Report to Rowan Chemistry Faculty On

An Experiment in Teaching
Advanced Chemistry I as
A One Year Course in General Chemistry to Engineering Students
In One Semester

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Summary

Dear Colleagues,

Attached is my Annual Report on the experiment with an alternative course design in Advanced Chemistry I (AC I) course.

In brief:

- In 2007 and 2008, to accommodate the scheduling requirements of engineering students, I conducted instructional experiments that attempted to teach a full two semester General Chemistry course in the schedule of a one semester course.

  The course was offered primarily to admitted engineers, prospective majors in the physical sciences, and students seeking admission to the College of Engineering.

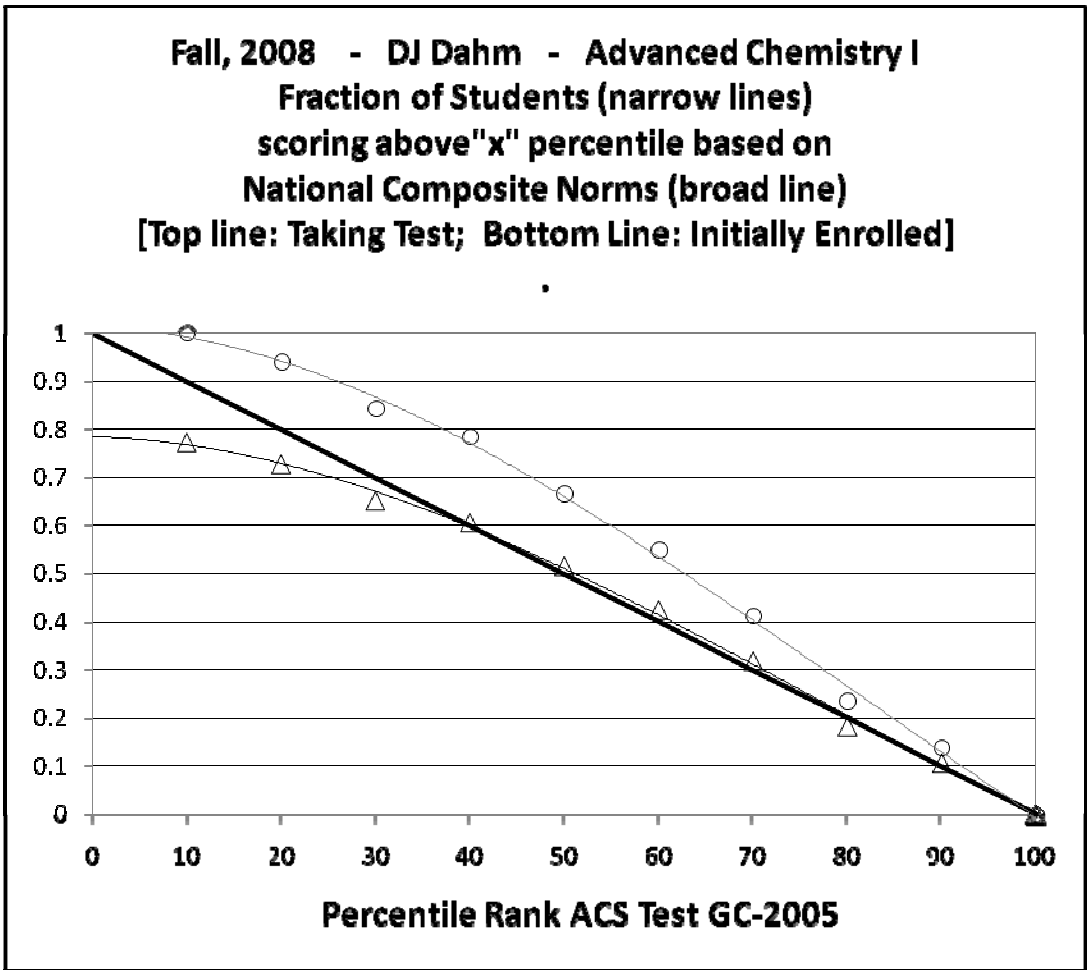
  At the end of one semester, students were given the *ACS Examination in General Chemistry* that covers the content in a standard two semester General Chemistry sequence.

- In December, 2008, in my three sections of AC I, students scored at the 63rd ACS percentile, up from the 52nd percentile in 2007. 67% scored above the ACS mean and median.

- The number of labs students were able to complete during the semester increased from 10 in 2006 to 12 in 2007 to 15 in 2008.

- Student retention rates among the majors and admitted engineers were relatively high, but a substantial percentage of the "engineer wanabees" did not complete the course.

- In the report that follows, items that may be of interest in the standard General Chemistry sequence are also discussed.



Top Narrow Line: The students taking the Final Exam scored above the National Norms (shown by the broad line above).

Bottom Narrow Line: Including the students who did not take the Exam, the students scored at the national norms (except of course, at the low end where the fraction can be no higher than the fraction actually taking the Exam).

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Disclaimer

From this report, I am not claiming that the method of instruction outlined here is superior to any other. In my case, the method described here worked better in my view than the one that I used previously, and furthermore, enabled me to cover more material and assign more laboratories in the class.

Disclosure

The experimental course design employed in my AC I sections included substantial use of two instructional supplements: the *ACS Official Guide to Examinations in General Chemistry*, and *Calculations in Chemistry*, *Calculations* is a draft, experimental textbook by retired instructor E. A. Nelson currently offered free online and in a non-profit paperback format. Since I am scheduled to have a clean break next semester, I have recently discussed with Mr. Nelson the possibility of a partnership with users of the draft textbook that would add to, edit, and review its content. If that collaboration proceeds and if the material is published in a commercially viable form, I and the other participants in the project would have an equity share in the publication. Rest assured, I am undertaking this because I have come to believe in the approach, not in hopes of material gain.

General Chemistry

It is my view that elements of the AC I experiment, if applied in sections of Chem I and II, might both assist students and ease the burdens placed on instructors.

The instructional supplements lend themselves to experimental use, and evaluation on a small scale, by individual topic. If instructors in Chem I or II have possible interest in this pieces of this material and/or other aspects of the project, I would be happy to discuss my experience in additional detail.

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Background for Non-Rowan Faculty

Rowan is a state university is located in Glassboro, NJ enrolling nearly 10,000 students. In 1992, the former Glassboro State College received a $100 Million gift from Henry and Betty Rowan with a focus on support for pre-doctoral instructional programs. Rowan includes a college of engineering and other professional programs as well as liberal arts and sciences.

In Chemistry, first-year students at Rowan have two options. Most enroll in a standard two semester sequence in General Chemistry.

However, students in the college of engineering, because of the credit requirements of their schedules, are only required to take one semester of Chemistry. To meet the their needs, a course termed "Advanced Chemistry I" (AC I) was created by the Chemistry Department. Though termed advanced, the course is better termed "Two semesters of General Chemistry taught in one semester -- for admitted engineers, aspiring engineers, and physical science majors." From 2006 to 2008, the course has been offered in each fall semester.

The AC I schedule included two 75 minute lectures and a 2.5 hour lab block each week for 16 weeks. The time allotted in AC I to cover two semesters of General Chemistry was thus the same as allotted for lab, lecture, and study outside of class for one semester of the regular two semester General Chemistry sequence. In AC I, voluntary after-class problem-solving sessions are also held for students approximately once a week.

Background -- Advanced Chemistry I

I have taught sections of AC I in the fall of 2006, 2007, and 2008. My initial enrollments averaged about 70 students divided into three sections. On average, roughly 75% were admitted engineers, 7% intended to major in the physical sciences or were pre-med, and 18% aspired to gain admission to the engineering college but had not yet been admitted (students dubbed the "wannabe Es").

2006: Concerns With Course Design

In the Fall of 2006, I taught three sections of Advanced Chemistry I. The text being used was the first ten Chapters of Zumdahl: Chemical Principles. I taught it in the traditional style: I assigned reading in the text (Zumdahl), lectured on everything I expected them to know, worked some problems in class, and used Lab time to get it all in. Along the way, I became convinced there were several aspects of the course that needed improvement.

1) The course did not cover electrochemistry, even though the Electrical Engineers did not take Advanced Chemistry II. (I included Electrochemistry in 2006, as a first "improvement".)

2) A large majority of the class members were not able to do the harder problems from the Test Bank accompanying the Text.

3) I would notice that in the next class after a well-crafted lecture explaining an important concept, many students would act as if they had never heard of the concept before.

With the permission and support of the department, I embarked upon experiments with significant structural course changes.

Goals of the Experiment

The primary goal was to see if the Advanced Chemistry I students could be taught, in a single semester the material described by the American Chemical Society as a one year Introductory College Course. Success was to be measured by using the American Chemical Society Examination for General Chemistry (the "ACS exam").

The second goal was to see if the material could be taught without using one of the conventional chemistry texts. My objections were:

a) They are far too wordy, so that it is hard to distinguish the critical from the merely important.

b) They are regarded as largely incomprehensible by students.

c) They are expensive.

Selection of tools for the Experiment

A colleague supplied me with the address of a website that he had recommended to his students. That site { ChemReview.net } contained a set of "module" workbooks labeled as *Calculations in Chemistry* covering most (but not all) of the "calculation-oriented" subjects covered in a one year general chemistry course.

The *ACS Official Guide to Examinations in General Chemistry* was used for student assignments, as I thought it was important to expose the students to the material content and style of the test on which their performance would be judged.

These two supplements became my primary "textbooks."

2007 -- Procedure for Class

Each Unit was covered in a fashion somewhat like this.

1) The Modules were assigned before the lectures began for the unit. (This was as recommended by the author.)

2) There was a conceptual lecture on the material for each Unit, and a lecture in preparation for the Laboratory for the week. The Laboratory included Supplemental Problems, for which answers were not provided.

3) There were supplemental reading assignments by "handout", or by "topic" in their reference book (or the web). These (and all assignments) were highlighted on the WebCT homepage.

4) An assignment was made in the ACS Guide. (Sometimes specific questions were assigned, often it was “do the Study Questions and every third Practice Question”).

On the convenient class day, there would be a Test/Quiz on the previous week’s material (from a textbook question bank), and on this week's module assignments (usually using quizzes provided by the module author). Homework was examined once a week, but not graded except to note how much had been done. Problems in Labs were graded.

There were four Exams, one at the end of each course segment. (In 2007, Exam IV was the same Test that had been given in 2006 as the Final Exam.) In 2007 (and 2008), the Final Exam was the *ACS Examination*. I did not look at the examination before I finished the course material to avoid teaching to the test. As the semester went on, I found myself using the *ACS Exam Guide* more and more as the basis for class instruction.

To evaluate the experimental results, three standards were chosen: student scores on the *ACS Examination in General Chemistry*, the number of labs conducted during the course, and the retention (and/or DFW rate) of students.

2007 Results

On the ACS Examination in General Chemistry (Form 2005), 52% of students scored above the ACS Median percentile.

Though some lab time was used for lecture in order to cover the General Chemistry curriculum in one semester, the number of labs administered increased from 10 in 2006 to 12 in 2007.

The percentage of students receiving a grade or D or F was about the same as in 2006, but the number of student who withdrew was somewhat reduced. Overall, the

DWF rate was approximately 25%, somewhat lower than seems to be the norm by the end of courses covering the General Chemistry curriculum.

A disproportionate number of the students who withdrew came from the students who had not yet been admitted to the College of Engineering.

There were several glitches in the course. The Equilibrium Quiz revealed that the information was not being learned properly from the modules. I added a week to the coverage of this section, and the test on the section showed improved learning on the section. Additionally, the *Calculations in Chemistry* modules in 2007 did not include solubility products, thermodynamics, or electrochemistry (these were added by 2008). These topics were covered by lecture.

There were topics that were not covered in as much depth as in past years. This seemed not to hurt results. The amount of class time spent working problems was considerably reduced and time spent in "help sessions" was significantly increased. There were no "D" or "F" grades among those who came somewhat regularly to help sessions.

The test and exam data during the semester consistently showed improved grades over 2006. While it was impossible to have the grades on scales of identical difficulty, the grade scale which wound up being used was numerically more demanding in 2007, especially at the A and B levels. Thus, I concluded that the increase in the number of "C" grades (compared to "D") represented a genuine improvement.

The 2007 performance is summarized in the Chart of Results below.

My conclusion was that the concept of covering a full year's course material in a single semester was shown to be feasible for this group of well-prepared first-year students.

Changes Between 2007 and 2008

Based on the 2007 results, several changes were made for the sections of AC I taught in the Fall of 2008.

A regular textbook was added to the course as a source of content, graphics, and problems. The ACS textbook *Concepts in Chemistry* was chosen.

Both *Calculations in Chemistry* and the *ACS Official Guide to Examinations in General Chemistry* continued to be used as in 2007. The 2008 version of Calculations included the units noted above, reducing the time required for lecture.

For 2008, the emphasis on a “homework grade” was increased. Students were asked to complete 200 or more problems in a problem notebook during the course (about 14 problems per week) from among the recommended assignments. The problem notebook was periodically evaluated for the number of problems completed, and spot

checked to make sure the problem solving approach was reasonable. The homework grade was intended as a way to both reward and evaluate student effort.

2008 Results

For my three sections of Fall 2008 Advanced Chem I, on the ACS General Chemistry exam, based on percentile distributions supplied by the ACS,

- The median student score on the ACS Exam scored at the 63rd percentile. 67% of students scored above both the ACS mean and ACS median 50th percentile .

- Only 10% of students scored at the 25th percentile or below.

- Out of 68 enrolled in AC I on day 1 and 58 enrolled at mid-term, 51 took the final exam -- a retention rate similar to that in past years in AC I. The majority of students who did not complete the course were students who had interest in, but had not been accepted to, the College of Engineering.

- The number of labs that were completed under the new course design increased from 10 in 2006 to 12 in 2007 to 15 in 2008.

Discussion of the 2008 Results

The experiment with the ACS Text Book I judged to be unsuccessful. In my view, the approach requires that the instructor stay right with the text and lecture extensively, because it is not sufficiently pedagogical for students to learn from on their own. More lecturing is what I was trying to get away from. At midterm, we changed its designation from "text" to "reference book." On the positive side, the set of problems at the end of the chapters are very good.

The bright spots were the *ACS Exam Guide* and the Modules from *Calculations in Chemistry*. The ACS guide does a better job of teaching the reasoning steps in the problem solving process, but the Modules do a far better job of teaching the concepts. I found both to be a good source for homework problems, though an additional source for more difficult problems is needed.

Compared to previous years, 2008 classes did poorly the first half of the semester, but much better the second half. While there may be other factors explaining this, the main change that I made at mid-term was to begin using *Calculations in Chemistry* as the primary text, and relegated the ACS Text to a position of Reference Book. This reduced the necessity of lecturing on many (but by no means all) topics.

Adding the homework grade was judged a success. Of the 13 A's for final grades in the course, 10 of the students had completed more than 180 Homework problems by 11/30 (I use that date to eliminate those who did a blitz of homework at the end). Furthermore, 10 out of 15 students who had done the 180+ problems got A's. In the few cases where students complained of the pace and difficulty of the course, reference to the homework grade usually spoke to their results.

For next year, I recommend that the enrollment in Advanced Chemistry I be limited to students who have been accepted into Engineering, or who have taken the AP Chemistry test and scored a 1, 2, or 3. Students scoring a 4 or 5 on the Chem AP should be scheduled into higher level chemistry.

ACI -- Summary

The grades and ACS Exam scores in my Advanced Chemistry I classes have improved over the last three years. This was concurrent with, and presumably due to, a greater reliance on the "workbooks" *Calculations in Chemistry*, in which assignments were made on a topic before lecturing began, and the *Official Guide to the ACS Exanimation in General Chemistry*, which was used to define a minimum depth of coverage on each subject. The textbook was relegated to a position of a reference, and was used as a source of harder problems. Lecturing was reduced, and the number of Labs offered was increased by 50% over the last three years.

The DFW rate for students initially enrolled was not insignificant, but was below the level that seems to be the norm in most full courses in General Chemistry.

Possible Implications For Regular General Chemistry

Initially, the one-semester timetable for AC I, an attempt to meet the scheduling realities of the Engineering College, was NOT viewed as ideal by anyone involved. That said, I believe that most of the engineering and science majors in AC I rose to the one semester challenge.

How might a similar course design would work for the much larger group of students at the more reasonable pace of standard General Chemistry? During the Spring of 2008, I was assigned two sections of regular General Chemistry I,. I taught them using the same course design and supplemental materials as in AC I.

No one should be convinced by results from a single semester for two sections. Further, the department did not have access to an ACS exam that matched our first semester topics, so ACS percentiles comparisons are not directly applicable in the way the Adv Chem I course was .

That said, using a course design similar to AC I (but the standard pace), the DFW rates in my section were about 40% below the historic average for the course, and on the ACS one semester exam which was not a good match for our content, student scores averaged at the 48th percentile.

Current Problems

The current design requires a regular textbook for reference, diagrams, difficult problems, and many "qualitative" topics not covered in enough detail in the *ACS Examination Guide* or *Calculations in Chemistry*.. Though the cost of the two supplements is relatively small compared to a text, on top of the cost of a major text, cost is a factor.

As I understand it, textbook publishers soon will be required to offer bookstores textbooks at prices both "bundled" and unbundled with supplemental materials. This may allow more instructors to experiment with alternative supplements.

The *Calculations in Chemistry* lessons do not cover all topics in the General Chemistry curriculum. According to the author, they remain "a work in progress;" not yet professionally edited or reviewed.

Chart of Results: 2006 to 2008 -- Advanced Chem I -- Dahm Sections

		2008	2007	2006
# Labs		15	12	10
Initial Enrollment		66	73	?
Withdrew, Transferred		5, 3	8, 0	1, ?
Mid-Term Enrollment		58	64	58
Took Final Examination		51	58	54
Majors Taking Final / Initially enrolled	# Admitted Engineers	45 / 51 : 88%	54 / 64	46 / (48)
	# Chemistry, pre-Med, Physics	4 / 4 : 100%		2 / (3)
In 2006, Taking Final / (enrolled at midterm)	# Wannabee Es or By Mistake*	3 / 11 : 27%	4 / 9	6 / (7)
# Chem AP		12		
AP 1-2		4		
AP 3		6		
AP 4-5		2		
ACS Mean		34.8	34.8	
Class Mean		38.5	35.4	
Mean Excluding Wannabees		38.9		
ACS Median		33 R out of 70 Q	33 Right	
Class Median		38 Right	35 Right	
Final Exam Mean % Grade		77.4 %	72.9%	67.3 %**
Success Rate DFW ***		70 % 30 % (24 %)	71 % 29 % (25%)	69% 31%
Final Grades	A	13	7	8
	B	21	15	15
	C	10	29	17
	D	5	5	13
	F / W	14	12	5
Mean % Grade Course of those taking Final.		81 %	75%	72%

* "By Mistake" students probably enrolled because Chemistry I classes were full.
** Scaled 2006 results to 2007 based on a common Comprehensive Exam.
*** The number in parentheses is the DFW rate if Wanabees and those who never attended after the first week (but received Fs) are excluded.