COLLABORATIVE STUDY GROUPS

A Learning Aid in Chemical Engineering

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Towards the end of the 1990 academic year, I introduced a system of collaborative study groups into a foundation course in chemical engineering—it proved to be the most exciting thing I have done in my twelve years as a teacher. Apart from the excitement of seeing how well the system worked, it was also the first innovative teaching technique I have found that is actually less work for everyone concerned. The course, "Chemical Process Analysis" (CPA), is taken in the second year of study for a four-year degree in chemical engineering. It lasts two semesters and covers basic material and energy balances in addition to computation and chemical process industries.[1]

The pressures which drove me to do something are evident in Figures 1 and 2. They show the increasing size of our second-year class, as well as its changing composition. The figures show students classified according to racial background because until lately the educational system in South Africa has been divided along those lines. The categories used in the figures are white, other (colored and Indian), and African.

The inequalities of resources and teaching qualifications have meant that non-white students have been disadvantaged to a greater or lesser degree relative to the white students. The result of the educational disadvantage has been reflected in the pass rates in the CPA course: from 1986 to 1990, 81% of the white students passed CPA, while only 52% of the "other" students and 39% of the

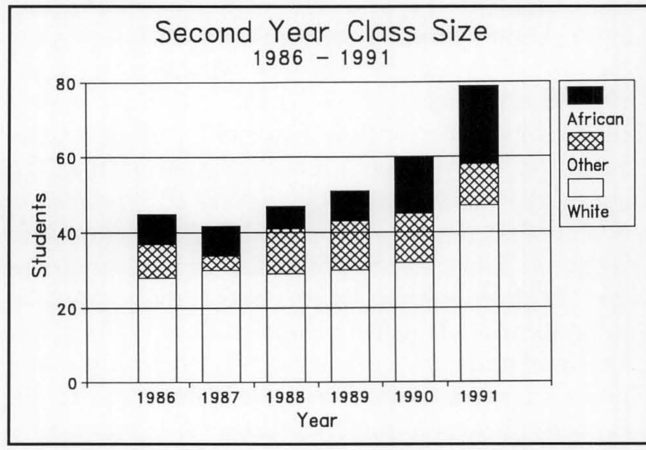

***Figure 1.** Second-year class size.*

African students passed.

I have yet to fully exploit the potential of this system, nor do I claim to understand all that is involved; but here is what I did and why it seemed to work so effectively.

BACKGROUND

Over the past few years I have been grappling with how best to cope with the increasing proportion of disadvantaged students in CPA and their poor success in the course. My first attempt was to set up special tutorials for students who were struggling, but this was only marginally helpful, largely because it added extra work for those who were already having trouble. Our department then decided to commit more tutors to the regular tutorials in the course so that extra help could be given to those who needed it. But even this had little effect in improving the success rate of disadvantaged students.

The tutorial system we were using at this stage was one in which the students were given a set of problems to work on and hand in, with one afternoon per week set aside when they could receive help on the problems. Attendance at the help sessions was voluntary, and one-half to two-thirds of the class generally attended for at least part of the afternoon. Students were encouraged to work on the problems

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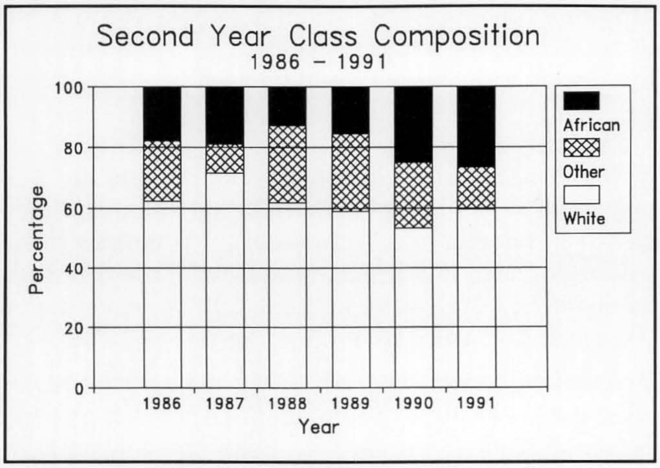

Figure 2. Second-year class composition.

ahead of time so they could come to the tutorial sessions for specific help in areas where they had encountered trouble. Generally, less than half the students took this approach; the rest came unprepared and only began work on the problems at the last possible moment. Typically, if two weeks were given for a set of problems, most students waited until the last week to begin work on it.

While struggling to solve this situation, in mid-1990 Professor Andrew Sass of ASPECT (a special academic support program for disadvantaged engineering students) introduced me to the concept of collaborative study groups. Landis in fact contends that a system of structured collaborative (co-operative) study groups is one of the key features required for a successful minority program.[2] I immediately saw that this might be a solution to the problems I was facing and trying to resolve.

The system which we eventually designed differs from the workshop program developed by Treisman at Berkeley (and since implemented by others) which generally involves minority students doing additional and more complex problems and where a high level of preparation is expected of the students.[2-5] My previous experiences prompted me to include the whole class in the exercise, to enable all to benefit from it, as has apparently been done elsewhere,[6] without adding extra work on any of them.

STARTING OFF

I discussed the idea of collaborative study groups with the class, and together we hammered out the details of running the system. Many of the students were opposed to the scheme—particularly the better students, who were concerned about having to spend more time on the course and were unwilling to "carry" the weaker students.

In the end we agreed that we would experiment, largely for the sake of the students who were struggling. I would compose the groups on the basis of student preferences. I would assign simple problems that could be worked beforehand and would give problems for each session as the students arrived. These last problems would have to be completed during that session. Each student would have to submit his/her own solutions to the problems to ensure that each had done the work, with or without help from the group.

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This first class had been together for the preceding six months and had had previous experience in group work through a design project earlier in the year. Some of the groups consisted of students who all wanted to work with each other, but others were more difficult to compose. In the end I had to appoint some groups comprising only the class "loners." Each group generally had a spread of abilities among its members, either towards the top, middle, or bottom of the class (*i.e.,* students chose to work with others of similar abilities).

As the students tackled the assigned problems that first afternoon, I soon sensed an excitement in the class. Although I gave them a break at mid-afternoon, many of them worked right through, and at the end of the session one student even commented that he had never realized he could work for a solid three hours. Altogether, I ran four of these kind of sessions with the 1990 class. Feedback was positive—even from those who were originally opposed to the idea. All of the students found that they spent less time than they would normally have spent on solving problems, partly because through the group approach to a problem they could discover and avoid silly arithmetic mistakes.

While the group plan was introduced too late in the year to have a significant effect on the students' success, they felt that it was so beneficial to them that they asked that it be repeated in their courses the following year. The second time around, when it was used for the whole year, there was a marked improvement in the pass rate for the course (detailed at the end of this paper).

PROBLEMS

There are problems which need to be addressed. The first is the constitution of the groups. The first time I used the system I noticed that the larger groups of five or six students worked better than the smaller groups of four. This was in spite of the fact that the larger groups often split into smaller groups of two or three. The reason for this seems to be that a critical mass is needed for a group to work effectively. Another factor could have been that most of the smaller groups were comprised of the "loners" in the class. I thought that they would be better off in a group together where they would not be overwhelmed by the others, but that may have been the wrong decision.

In 1991 I again absorved that the smaller groups did not work as effectively, even though in this case they were not groups of loners. In fact, one of the groups started off with six members and was reduced when some of its members left the course. This supports my contention that a critical mass is necessary.

The larger the class is, the more difficult it is to form the groups. I experienced this in 1991 with a class of eighty instead of the sixty that made up the 1990 class. It is also more difficult to constitute groups where the students feel comfortable when the members of a class do not know each other initially. Another factor that I felt had to be considered was that weaker groups needed to be reinforced by including some of the better students in them. In the 1991 class, most of the self-appointed groups had a larger spread of abilities, and I was careful to group the remaining students in like manner, avoiding groups made up of only weaker students.

There has not been any problem in getting students to work together in this manner. Only a few students isolated themselves from their groups, and there was no significant copying from others in the groups. Some groups of disadvantaged students did not readily interact with one another at the beginning, but this was overcome by simply encouraging them to work together (and exciting to see how they changed).

Another problem was how to determine exactly what an average student could reasonably achieve in one afternoon, but this will become easier to determine as we gain more experience in running these sessions. At times I have had to let the students complete some problems at home; but this is not necessarily a bad thing.

Some instructors may have difficulty finding a suitable environment for accomodated a class such as this one. It is essential that each group be able to sit around a table to work, which is impossible in most lecture theaters. I was fortunate in have a suitable flat design room which could be used.

BENEFITS

The benefits of an approach such as this are numerous. The first direct benefit for me was the immediate reinforcement of lectures in the problems tackled, relative to our previous system. This could be achieved in other ways without collaborative study groups, but it was a by-product for us.

Another benefit is that staff time is used more effectively—especially important in view of the increasing academic pressures. Staff can concentrate on the more serious problems which the students cannot jointly resolve in their groups. The result is that students with serious problems have more direct access to the best help since the lecturer is not tied up with trivial problems. Moreover, senior staff can be available to a whole class at once. I have also found that I need fewer tutors.

Student time is also used more effectively since they are able to immediately solve their difficulties in a group setting of collaboration rather than struggling for long periods of time on their own. Marking tutorials become more efficient in that the solutions from each group are generally the same. This means that the instructor can concentrate on conceptual problems and can more readily identify common difficulties.

The system encourages peer-group learning and helps students to build helpful working relationships with others in the class. This is particularly important for students who by their circumstances or nature have difficulty in forming relationships outside of regular classes. It also breaks down the dichotomy found in many minority students between their work and their peer relationshps, which Treisman found was a key factor in their failure.[6,7] I would rate this as one of the most significant educational benefits from the collaborative study group system. It is also in accord with the emphasis placed by Landis on collaborative study.[2]

Another benefit is that students learn to communicate with one another on a technical level, which is very important for aspiring chemical engineers. This was noted by Hudspeth in the academic excellence workshops run at California State Polytechnic University,[3,5,8] as well as being one of the reasons Landis used to encourage students to work in such groups.

An additional advantage is that the problems from previous years can be re-used since students work the solutions on their own in class and do not copy the solutions. This is particularly helpful when there are significant numbers of repeating students in the class (as was the case in this course).

The second time I taught these sessions I realized that most students were not solving the straightforward problems I gave them as preparation, which meant that they were taking too long coping with the more complex problems. I rectified this by assigning a straightforward problem first off, and it had the desired benefit of enabling them to handle the more difficult problems that were assigned later.

With students working in groups there is also the potential to pose problems which require interaction and which cannot be solved alone. I have yet to exploit this potential.

ESSENTIAL FEATURES

The following key elements can be identified as essential features of the collaborative study group system. I doubt whether the system would work if any one of the features was missing.

- Students work in groups but produce their own solutions to the problems.
- The groups are chosen on the basis of student preferences, subject to the constraint that each student must be part of a group.
- The groups are large enough to allow for significant interaction between the members, but not so large as to be unwieldy (six members per group seems to be optimum).
- Attendance at group problem-solving sessions is compulsory. (This is done by making it a requirement for entry to the examination.)
- The groups work together on the problems. (Students who like to streak ahead are discouraged from doing so, as are those who want to work entirely on their own.)
- The groups work around a common table. (A group of six working in a row does not allow for meaningful interaction.)

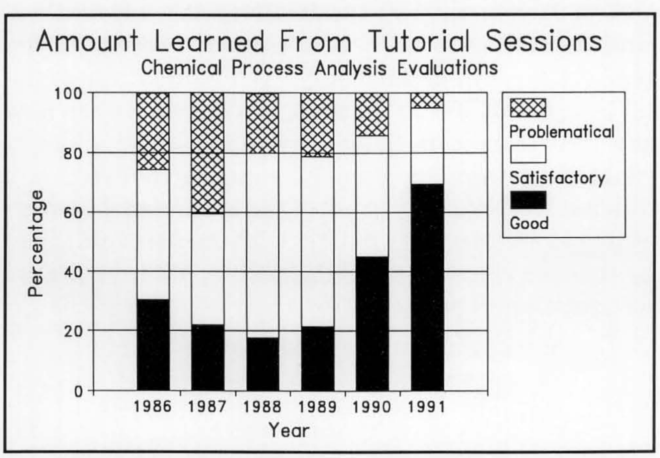

Figure 3. *Student evaluation of tutorial sessions.*

- The problems assigned are not known by the students beforehand (allowing the session to become a shared experience, which generates much of the excitement).
- Solutions to the problems must be handed in by the end of the session. (This makes the students get on with the job; there has been some flexibility as to how much must be completed).
- The system was adapted from similar systems used elsewhere, in consultation with the students themselves.

OUTCOME

Figure 3 shows the response in course evaluations to the question concerning the amount learned from tutorial sessions. The effect of the few group sessions run in 1990 can be clearly seen in the increase of those responding positively, compared to previous years, with a concomitant decrease in negative responses. There was further improvement in these responses in 1991 (when the collaborative study group system was used for the whole course), with 69% responding favorably and only 5% indicating that they had problems.

In 1991 the pass rate for the course improved as follows: for the white students it increased by 15%; for the disadvantaged students, 65%; and for the class as a whole, by 28%.[9] This is a clear indication of the general educational benefit of collaborative study groups, as well as the special benefit derived by disadvantaged students.

Judging from the student reaction and by the improved pass rates for the course, the system of collaborative study groups was a success. One of the secrets of its success was that the system structure was jointly forged by the students and the instructor. This meant that the next group of students also accepted the system well in spite of not having been involved in its formulation.

The challenge for me as instructor is to be creative in how I use the system. But I am convinced that even if I simply use the same problems that I have already used, the students will still be much better off than they were under the prior scheme. It took a good amount of courage to implement the system the first time, but that courage was amply rewarded. I strongly encourage others to try something similar, even if only a single period is available for this sort of exercise instead of a whole afternoon. It can still have a lasting impact on the way in which students learn.

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Continued on page 64.

neering professionals in general, as they are at present, we may see calculators aimed specifically at chemical engineers. Such a series of calculators might consist of a common hardware core, with large-capacity plug-in modules of extremely specific information and operations which customize the calculator for particular professions.

My own view is that the computing component of the engineering curriculum should include serious treatment of advanced calculators and that their use in all aspects of engineering education (including student performance evaluations) should be encouraged. I do not suggest offering a course specifically on calculator usage for two main reasons. First, how could one justify the selection of one brand over another, or indeed the selection of calculators *per se* over, for instance, spreadsheets as a topic worthy of instruction? Second, the utility of such material would rely heavily on existing technology which quickly becomes outdated, leaving the graduate no further ahead.

Rather than viewing this as just another subject vying for attention in an already overcrowded curriculum, perhaps it should be looked at as a way of legitimately easing the teaching load, alleviating the drag caused by those students who are currently overloaded with mathematical tasks of dubious educational value. In particular, using advanced calculators could give the instructor an opportunity to place greater emphasis on "what if"-type problems from which the students can quickly grasp the effect of varying the parameter values on the outcome of a solution without significantly increasing the time required for completing the assignment.

Certainly, the future of calculators is aimed at more comprehensive and sophisticated utility for the engineering professional. We should take them seriously. ❒

Cooperative Study Groups

Continued from page 41

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Review: Process Dynamics

Continued from page 33.

has costs and benefits. The most evident cost is that a sequential reading gives a repetitious treatment of some topics. Material regarding PID implementation is found in at least three different parts of the book. Stability is treated in different parts with distinctly different approaches. Counting the degrees of freedom in a process is discussed in both the first and last parts of the book. A more subtle penalty is that this already large book doesn't have room for more detail on some important topics. Anti-reset windup, for example, is mentioned in passing. Thus, an instructor has to carefully plan an approach to the book and what parts to emphasize or omit. Students also have to be patient with the discursive nature of the book.

Of course, the positive side of modularity is that the book can be adapted to a variety of uses. This is a strong feature, given that process control courses are often by academics who are not experts in the field. This is enhanced by the large set of well-chosen, end-of-chapter problems.

References to widely available tools for computer-aided control analysis are given in a separate appendix. Unfortunately, these are not incorporated into the text or problems. Matlab and its associated toolboxes have been widely adopted in many universities. A low-cost student edition of Matlab is now available which would be a good supplementary text for a course based on this book.

Process control is a rapidly growing subject driven by advances in computing technology, needs for improved process automation, and new theory. This text gives a contemporary overview in an accessible, teachable format. I suspect that the ideal turn-of-the-century course will deemphasize complex variables in favor of statistics, optimization, and model predictive control. But in the meantime, this book is a worthy competitor for market dominance among existing process control textbooks. ❒