AC 2007-2074: THE WIKI APPROACH TO TEACHING: USING STUDENT COLLABORATION TO CREATE AN UP-TO-DATE OPEN-SOURCE TEXTBOOK

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The Wiki Approach to Teaching: Using Student Collaboration to Create an Up-to-date Open-source Textbook

Abstract

We present an approach to teaching whereby students and faculty collaborate to explore subject matter through the creation of articles for an open-source textbook viewable using the wiki format. In this approach teams of students wrote sections of a new textbook for a senior level Chemical Engineering Process Controls course. The resulting text is available online at www.controls.engin.umich.edu/wiki. Each team of students presented their articles in a poster session during class, answered questions from other class members, and acted as personal tutors for the practice problems the group developed. The writing and presenting of articles provides opportunities for students to learn by teaching. Each article was also formally reviewed by other students in the class to provide suggestions and correct errors. The wiki authors then offered specific rebuttals where appropriate to the reviewer comments. Finally the original set of reviewers graded the wiki article in light of the suggested changes and rebuttals. Throughout this process, the instructors acted as advisors, gave the general topic outlines, provided reference material and made connections between the various student topics through short lectures. In addition to the wiki activity, the students were also given two exams, one group project and one individual project as assessment tools for the instructors. We present evidence in the form of standard course evaluations and grade distributions for the students' response to this approach.

Introduction

Engineering course structures traditionally rely upon instructor lectures with the students performing various assignments to check understanding. These assignments include redundant homework problems, mid-term exams, comprehensive creative exercises (projects) and a diagnostic final exam. These types of assignments rely heavily upon repetition for learning and they work well for many lower-level engineering courses, but often do not include synthesis of ideas by the students. Typically, higher level courses require the students to do more synthesis and rely less on memorization of material for learning.

Using the traditional approach, the student creates an extensive body of work. While completing homework assignments in the form of problem sets is invaluable for introductory courses,[1] the physical pieces of paper produced by doing homework are likely of little use as reference upon completion of the course. Typically, if referral to information covered in a particular course is required for future work, the student will reference the course textbook, relying upon the problem solving strategies developed to solve the new problem.

We present an alternate approach to teaching which facilitates students and instructors working more closely together. Under this alternate approach student teams synthesize information from various sources to explore topics to create an open-source textbook available to the entire class and anyone else wishing to explore that subject. We used this wiki approach to allow students to collaboratively write an updated text for Chemical Process Dynamics and Control.

This alternate approach fosters the students' own exploration of the material which leads to greater ownership and mastery of what is learned. The students asked more genuine questions of

the instructors, and the questions tended to be more sophisticated because the students are learning by teaching. Creating such an environment that supports and encourages students to seek answers to their own questions fosters learning that is more motivated, relevant, and satisfying to students[2].

The wiki articles and presentation provide the student authors with instant feedback on their understanding of the topics covered. The timing of this feedback has been shown to be key to student's understanding[3,4]. The wiki articles and presentations provide the instructors with a good idea of how well the students are understanding the material and what misconceptions need to be corrected. The large amount and high quality of this feedback helps instructors build models of the students. These models involve what is known as pedagogical content knowledge [5] which includes knowledge of typical pitfalls, which ways of explaining each topic are students finding particularly helpful, what analogies are useful, etc. Pedagogical content knowledge is different from the knowledge an instructor has of the course content itself. To teach effectively, instructors must acquire pedagogical content knowledge in addition to understanding the course material well[6,7], and the wiki approach provides instructors with large amounts of useful feedback for building pedagogical content knowledge. Furthermore, the wiki approach provides this feedback immediately while there is still time to make appropriate adjustments. In contrast, because lecturing by instructors does not yield much feedback, the delayed feedback that exams provide is typically the main source of information on student understanding. This information often comes too late for both instructors and students.

Other Wiki Projects

Similar projects have begun at wikibooks, an online project focused on providing open-source textbooks, and on its sister site, wikiversity. These textbooks are written by the public hoping to offer open-source information to others and are part of a larger trend toward free decentralized education. The texts are likely edited by others, keeping the quality high. This quality issue has also been addressed by the contributors of Scholarpedia (www.scholarpedia.org), in which contributors are either invited or elected to provide expert information. We used this same general methodology to construct a text written by the students. The advantage of this is that nothing is entered into the wiki that the students do not understand. While this may lead to a lower quality, the editing and review process amongst the students keeps this from occurring. Formal reviews require that student authors update anything that is confusing to reviewers and correct anything that may be wrong.

Why Process Control?

In most chemical engineering curricula, Process Dynamics and Control has typically required a substantial portion of the course to be dedicated to learning and using Laplace transforms on linear systems. This required that the students learn this mathematical technique and then apply it to their understanding of process dynamics, leaving a gap between the students understanding of the mathematics and the understanding of real complex phenomena involved in dynamic and control systems. Simple modeling techniques available with common computer software, have made frequency domain analysis less important. Students can model linear, nonlinear, and

piecewise systems and then apply control strategies they have learned to those systems using Microsoft Excel, Matlab, or Mathematica[8]. Unfortunately, most chemical engineering controls textbooks dedicate much of their material to Laplace transforms. This causes increasing confusion if they are used when the subject is taught without these techniques. If the instructors choose to forego Laplace transforms when teaching the dynamics and control, a new textbook was needed to avoid the confusion of the students.

Our Process Controls course also lends itself well to requiring more synthesis and creativity from the student because of its placement near the end of the curriculum and its break from the "single answer" teaching style of the previous engineering courses. Ideas taught in this course often require the student to choose the best of many correct answers. Often this is one of the first courses that requires this type of thinking. It often makes the students quite uncomfortable. By allowing the students to develop much of the material for the course, they are completely engaged in the open-ended nature of the subject and find themselves making these choices throughout the course. By making the textbook the substantial part of coursework, the students use the open-ended nature of writing an article on a given subject to become used to the skills needed to define a problem and provide a solution on subjects with many "grey" areas.

Setting up the wiki

The term wiki refers to a website that can be edited collaboratively by any user (www.wikimedia.org). This technique for collaborative information gathering is most widely known by the online encyclopedia Wikipedia, created using wiki software. This software is available free and in many forms. For the purpose of this course, we used MediaWiki available at www.mediawiki.org.

The advantage of using a wiki is that anyone can edit any of the content. For the purpose of this course, editing privileges were granted only to students and instructors to prevent outside editing during the course. This allowed instructor control of the content and prevented subject matter from becoming too complex due to editing from outside experts. But it still allowed all students to review and edit the information.

The wiki articles also benefit from the software's ability to post any type of media. In the articles created for the course, Microsoft Excel and Mathematica files were used to provide examples of simple models and dynamic analysis. There are also links to other kinds of media including video files providing an example of neural network control and diagrams created using Microsoft Word and Visio Basic showing examples of piping and instrumentation diagrams.

Creating the text

The course was divided into three sections with each section having various numbers of subsections:

- Chemical Process Dynamics
- Chemical Process Control Systems
- Statistical Process Control

From this division, 63 sub-topics were created for the purpose of having student teams of 3-4 members write a wiki article on their subject. Each group was responsible for 3 articles spaced evenly through the semester with at least two being from different topic areas. For each sub-topic, the instructors provided reference material for the authors to use in their draft along with some very basic guidelines for the topics to cover. The wiki itself provided an outline of each topic asking the author to provide an introduction to their topic, at least two subsections within their topic, a summary and at least two worked out example problems that the authors created. In addition, the wiki authors were required to generate two multiple choice questions to be answered by all students via electronic submission before the class in which the topic was presented. Adding multiple choice questions was introduced to ensure that all of the students had at least skimmed the subject wiki before class. Utilizing broad outlines, allowed students to determine what is important from the primary sources and to present this material in a manner consistent with their understanding and background.

After the student groups published their article to the wiki, the groups presented their information in class in a poster presentation format. Each class had three or four groups presenting related topics simultaneously keeping the audiences smaller. This created one-on-one learning time among the students. The instructors would attend the presentations asking questions to promote discussion and ensuring that key points were explained well. After the poster presentations, the instructor would give a short lecture bringing all the topics of the day together and pointing out any missing links between the topics. This time was also used in conjunction with active-learning techniques such as think-pair-share and some example worksheets to help the topics of the day come together for the students. The wiki approach is not in lieu of already established pedagogical techniques. It provides instant feedback for the instructor to adjust those techniques immediately.

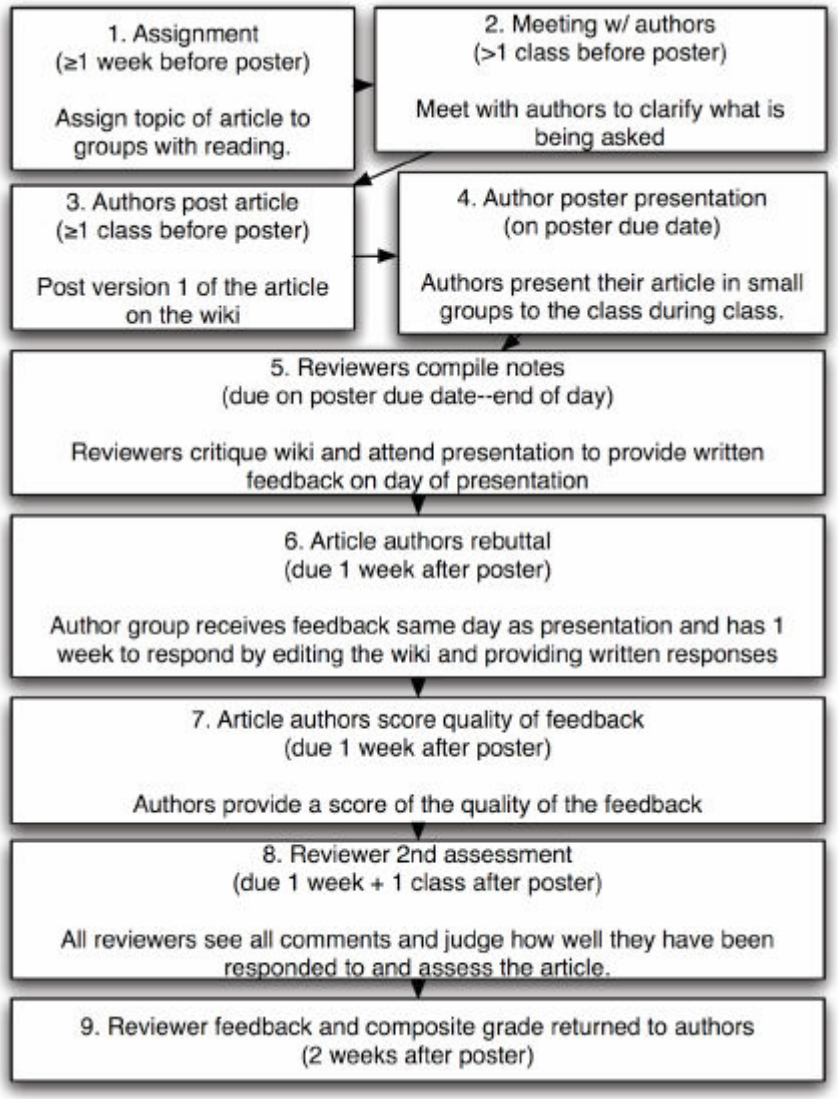

Figure 1: Writing process for wiki articles.

After the presentation, student reviewers would submit anonymous peer reviews of the article. These reviews were given in standard form asking the reviewer to provide key points, major difficulties with the article and specific improvements needed. The reviews were then compiled and given to the authors for rebuttal. One week after the initial review of the article, the rebuttals were given to the reviewers who then submitted final reviews based on the edits completed by the initial authors. The authors are assigned grades from the reviewers based on their work and reviewers are also graded on the quality of their reviews. One benefit of the wiki format is that all reviews and rebuttals can be posted directly to the article for reviewers and authors to benefit. This process is generally intended to mirror the peer review process for scholarly works and is illustrated in Figure 1.

The benefits of the peer review process can not be neglected. It has been shown that Peer Review of classwork can enhance learning by providing a clear need to understand their material and increasing care in reducing errors in their work[9]. The wiki approach provides an opportunity

to get this experience while creating the text. The peer reviews also provided a sense of how students assess their work.

Example Articles

In many ways the first article presented represents both the strengths and deficiencies of this approach. In the first article, the authors were assigned the topic of Noise Modeling, a topic to which entire texts have been devoted. The topic presented student difficulties in many areas. Many students had no exposure in this area, the primary reference contained difficult mathematics, and, being the first topic, it was not yet clear how noise applied to chemical process control. In presenting the article, the students had to determine what material the other students would need to understand and to ensure that they covered the topics the instructors required. The final product presents the power spectral densities of various colors of noise, followed by an algorithm to determine the color of noise based on given data and a brief description of how to model specific colors of noise. The student authors analyzed the information well and presented a logical overview of the topic. While all of the information presented is correct, the connection to application is never made clear in either the general background of the article or the example problems. The students, at that time, did not yet understand the impact of using a noise model to predict the usefulness of a control strategy. This connection was made later in the course, but was not explicitly covered in the article. This was presumably due to the timing, being the first article in the course.

Another student article later in the course provides an outline of designing experiments using Taguchi methods of orthogonal arrays. The authors present a logical representation of how to reduce the number of experiments needed to test the effect of parameters on an outcome. In this article the authors provide detailed information on how to set up experiments based on the orthogonal array theory. They provide the basic math needed to determine the most influential parameter including the size array needed depending upon the number of parameters and the number of levels for each parameter. The article's examples show the method's applicability to chemical processes. These authors show a good grasp of the information and provide the information needed to set up an experiment and analyze the results.

Lessons Learned

Facilities organization was one of the major difficulties to overcome in presenting the topics of the day. The class was held in a lecture hall and the four groups presenting were split into the four corners of the room. Two of the corners had access to blackboard space and the others were provided flip chart paper and markers to make their points. The ability to hear presenters and see laptop monitors when used was difficult. To help with this problem, the presenters within a team were asked to present individually with even smaller groups. This was accomplished on a limited degree. Group members tended to be uncomfortable covering the entire topic, when they had written a specific section. In the future this rule could be enforced more or separate classrooms could be used.

The quality of the presentations also depended upon all students reading the articles prior to class. Initially, the students were not given incentive to read the articles until the exam. As

mentioned above, procedures were modified so that students were required to answer and submit two multiple choice questions prior to the class presentation. These questions then prompted discussion during the in-class presentation.

A recurring problem was that students often tended to write their articles from an exclusively mathematical prospective. When they presented the material it became apparent they were not making the connection between the mathematics and the application. Some of the example problems tended to be strictly mathematical in nature with little thought towards chemical engineering applications. These authors were asked to develop examples using Chemical Engineering applications in order to help illustrate these connections. Feedback from faculty both during the presentation and via written reviews tended to clear up this problem in the final versions of the wiki articles.

One of the largest issues with this type of coursework is the review process. In order to maintain reviewer anonymity, the reviews were collected, rendered anonymous and then distributed to the authors by hand. This process was repeated for the rebuttal and again for the final review. The work-load for the grader was quite extensive and timing became difficult to track based upon the amount of information exchanged. This process was improved by posting the reviews and the rebuttals on the actual article, but the grader's handling of paperwork was still quite extensive. The Public Knowledge Project has an Open Journal System that has been developed to improve the review process (http://pkp.sfu.ca/?q=ojs). In the future this system may be used to help facilitate the review process.

Continuing Development

While this approach can be adopted for different courses, one issue with this technique is the lack of exact repeatability in the same course. Future students will not be starting from scratch in writing the wiki textbook as the first set of students did. There are many approaches for handling this issue.

One approach involves further editing of the current content. There are many articles that need to be reworked for clarification. Future iterations of the course could include giving the same primary references but having the students redo some sections or add information where more explanation is needed, essentially major editing of the existing text.

There are also more topics to be explored in Process Controls. A further approach could include each group introducing one new topic and providing extensive editing of two others for the remainder of the class. This allows new topics to be introduced, keeping the text current.

Another approach is to have students write additional problems for each section. One of the most valuable aspects of traditional textbooks is the workable problems at the end of the chapter. Having future students write problems and provide solutions would be a natural extension of the wiki approach. If a new problem is difficult given the current version of the article the student group could edit to add sections to the article covering the solution technique they would like to employ.

With each of these approaches, although future students will not be producing a brand new textbook from scratch, there are many opportunities for writing new sections. Having students redo some sections from scratch, write wiki articles for new topics, and write new problems for each section are ways to provide future students with a similar writing experience as the first set of students had. But even if the writing experience is different, the important aspect of learning by teaching by presenting course material to their peers in class remains the same for future students.

Course Acceptance and Results

The wiki articles and reviews accounted for 60% of the student's grade. The course also included two exams, one group project and one individual project to check for understanding. These accounted for the remaining 40%. Grades for the wiki articles were based on a combination of the reviewers' assigned grade, weighted towards the final review. Individual grades were then assigned based on an average contribution score from each group member. The grades reflect a normal distribution for a senior level engineering course.

We assessed the peer review process that was used to assign grades to the wiki articles. We performed an analysis of variation to see if the peer reviewing produced different results than if we had assigned grades randomly for each of the articles, and to see if there was agreement on which of the articles were of higher and lower quality. Our goal was to determine how strongly the article quality influenced the scores the article authors received. We realize that some student reviewers tended to be more lenient and some harsher, so we needed to control for this reviewer to reviewer effect. We analyzed this data using a two-way analysis of variation, where one factor was the article being reviewed and the other was the reviewer. As expected, individual reviewers did give significantly different scores (p-value < 0.0001) for both initial and final reviews; however our requirement that each article be reviewed by approximately 6 students tended to minimize the impact of any one reviewer. Thus we also see a strong effect on the article quality on the final article score (p-value < 0.0001). This result indicates that students are grading articles consistently and not just assigning random or near random scores to their peers.

Course acceptance was average for the college. Scores on the end of term evaluations showed an increase over scores received from the same course without the wiki. Students generally agreed that the course was excellent and that they learned a great deal from the course. Feedback indicates students view the workload as very high but that they felt like they were learning more from the wiki teaching approach than they would have from a typical lecture-based approach. Informal discussions with students have suggested that due to the complexity and stress of open ended problems, this course expected significantly more work, time, and creativity than they expected for a 3 credit hour course. At the same time, many students reported finding it one of their most interesting and engaging courses, both because they were contributing to a larger cause of creating a public domain textbook, and also because they were being allowed to think independently and creatively. Finally, students agreed that they did help their classmates learn, showing the desired outcome of peer tutoring of the material.

Conclusions

This approach to teaching forces the students to synthesize material for better learning while using that time spent to create a tangible outcome for everyone to use. The page count of the "book", if printed, is 892, and the size with all the examples is 105 MB. The workload for the instructors is a tradeoff from time in the classroom to facilitating the transfer of knowledge and acting as a mentor in the writing process.

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