LEARNING THROUGH DOING

A Course on Writing a Textbook Chapter

PHILLIP C. WANKAT
Purdue University
West Lafayette, IN 47907

People learn best when they become *involved* in the process of doing something.[1] While actually working on a project, there is great motivation to learn those things that are needed to finish the project.[2] Properly organized projects which allow students to function as engineers and to receive feedback are an excellent teaching method.

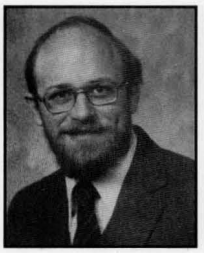
In the course described in this paper, graduate students completed projects which required them to perform one of the functions of a chemical engineering professor—writing an advanced textbook chapter. The idea for a seminar course in this form came from a book by Eble,[3] and the result was a course wherein the students worked harder and learned more than the professor. This is in stark contrast to a "normal" course where the professor works harder and learns more than the students.

THE COURSE

The course was titled "Seminar in Separation Reviews," but the methodology can be used for any technical topic. The prerequisite for the course, an advanced class in ChE separations, ensured that time did not have to be spent teaching basics. Since this was a graduate-level elective, it was not necessary to cover a specific body of material, and the students could pick their own topic. This procedure has the advantage that the students cannot later blame the instructor if their topic proves to be difficult for them.

The seminar was advertised to all students who met the prerequisites, and four students eventually registered. Two other students were interested but could not take the course because of schedule conflicts. A larger class could easily be taught (see "Possible Course Modifications" appearing at the end of this article).

The students were told to produce a professional quality textbook chapter on an advanced topic in separations. To make sure that writing was done for *this* course, the topic could not be on the subject of their thesis research. This requirement meant that everyone started with a very modest knowledge base of the chosen topic. This mimics industrial practice where engineers are often assigned projects in areas outside of their expertise. The topic had to come from a list of over fifty separations, the chapter was to be written at the graduate level, and the students were to work in teams of two. The course grade was based on this project.



Phil Wankat *received his BSChE from Purdue and his PhD from Princeton. He is currently a professor of chemical engineering at Purdue University. He is interested in teaching and counseling, has won several teaching awards at Purdue, and is Head of Freshman Engineering. His research interests are in the area of separation processes, with particular emphasis on cyclic separations, adsorption, preparative chromatography, and simultaneous fermentation and separation.*

During the first class meeting I introduced the course objectives and rules and presented an overview of separations. In the second class, the students analyzed the structure of a separations textbook to determine what is typically included in a textbook chapter. They concluded (with my help) that the following sections are necessary: introduction; body, with appropriate figures and tables; examples, including some for real systems; summary; notation; references; and homework, with a separate solution manual.

In the third class the students critiqued a recent paper from the literature. Fortunately, the paper chosen by the professor had several flaws, and a lively discussion developed—the flaws made it clear that not all papers are created equal. The students were then given a list of journals which included papers on separations, and they were told to skim through several to obtain topic ideas. They came to class with a list of three topics.

We spent much of the fourth class period in teaming up students who had an interest in working

together, and this was eventually accomplished to everyone's satisfaction. The remainder of the period was consumed by a mini-lecture on the different work styles for doing big projects. For example, some engineers prefer to do the work serially by first collecting all the information, then doing calculations, and then writing the report. Others prefer parallel processing and mix their work on the different aspects.

A librarian from the engineering library gave three lectures on manual and computer library search methods. To get started, the teams worked with the librarian on performing computer searches using *Dialog*. The groups were required to do a patent search and to include patents in their bibliographies. Once they had learned how to do computer searches, the students did their searches independently.

We spent much of the remainder of the semester in individual group meetings. I met with each group for twenty-five minutes during the regularly scheduled class meetings, and since each group met with me three times during the week, procrastination was not a problem. On a few occasions the students told me that they had not had time to do any work since the previous meeting, but this never happened twice in a row. I used the group meetings to discuss technical points and work habits.

One work habit that both groups needed assistance with was how to *efficiently* read journal articles. The students had a tendency to try to read all of the papers thoroughly in an effort to completely understand each article. So we had a discussion on how all papers are not of equal importance. I illustrated the concept of *triage* to them—that through skimming, papers can quickly be classified into three piles: important, possibly important, and unimportant. Since only the important papers need to be read carefully, triage can save considerable time.

Later in the semester I used the group meetings to discuss the outlines, the written sections, the examples, and the homework problems. On occasion, when I felt the students were overwhelmed, the group sessions became pep talks. This kind of support facilitates learning.[1,2]

I dispersed other class activities throughout the semester. Once the students had read a reasonable number of articles, I critiqued their notes on the articles. I found that, almost invariably, the students were not keeping complete enough reference citations. Each group presented two informal progress reports to the class during the semester. In addition to serving as informal communication practice, these reports forced the students to integrate their progress and see what else had to be done.

After mid-term break and shortly before the chapter outlines were due, I gave a lecture on organizing papers and writing, following the ideas of Peter Elbow.[4] Briefly stated, Elbow's idea is that writers should do the first draft as quickly as possible, and then rewrite and rewrite. Toward the end of the semester a technical communication expert gave a lecture on common mistakes in written English and a lecture on oral presentations. I gave a mini-lecture on critiqueing papers after the students turned in their first drafts.

In addition to the two informal progress reports, I used a series of partial assignments on the project in an effort to prevent procrastination. A couple of weeks after the mid-term break the teams turned in a detailed outline of their chapters which I quickly returned to them with extensive comments on what could be deleted and what should be added. Then a first draft of the entire chapter (without homework) was turned in and was critiqued by both myself and the other student team—I told the students to read the chapter and to respond as students who were trying to learn the material. The teams then completed a final version of the chapter which corrected the rough draft. The final draft was due on the last class day of the semester, and during finals period each group gave a formal oral presentation.

THE PROFESSOR'S DUTIES

In this class, the professor's duties differ from those in a normal lecture class. The professor must

- *Develop the class schedule and arrange for the guest lecturers*
- *Present three of the eight lectures*
- *Lead the discussion on book chapters, critique the literature article, and critique the first drafts*
- *Develop an extensive list of acceptable topics and set the criteria for acceptable projects*
- *Serve as a facilitator for selection of groups and topics*
- *Read and grade the first drafts and the final chapter plus the solution manual*
- *Listen to and grade the oral reports*
- *Serve as a consultant and listen, question, encourage, and prod during the remaining thirty class periods*
- *(Perhaps the most important) Set the tone that the students could and would produce a professional quality chapter.*

Since little preparation time was needed, during most of the semester I averaged about four hours a week on this course. This number increased, how-

ever, during the two weeks that reports were graded. Overall, the professor's workload in a class of this type is so low as to be almost sinful. Yet, the students learned a lot and the class was very successful! Student learning depends much more on how hard the student works than on how hard the professor works. Since I was able to focus most of my attention on the students instead of on the material, they received much more personal attention than normal. This class was also *fun* to teach. The students all worked hard in a positive and encouraging atmosphere.

The professor's technical knowledge plays a definite role, but it is not as obvious as it is in a lecture class. An experienced professor can quickly tell when the students are getting bogged down on relatively unimportant points; he can look at their chapters and evaluate how a student who did not know the material would react to it; he can see when the students are developing reasonable knowledge structures and including most of the important material; he can understand the text material, the examples, and the homework problems and thus can evaluate them even though he may not have read many of the cited papers. In my opinion, it would be extremely difficult to teach a class like this if the professor is not an expert in the general topic.

THE STUDENT REACTIONS

The students all became very involved in this course. They invested too much time on their projects and had to work to keep the chapters manageable. They thought that learning how to do library searches was extremely useful and expressed the wish that they had learned how to do this sooner. The following quote from Quarderer is appropriate: "Four to six weeks in the lab can save you an hour in the library."[5]

The students also thought that writing was useful, but difficult. The difficulty involved in developing good homework and example problems surprised them. They found that writing a problem requires better understanding than they could get from merely reviewing the literature.

The students chose to write on Reactive Distillation and on Supercritical Fluid Extraction of Solids. The first topic was almost ideal for this course. There are enough references, but not so many as to overwhelm the students. The material is not covered in any depth in existing distillation texts, but is of considerable industrial and academic interest. *Aspen Plus* was used to develop example and homework problems and solutions.

The second topic was much more of a challenge, mainly because of the huge number of references (almost 19,000 were identified in the computer search). This team had more difficulty in limiting their chapter and in finding appropriate data for examples and homework. They eventually decided to focus on coffee decaffeination since it is the most important industrial process and since there is more information available on this process than on others. They also wrote their own computer programs to solve some of the examples and homework problems.

The reports were excellent as student papers and would be acceptable, but not outstanding, as professional contributions. After one semester of studying a topic, the students' knowledge base remained thin. This was evident from their inability to critically evaluate the work they were reporting on and from their difficulty in writing good examples.

Student evaluations showed that half the students agreed, and half strongly agreed, with the statement that this was among the best courses they had ever taken. Three of the students strongly agreed, while one student was undecided, about the statement that this instructor was among the best teachers they had known. Since the professor did not teach in the traditional sense, it is difficult to interpret this result.

In general, the students thought the course was intellectually fulfilling, that it contributed significantly to their professional growth, and it provided a good background for further study. They also put a lot of effort into the class, were satisfied with their accomplishments, and thought they had done well.

POSSIBLE COURSE MODIFICATIONS

By putting the students into groups of three, one professor could handle up to twelve students. Group meetings with the instructor every other class meeting (that is, three times every two weeks) for twenty-five minutes should be sufficient. With three people in the group, students would still receive significant individual attention. The effort required to grade projects would double with four groups, but grading only occurred twice during the semester. The basic format should be retained with this number of students, including the checkpoints used to minimize procrastination.

The students suggested requiring, or strongly encouraging, all new students to take this course during their second semester. At this point in their studies, new students have chosen a thesis project and a major professor, so the textbook chapters could be written on their thesis topics. Because of the

broad range of topics involved, however, one professor could not teach the course without assistance. The professor in charge could serve as a course coordinator and could present the lectures, while other professors would be involved in working with the groups containing their new students. This procedure would structure the process of learning how to do library research, it would give the students a chance to get a good start on understanding the literature in their research area, and it would provide an early opportunity to improve communication skills. During the process of developing their chapters (particularly the examples and the homework) most students will obtain a good picture of what needs to be done in a given area, and the net effect should be a faster start in research.

The difficulties of a team-taught course include ensuring uniformity in the group meetings and in grading. In addition, students who have not had a graduate-level course in the general area of their topic may have extreme difficulty reading the literature. They would either have to delay taking the course or get extra help from their major professor.

COMMENTS

This course was unusual as a graduate course in chemical engineering since the focus was on learning the *processes* of doing library research and writing a book chapter instead of on learning specific knowledge. Since the students found their own sources and charted their own paths, there was very little structure for the technical material. But there was quite a bit of structure and support for the processes of doing library research and in developing a book chapter. This structure (deadlines, lectures, and continual meetings) is probably necessary to prevent procrastination.

Obviously, the students learned technical content in addition to the process. The content learned was in one narrow area, but with significant depth. A normal lecture-homework-test course could probably cover at least twice as much content, but it is doubtful that the students would learn the material as well, and they certainly would not learn how-to-learn as well as they did in this course.

The original course plan was to ask students to write critical reviews. Discussions in the graduate committee convinced me, however, that this was inappropriate since the students did not have enough expertise to critically evaluate papers. So the course plan was changed to have the students write textbook chapters. In addition, the students would have to develop example and homework problems. Developing problems stretched the students and forced them to learn material they might otherwise only half learn. Including problems also forced the students to write computer programs or to use simulation programs. Overall, asking the students to write a textbook chapter is an excellent pedagogical approach.

The students had to work in teams, and this, of course, follows normal industrial practice. In addition, the projects were too big to be done by a single student within a reasonable period of time, so the team members encouraged each other when the task appeared overwhelming (as it did midway through the semester). The members of one team worked very well together. Their chapter meshed well and it was not obvious which student wrote which section. The other team, however, needed significant encouragement to work together. For much of the semester, the group meetings with the professor served as this team's only point of contact. Their chapter showed a seam where the two parts were glued together. Of course, the presence of seams in multi-author textbooks is not unusual.

SUMMARY

In this seminar course, the students became involved in the processes of doing a literature search and in writing a textbook chapter. As a result of learning these processes, in the future they will be able to learn more efficiently on their own. The professor functioned as a consultant rather than a lecturer, and the net result was that most of the effort and learning was done by the students.

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