmalefsky, Noah Lorang, Bryan Springer

Figure 1: Screen shot of student team list from the wiki

After forming teams and selecting a mechanical system, each team dissected its system, studied it from several perspectives, and wrote a report on the product. Figure 2 shows an example of a student report. Because the instructor has access to the reports at all times during student editing, it is possible to catch misunderstandings and errors prior to official submission and make clarifications for the entire class.

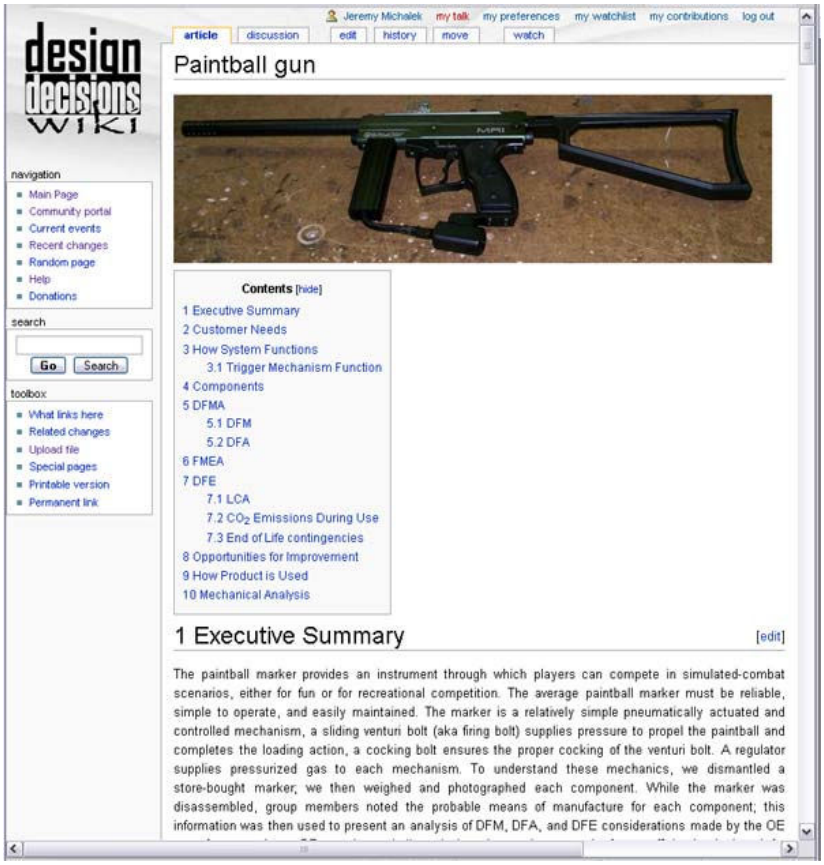


Figure 2: Screen shot of an example student report

4.1.1 Peer-to-peer interaction

Because all teams have access to the work of all other teams as well as student reports from prior semesters, students can use these references to benchmark the quality of their work and search for ideas to improve their work. Such a setup would not be appropriate for most engineering courses where all students are solving identical problem sets. However, this feature provides an excellent supportive learning experience for creative courses where each student or each team is creating a unique project. By learning from one another and learning to utilize references, students are encouraged to engage in lifelong learning. Additionally, many students respond to the pressure of knowing that their work is accessible to others beside the instructor, and they work to create something of which they can be proud. Finally, because the reports are in the public domain, students can choose to provide links to potential employers to showcase their work.

In the course, students were also asked to post comments critiquing the work of other teams. This could have been accomplished by asking students to post to the "talk" page of each report; however, in this case a separate bulletin board external to the wiki was used because discussion revolved around in-class prototype demonstrations as opposed to documented wiki content.

4.1.2 Student-instructor interaction

After submitting the report, Professor Michalek used the “talk” page of each report to provide feedback and ask for clarification and additional information. Student teams then responded to this feedback by editing the report and responding point-by-point to each comment. Figure 3 shows an example of this feedback. This feature enabled meaningful interaction and improvement for each team on an open-ended project assignment, and it initiated a dialogue between student teams and the instructor.

Figure 3. Screen shot of an example of feedback on a student report

4.1.3 Issues with work in public domain

After revising the product-analysis report, students went through a process of identifying an unmet need associated with the product, and each team either redesigned the existing product or designed an entirely new product to address the unmet need. Because of the

innovative component, many teams chose to submit subsequent reports on their product ideas privately instead of on the wiki, since wiki posting of ideas may constitute public disclosure with respect to intellectual property claims. Some teams chose to submit reports on their new product design via the wiki anyway because of its advantages in supporting collaborative writing - maintaining contribution histories, providing version control, and even allowing multiple team members to edit different sections of the report simultaneously.

4.1.3 Contribution history

One common challenge in team-based project courses is to ensure that all members of each team contribute roughly evenly, to catch problems early on, and to intervene where appropriate to correct such issues. A common approach is to require students to submit confidential peer evaluations along with each team submission so that instructors can identify problems. The wiki provides substantial help with this issue. Because the instructor and students have access to the full history of individual contributions to each page, it is easy to assess the relative contributions of individual team members at a glance without requiring one team member to report another. This can help allow the instructor to intervene as an authority figure without creating difficult team dynamics because the instructor has concrete, quantifiable evidence of individual contributions. This feature can support identification of appropriate interventions and also support fair individual grading of team projects. Because team-based learning is so important in engineering education, this feature for improving team experiences is particularly valuable.

4.2 Graduate course experience in collaborative writing

Professor McGaughey's Small-Scale Heat Transfer (SSHT) course, taught in the winter semester of 2007, had an enrollment of ten graduate students. In the first lecture, students were broken into three groups and asked to write down what they knew about conduction, convection, or radiation on the blackboard. After five minutes, the groups rotated and were asked to edit what another group had written. A class discussion ensured on how what they had done was analogous to how a wiki page is built.

The first wiki assignment, presented on the wiki,[14] was as follows:

Task 1: First Page Due: March 27, 2007, Value: 10 points

In the first class we discussed the concepts of

1. Conduction
2. Convection
3. Radiation
4. Solid
5. Liquid
6. Gas
7. Vapor

8. Phonon
9. Photon
10. Fluid Particle

McGaughey: Electron

There are ten terms and ten students in the class. You have a number assigned to you in class. You are responsible for making a wiki page on the corresponding topic by the due date (start by clicking on the link above). Add your name to the number above, as I have done for electron. Include *introductory* information using what we discussed in class, things you learned in other classes, reference books, the internet, etc. Be sure to reference all your sources. **The content should be appropriate for an undergraduate mechanical engineering student with some exposure to heat transfer, thermodynamics, and fluid mechanics.** Try to include a few equations, some figures, etc. and make links to the other NTPwiki pages. Your grade will be based on both the content and visual appearance of the wiki page.

Using the *history* feature on the wiki, it was possible to track the creation of each page. In initially constructing their pages, students made between two and 22 modifications. Note that a change is noted every time the user saves the page, if it is every minute or every hour. Some students make many changes by previewing each one before submitting, while others submit changes more frequently. Professor McGaughey then read all the pages and left comments for improvements. The students returned to their page and addressed these points.

The second wiki assignment was as follows:

Task 2: Page Editing Due: April 5, 2007, Value: 10 points

Revise/modify/add to the wiki page corresponding to the second number given to you in class. Include some more advanced information. Make links around words/terms that you feel deserve their own page. Add figures. You should consult with the original author. The final grade for each wiki page will given to both people who worked on it. Also feel free to look at the other pages and offer suggestions on what should be included. McGaughey has already done this, and left comments on the pages.

All students edited a second page. The majority of students, even though it was not required, worked on their original page after it had been edited. A number of students edited pages that they were not assigned to. The fine quality of the wiki pages was clearly a result of the collaborative writing aspect of their development. There was also a clear sense of an evolving class identity. The collaborative aspect of the second wiki assignment brought students together both online and in the classroom. The students often discussed their pages before and after class. Students had a third wiki assignment where they were allowed to choose the topic for a new wiki page. They were encouraged

to make links with all the other pages. These wiki pages will be used in subsequent offerings of the course.

4.3 Graduate course experience in independent research

Similar to the small-scale heat transfer course, in the graduate course on optimization and product development, students were given two assignments in creating wiki pages:

1. **Reflection:** Create a wiki page on a topic covered in class. The material should introduce the topic to a user with general engineering knowledge who is new to the specific topic, similar to a typical Wikipedia entry.
2. **Independent Research:** Create a wiki page on a topic related to the course but beyond what was covered in class. The material should introduce the topic to a user with general engineering knowledge who is new to the specific topic, similar to a typical Wikipedia entry.

In the reflection assignment, students proposed topics (via the wiki) that were approved by the instructor and then wrote content drawn from course notes. Examples include pages on the logit model, sequential quadratic programming, and curve fitting.

In the independent research assignment, students proposed topics (via the wiki) that were approved by the instructor and then wrote content drawn from independent reading, including chapters of the textbooks not covered in class, recommended readings, and outside sources. Examples include pages on shape grammars, genetic algorithms, and the mixed logit model.

In both assignments, students presented their pages to the class at the end of the semester. This activity allowed students to learn from the research of others as well as to organize thoughts in order to formally present their ideas.

4.4 Accuracy of content

Because content management is distributed with no formal review process, it is not possible to guarantee accuracy of content; however, experience shows that users tend to take pride in the accuracy of their entries and in correcting inaccuracies they find. For example, an article in the journal Nature reported in 2005 that science articles in Wikipedia were comparable in accuracy to those in Encyclopædia Britannica[15,16]. Because it is known that entries can be changed by any user, authors tend to migrate toward balanced descriptions of controversial topics that will not prompt others to revert or revise the entry. In the case of course-assignment entries, pages are graded by the instructor, providing an automatic mechanism for checking accuracy. In some cases, the instructor may make corrections directly to the page. In other cases, the instructor can simply tag the page as containing errors so that other users looking for content would be alerted to potential mistakes.

4.5 Information growth, consolidation and sharing

Through a combination of

1. assigning wiki content creation and modification as course assignments and independent study assignments,
2. writing course notes as wiki pages on topics covered in several classes,
3. soliciting entries from experts in the field, and
4. encouraging multiple instructors to use the wiki for multiple courses

a substantial database of accessible content can quickly build on the wiki, creating a useful tool that will draw in more users. For example, 1.5 years after initial creation, the Design Decisions Wiki has over 300 pages of content, 150 registered users, and 80,000 page views (see the special:statistics page for more detail). Pedagogical learnings and insights can also be shared on the wiki. For example, in addition to publication in ASEE, a wiki version of this article is available that can be edited by other users to serve as an active, dynamic resource for sharing experiences on **wiki-based learning in the classroom**.[5] This page has been added to the category:pedagogy, which also contains other information for instructors, such as lists of textbooks on a range of topics, links to wiki-based courses, and philosophical positions, such as opinions on teaching design.

5. Summary and conclusions

The wiki provides a powerful tool for supporting course creation, management, and implementation while creating an active, dynamic learning environment for students. Free wiki engines, such as MediaWiki, exist that are easy to set up, maintain, and use, and students typically require no training to begin interacting with a wiki website. We presented our experiences applying wiki-based learning to one undergraduate and two graduate courses in mechanical engineering at Carnegie Mellon University.

Wiki-based learning in the classroom offers two core types of benefits over the traditional course website:

1. course management support, and
2. student interaction opportunities.

Course management benefits include

- improved information dissemination with customizable student interfaces;
- layered, linked, accessible, and reusable course notes;
- the ability to monitor student progress in real time;
- support for scheduling and team formation; and
- support for course co-development.

Student interaction benefits include

- increased peer to peer interaction;
- increased student-instructor interaction;
- accessibility of all work in the public domain;
- full historical records of individual contributions to group assignments;
- support for collaborative writing;
- mechanisms to control accuracy; and
- growth and reuse of information over time, across courses, and across multiple offerings of a course.

With these advantages, we see the wiki as a powerful tool to support learning, and we advocate increased use in engineering courses. We invite other instructors with experience implementing wiki-based learning in the classroom to contribute to the wiki version of this article.

6. Acknowledgements

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