AC 2012-3359: INCREASING THE SPIRALITY OF MATERIAL AND ENERGY BALANCES

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Increasing the Spirality of Material and Energy Balances

Students in the material and energy balances course often cannot keep up with the pace of the material, in particular as it evolves from simple systems with only material balances to complex systems consisting of simultaneous material and energy balances. As one basic goal of the course is learning the fundamentals of chemical engineering problem solving, a principal instructional strategy is repeated attempts at problem solving with feedback. However, it is typical that students do not attempt homework until it is too late to dedicate sufficient time to complete it correctly. Therefore, these students often do not achieve the level of mastery that instructors would desire before moving on to more difficult topics. To further confound matters, the ready access that most students have to the solutions manuals for textbooks makes it difficult to judge the level of student understanding from homework. Finally, with the enrollments in chemical engineering increasing and instructional resources decreasing, it is far too common that any feedback the students receive on completed homework is received too late to be useful to the student, if the student reviews it at all. Rather than abandon homework, we sought to restructure the course to maximize the number of times students hear the material (the spirality of the course), to scaffold students to mastery, to improve the speed of feedback, and to utilize homework problems for which solutions were not available.

To do this, we combined traditional homework assignments with an online homework system for material and energy balances available through Sapling Learning, Inc. This on-line system provides students with scaffolding in the form of hints and allows students to enter multiple solutions until they have answered the question correctly, albeit with reduced credit for each answer after the first. In this way, the online system drives the students towards mastery learning rather than to maximizing partial credit. However, because of the nature of the online interface, there are aspects of problem solving, e.g., drawing process flow diagrams, that are not effectively tested using the software. Thus, students were instructed to emphasize these aspects of problem solving in the written assignments.

The structure of the homework process was as follows (Figure 1). Homework from the textbook was assigned initially and was due prior to the material being discussed in lecture. Thus, students had to rely on the textbook, the professor and TA, and collaboration with their colleagues to get solutions. This type of "look-ahead" homework has been successfully applied by others previously [1, 2]. However, in this case, the paper homework was intended to be primarily a tool for formative assessment. As such, it was graded according to a scale of 0, check-minus, check, check-plus. Any paper not turned in or of insufficient effort, quality, or completeness received a score of 0. Anyone who received a score of 0 did not get credit for the subsequent online homework assignment, which was due after the material was discussed in lecture.

In this way, the students covered the same material three times during the course, twice with formative assessment (including problem solving exercises during lecture periods), and the final time with summative assessment. (As an aside, the students were also required to complete glossaries of many of the important terms from each chapter; this further required them to read the textbook, an often overlooked task, and gave them a fourth opportunity to review the material being covered.) While not eliminating the utility of solutions manuals for those completing the textbook homework, we felt that this grading approach mitigated their use, because students did
not have to get all of the answers correct to get credit. Thus, incomplete or incorrect assignments, as long as sufficient effort was made, did not lower their course grade.

As a first trial of this approach, we assessed student attitudes towards the approach. As expected, the student response was mixed, though primarily positive (Figure 2). Comments from the end-of-term course evaluations also reflected this dichotomy:

- I don't like that you wanted us to struggle with the homework and waste our time. My time is precious.
- I liked everything in the class except the fact [that] we did book homework before we learned it.
- Homework, online homework, and lectures all went together nicely.
- His set up of the homework/glossary/Sappling [sic] made sure you did the work first and had an understanding of the material before it was covered in lecture.
- I think that I've learned more in this class in one semester than any other class I've taken here.

The principal complaint about the course centered on course organization. With the sequence of the course unlike what students have come to expect, many commented that it was difficult to have textbook work on one subject with lectures on another and online homework on a third. This reflects that perhaps we did not communicate clearly enough the goals of the homework structure. More importantly, students noted rightly that the process only works if the textbook homework can be returned in a timely fashion with sufficient feedback to make it helpful when
The homework structure (textbook HW, lecture, online HW) helped me learn.

Figure 2: Attitudes towards homework structure. Students were asked if the three-step structure used for homework in the class helped them learn, with 70% agreeing. Actual survey question is above figure.

As we continue to analyze the data on course performance and our surveys, we will compare course performance to the prior year, when no homework was collected or graded, to determine if there were any measurable gains in learning due to the homework structure. That said, we feel that the approach was successful and will continue to refine it for future implementation.

References: