Revitalizing Statistics in the Chemical Engineering Curriculum

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For many years, the Department of Chemical Engineering at the University of Colorado has struggled with the dilemma of how to provide our undergraduate students with appropriate knowledge and skills in applied statistics. We have attempted, with varying degrees of failure,

⇒ traditional "introduction to probability and statistics" courses at the sophomore and freshman (!) levels taught by ChE faculty or applied mathematicians
⇒ statistics "modules" concurrent with our junior and senior laboratory courses
⇒ a capstone statistics course in the last semester of the senior year

In the last two years, we have developed and implemented a new approach embodied in a new course at the beginning of the junior year. This new course, Applied Data Analysis, combines a mainstream of applied statistics with a threadline of content in instrumentation and measurement techniques. The purposes of this integration are two:

⇒ to bring relevance and life to the statistical material, and
⇒ to prepare students for the measurements and data analysis of the following laboratory courses

A first attempt at this course was not successful (students' point of view). In a second attempt, the instructional format was revolutionized to an active-learning environment, where lecture presentation has been minimized and group workshop activities now take up a significant portion of class time. This transformation has brought about a successful offering of the course, and a tale worth recounting.

In the third offering of the course, the active-learning environment will be enhanced through use of a new classroom designed around cooperative learning in the new Integrated Teaching Laboratory of the College of Engineering and Applied Science at Colorado.

An alternate title to this paper/presentation might be:

How to keep 60 ChE juniors awake and interested in statistics at 8 o'clock in the morning!

Background – Statistical Content in the ChE Curriculum at Colorado

The Department of Chemical Engineering at the University of Colorado has been struggling with the issue of statistical content in the curriculum for over a decade. We have tried a number of approaches and have been unsatisfied, for diverse reasons, with them. These include:

⇒ a 2^{nd}-semester freshman course in introductory probability and statistics
⇒ a 2^{nd}-semester sophomore course in the same
⇒ companion instruction in our junior/senior ChE lab courses
⇒ a senior-level capstone statistics course

Two years ago, our latest attempt was to create a 1^{st}-semester junior-level course called Applied Data Analysis. This course was to combine elements of applied probability & statistics with measurements & instrumentation. The rationale was two-fold:

use of real measurements & instrumentation would bring statistics to life
on-target material would prepare students well for the two lab courses that follow

The general outline of this course is shown in the table below:

Course Outline

Topic	No. of Meetings
Probability and measurement fundamentals	5
Discrete and continuous distributions	5
Sample statistics, intervals & hypothesis testing	6
Pressure and flow measurement	4
Regression analysis & correlation	6
Temperature measurement	2
Hour Examinations	2

	30

The course was taught for the first time in the Fall 1995 semester. We were disappointed when the course was not well received by the students. There appeared two be a number of causes:

⇒ class meeting time of 75 minutes, Tuesdays & Thursdays, starting at 08:00 hrs
⇒ straight lecture presentation of all material
⇒ perceived lack of relevance
⇒ course topics perceived to be encyclopedic, dry and boring

This was discouraging to say the least, since the institution of the course was well motivated. Our department was interested in making Applied Data Analysis a successful course.

Applied Data Analysis in an Active-Learning Environment

An obvious remedy to a typical student complaint would have been to reschedule the course away from the 8 a.m. meeting time. Given the constraints of our curriculum, this was not possible for the Fall 1997 offering of the course. It may be considered in the future though. Rather, the Applied Data Analysis course seemed an ideal candidate for an innovative and revolutionary change in mode of instruction (we were desperate!).

As part of the development of our Integrated Teaching & Learning Laboratory (ITLL) in Engineering at the University of Colorado, active-learning environments were envisioned and encouraged. The general concept is to move away from the passivity of students listening to lecture toward more direct involvement of students in learning activities, hands-on activities wherever possible.

In the Fall 1997 I took on the challenge of teaching the Applied Data Analysis course in such a mode. I was provided with a 50% increase in TA resources, a 5% release, and $2,500 for materials from the Undergraduate Excellence Fund of our College. This is a student-managed fund that receives approximately $700,000/year from student fees and differential tuition. I envisioned an active-learning workshop in each class and patterned class meetings in the following way:

- ⇒ 5-10 minutes of Q&A
- ⇒ 10-minute mini-lecture (just the main concepts & high points)
- ⇒ 10-minute example problem
- ⇒ 40-minute active-learning workshop
- ⇒ 10-to-15 minute synopsis

This plan required the development of 28 active-learning workshops. These are described in the table below:

Workshop Theme	Activity
1: Binomial distribution	10-coin flip
2: Temperature measurement	Measure temperature distribution in Engineering Center
3: Permutations/combinations	Exercises with lettered cubes
4: Probability	Exercises with playing cards
5: Error analysis	Cylinder volume using calipers
6: Hypergeometric distribution	Exercises with lettered cubes, w & w/o replacement
7: Poisson distribution	Traffic measurements
8: Normal distribution	Weight of commercial coffee bags
9: Exponential distribution	From traffic measurements
10: Independence	Build joint distributions on checkerboard
11: Graphical techniques	Stem-and-leaf & box plots of coffee bag data
12: Estimation	Random number sets, effect of sample size
13: Pressure measurement	Dead weight tester calibration

14: Uniform --> normal	Excel computer exercise
15: Rotameter Calibration	Rotameter reading versus catch-and-weigh
16: Confidence Intervals	Fluid flow apparatus: flow signal
17: Hypothesis test: Type I & II Errors	Coffee bag data
18: Comparison test	Fluid level data
19: Orifice: heat exchanger	ΔP cell versus catch-and-weigh, orifice equation
20: Straight-line regression	Rotameter data
21: Linear Regression	Orifice data
22: Regression: transformed data	Arrhenius reaction data
23: Correlation: Analysis of Residuals	Orifice Plate regression results
24: Characterizing Fluid Friction	Fluid-flow apparatus
25: Polynomial regression	Fluid friction data
26: Regression analysis	Model discrimination
27: Temperature measurement	Thermistor measurements, linearization
28: Temperature measurement	Thermocouple measurements

All workshops were completed in groups of four students. Five cycles of groups were used during the semester. Three of the cycles used randomly assigned groups: the other two allow the students to select their groups. Students did not complain about this arrangement.

Other course activities included reading assignments for each class, weekly homework assignments, two mid-term examinations and a final examination.

Course Results and Evaluation

Comparative student evaluations from the Fall 1995 to the Fall 1996 course are listed below

	Fall 1995	Fall 1996
Overall course rating	D	B-
Instructor rating	C-	B+
Workload	6.5	6.7

Note: workload is on a 0-10 scale, with 10 heaviest, and 5 just right (in the student's mind).

Students evidently evaluated the course more highly in the new format. In general, comments of students were supportive of the active-learning format with the exception of a small minority that found the group workshops difficult to adjust to. Also, the workshops placed a premium on attendance in class, and a few students objected to losing their "inalienable" right to cut class.

Learning achievement appears to have been improved over the previous offering of the course. Additionally, the instructors of the follow-on ChE laboratory course have consulted with me to determine ways in which to link the two courses strongly. Consequently, students are revisiting many of the concepts and methods of Applied Data Analysis in their junior ChE lab course, as it should be.

Classroom architecture was not ideal for the active-learning mode of instruction. The course was taught in a tiered room with long, narrow tables. This made organization into groups somewhat awkward. Next year we have the luxury of using an active-learning classroom that is available in our new Integrated Teaching & Learning Laboratory. This room is ideal for this mode of instruction as it is based on a series of round conference tables. In fact, this room will be awkward for traditional lecture.

Future Directions

We anticipate that the course will improve next year based on the following facts:

1) The new classroom suited to active-learning instruction will be used.
2) The workshops will be revised and, hopefully, improved.
3) The course will now meet from 9:30 to 10:45 a.m. (coup!)

This author has now incorporated active-learning techniques into a senior-level process control course, and the early reviews are rave. We have bought into this mode of instruction in order to improve the education of our students.

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Biographical Information

David E. Clough is Professor of Chemical Engineering at the University of Colorado in Boulder. He joined the faculty there in 1975 and also served as Associate Dean of the College of Engineering and Applied Science from 1986 through 1992. His research and professional interests are centered on process control.