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The Curriculum in Quantitative Analysis: Results of a Survey

During the course of undergraduate studies, every chemistry major is introduced to the concepts of quantitative analysis. As instructors of sophomore-level quantitative analysis courses at the City University of New York, we wanted to learn whether the content of our courses was similar to that of others in the United States. We developed a short questionnaire to determine which topics our colleagues teach, how much weight they give these topics, and which experiments they use in the laboratory. We also wanted to discover how closely the ACS examination in quantitative analysis (*1*) matches the typical course curriculum. This REPORT describes the questionnaire and the results we obtained and poses some basic questions about the curriculum in quantitative analysis.

Questionnaire, distribution, and response

The three-page questionnaire contained three parts. The first part asked for demographic and general course information. The second part asked for an estimate of the number of lecture hours devoted to a given set of topics. This set was essentially the table of contents of Day and Underwood's text (*2*) plus a few additional topics; any of the popular current texts include virtually the same topics. We also requested estimates of the number of lecture hours spent on these same topics in the instrumental analysis and general chemistry courses, primarily to determine where subjects not discussed in the quantitative analysis course were covered, if at all. However, responses to this question were insufficient for meaningful conclusions to be drawn. The third part asked about the laboratory experiments performed in the quantitative analysis course and in the other two courses; the list of experiments was drawn from the Day and Underwood laboratory manual (*3*) and from our own experience. Space for listing additional topics was provided, and comments were solicited.

REPORT

The questionnaire was sent to approximately 300 colleges and universities in the United States. The addressees either were known by us to be ana-

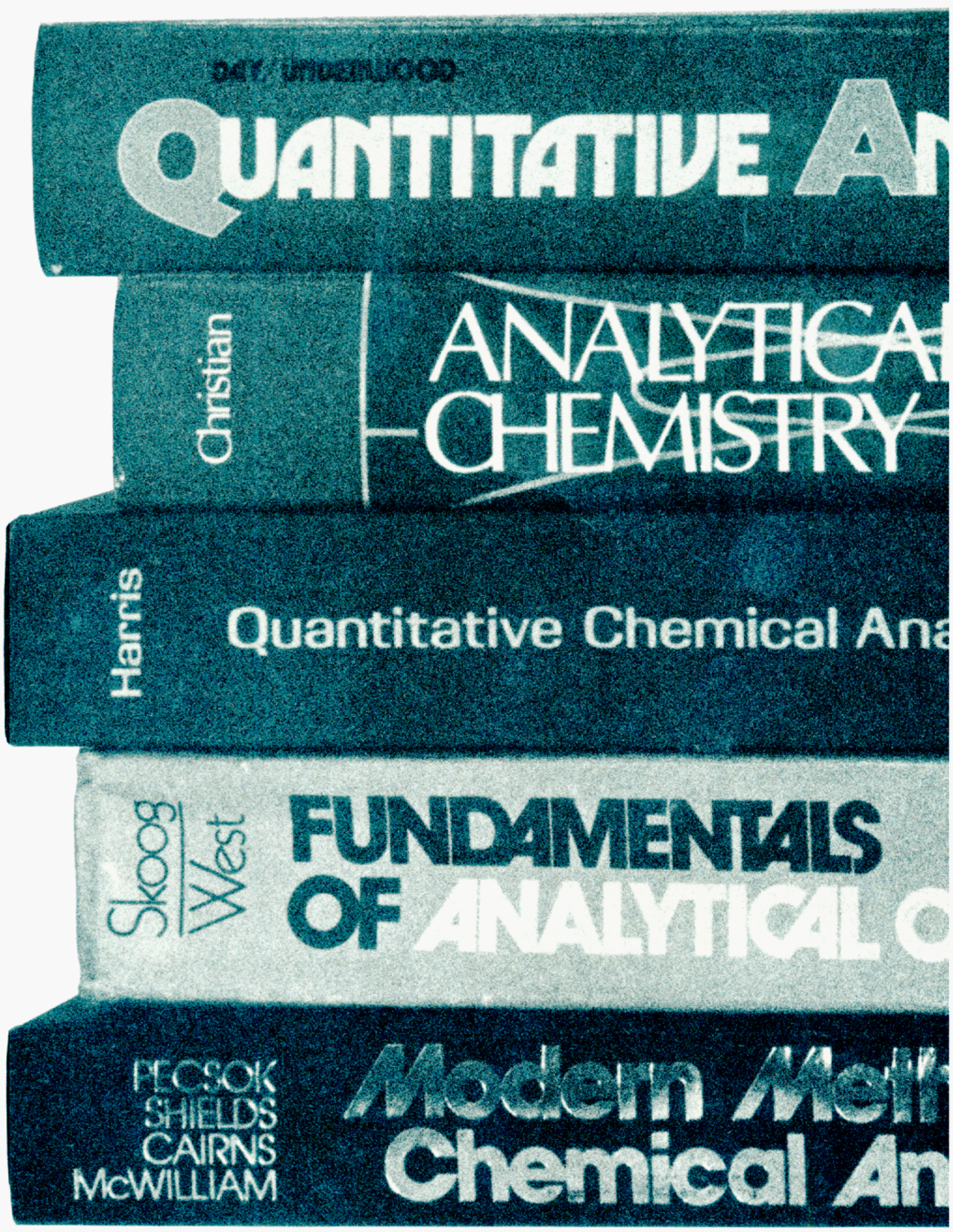

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Table I. Textbooks used in quantitative analysis courses

Textbook authors	% of Respondents using[a]
Skoog & West	31.1
Harris	23.6
Day & Underwood	11.3
Fritz & Schenck	7.5
Christian	5.7
Ramette	4.7
Kennedy	3.8
Flaschka, Bernard, & Sturrock	2.8
Harris & Kratochvil	1.9
Kenner & Busch	1.9
Brewer	0.9
Guenther	0.9
Pecsok, Shields, Cairns, & McWilliam	0.9
Peters, Hayes, & Hieftje	0.9

[a] $n = 104$

lytical chemists or were listed in the ACS *College Chemistry Faculties* (*4*) as specialists in analytical chemistry. The specific colleges were chosen somewhat arbitrarily, but we attempted to strike a balance among two-year community colleges, four-year colleges, and research-oriented universities. The surveys were mailed out in June 1986; those returned to us by October 1986 are included in this summary.

Of the 300 questionnaires sent out, 119 were returned, and 109 of them contained usable information. However, because only three of the approximately 50 two-year schools that received the questionnaire responded, the effective rate of return is 109 out of 250, or about 40%. This high response rate—and the fact that nearly every respondent requested a copy of the survey results—indicates to us that academic analytical chemists are greatly interested in the content of quantitative analysis courses.

Respondent profile

From the general information section we learned that the respondents were predominantly (98%) from four-year colleges and universities; 83% of the schools offer a one-semester course, 16% a one- or (rarely) a two-quarter course, and only one a trimester course. The course size varied considerably; 44% of the schools typically register 20 or fewer students per course; 41% between 21 and 50; and 15% have 51–150 registrants. Two-thirds of the quantitative analysis courses are scheduled for 3 hours of lecture per week; one-third have 2 lecture hours. A few have either 1 or 4 hours of lecture. In the laboratory, 6–10 experiments are done in three-quarters of the courses; 90% schedule 3–6 hours of lab per week (3 or 5 lab hours, 12.5% each; 4 hours, 20%; 6 hours, 45%), and a few have 7–9 hours. However, if we group responses by number of lab hours and separately average the number of experiments done by each group, the average number, 8.9 experiments, is almost independent of the number of scheduled lab hours.

The textbooks used in the respondents' courses are listed in Table I. Editions were usually not specified, but presumably the most recent editions were used. Two-thirds of the respondents used one of only three texts, and 90% used one of eight texts.

Course content

The most important information obtained from this survey concerns the content of the courses, which we express as the relative amount of lecture time spent on various subjects ordinarily considered to be in the domain of the quantitative analysis course. The results are presented in Table II. The data supplied (hours of lecture per topic) were converted to a percentage of the total lecture time, and these percentages were averaged. We used this parameter, rather than hours of lecture, to normalize for the variable number of lecture hours per week and weeks per course. We also calculated the percentage of respondents who reported spending more than one-third of a lecture hour on each subject (the column in Table II headed "% Courses"). The relative lecture times hold few surprises, although the variations (expressed as % SD [standard deviation]) from one instructor to another are significant. In the typical course, 3% of lecture time is equivalent to about 1 lecture hour. Topics covered in less than 1 hour on the average can be considered specialty topics, and the greater apparent variations in coverage of subjects from activity concept on down the list merely reflect the absence of coverage of the topic in many courses. This is evident from the "% Courses" column in Table II. For example, every instructor covers experimental error and acid–base and redox equilibria. Most instructors spend between 7% and 15% of total lecture time on acid–base equilibria, but the range is from 3% to 38%. On the other hand, 10% of the respondents spend 0.5 hours lecturing on fluorescence spectroscopy; 11% give the topic 1 hour, and 3%, 2 hours; but 76% don't mention the subject at all in this course. Presumably the topics covered in quantitative analysis vary from institution to institution at

Table II. Quantitative analysis course lecture topics

Topic	% Lecture	% SD	% Courses	% ACS standardized test questions
Acid–base equilibria	12.3	54	100	14
Redox equilibria	7.1	49	100	14
Advanced acid–base equilibria	6.3	60	100	0
Complexometric titrations	5.6	52	96	12
Review of chemical equilibria	5.3	72	90	0
Statistical methods	5.2	63	94	10
Spectrophotometry	5.2	73	86	16
Gravimetric analysis	5.1	65	85	6
Introduction to volumetric analysis	4.8	75	95	0
Solubility equilibria	4.8	69	88	2
Potentiometry/pH	4.6	61	88	0
Application of redox titrations	4.0	65	90	2
Experimental error	3.6	64	100	0
Activity concept	2.8	89	83	0
Introduction to separations	2.8	103	60	0
Precipitation titrations	2.6	96	71	4
Ion-selective electrodes	2.2	86	67	2
Gas chromatography	2.1	143	44	4
UV spectrophotometry	1.9	128	47	0
Sampling for chemical analysis	1.7	100	69	0
Atomic spectroscopy	1.7	88	36	0
Nonaqueous pH/titrations	1.6	113	56	2
Solvent extraction	1.4	143	42	4
HPLC	1.4	150	38	2
Polarography	1.0	210	27	0
Coulometry	0.9	156	29	0
Electrogravimetry	0.8	188	28	0
Fluorescence spectroscopy	0.6	217	24	2

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Table III. Lecture vs. text coverage, by textbook used

Topic	Skoog & West ($n = 32$) % Text	% Lecture	% SD[a]	Harris ($n = 25$) % Text	% Lecture	% SD[a]	Day & Underwood ($n = 14$) % Text	% Lecture	% SD[a]
Acid–base equilibria	10.2	12.8	47	12.0	14.3	48	5.7	10.1	54
Redox equilibria	9.6	7.6[b]	46	6.8	7.3	61	6.1	7.7[b]	30
Advanced acid–base equilibria	2.7	7.1[b]	72	6.5	6.5	55	4.0	6.0[b]	48
Complexometric titrations	3.8	6.5[b]	55	3.8	5.7[b]	55	4.6	4.6	57
Review of chemical equilibria	3.4	6.6[b]	68	4.8	6.2[b]	56	5.1	3.9	66
Statistical methods	5.4	5.9	53	3.4	4.1	65	5.1	4.5	61
Spectrophotometry	9.0	4.7[b]	89	6.2	4.9[b]	46	8.3	4.8[b]	67
Gravimetric analysis	5.0	5.3	56	3.4	4.6	72	5.2	4.9	73
Introduction to volumetric analysis	4.2	4.7	62	0	4.3[b]	72	4.6	4.1	66
Solubility equilibria	4.4	5.0	73	3.2	5.4[b]	56	4.3	4.7	63
Potentiometry/pH	6.3	4.4[b]	67	3.4	4.9[b]	57	3.8	5.6	89
Applications of redox titrations	5.4	4.1[b]	66	5.5	3.5[b]	91	4.9	5.0	42
Experimental error	2.9	4.0[b]	75	2.4	3.3[b]	63	2.2	3.0	52

[a] % SD = % standard deviation in lecture hours.
[b] Difference between % lecture and % text is significant at the 95% level.

least in part as the coverage of subjects varies among other chemistry courses at that institution. However, our data are too sparse to draw a firm conclusion.

We thought there might be a relationship between the relative amount of time spent on a topic in lecture and the relative emphasis in the textbook used. To test this, we separated questionnaires according to textbook used and determined for the three most popular texts the percentage of lecture time spent on the 13 topics to which more than 1 hour of lecture was devoted on the overall average (Table II). The differences for each topic were subjected to t tests. These results are given in Table III. The variation among lecturers is again large. Although it is clear, and hardly surprising, that lecturers do not feel constrained to follow slavishly the emphases in their assigned texts, the range of topics clearly does follow the textbooks.

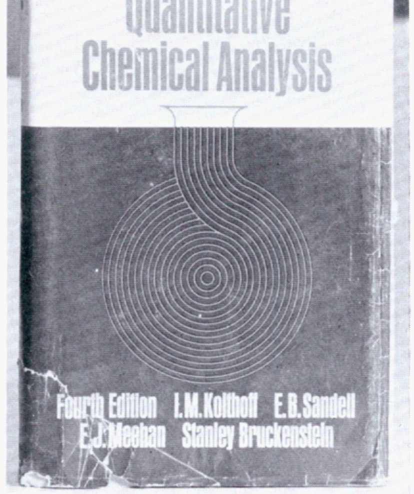
Textbook evolution

We also thought it would be of interest to trace text content through the years. We counted pages in four earlier quan-

Table IV. Subjects covered by % text pages

Topic	Harris (*11*)	Kolthoff et al. (*5*)	Kolthoff & Sandell (*6*)	Rieman et al. (*7*)	Willard & Furman (*8*)
Acid–base equilibria	12.0	9.5	7.9	15.6	12.3
Redox equilibria	6.8	3.6	3.4	6.9	7.0
Advanced acid–base equilibria	6.5	1.1	—	—	—
Complexometric titrations	3.8	9.5	—	—	—
Gravimetric analysis	3.4	11.9	44.1	28.7	28.6
Review of chemical equilibria	4.8	4.0	5.4	—	3.4
Statistical methods	3.4	5.9	6.5[a]	1.7	2.2[a]
Spectrophotometry	6.2	7.7	5.7	4.5	2.4
Introduction to volumetric analysis	—	2.2	2.2	4.8	4.8
Solubility equilibria	3.2	5.9	3.6	—	—
Potentiometry/pH	3.4	1.5	1.4	7.7	—
Application of redox titrations	5.5	9.1	10.4	14.4	16.5
Experimental error	2.4	1.1	[a]	1.7	[a]
Activity concept	2.0	0.6	0.4	1.2	0.7
Introduction to separations	2.6	0.6	—	2.4	1.9
Precipitation titrations	4.3	1.4	4.7	3.3	6.8
Ion-selective electrodes	1.7	—	—	—	—
Gas chromatography	3.2	2.5	—	—	—
Sampling for chemical analysis	—	—	—	0.2	0.7
Atomic spectroscopy	3.4	1.0	0.7	—	—
Nonaqueous pH/titrations	0.3	1.0	—	—	—
Solvent extraction	2.9	5.5	1.1	—	—
HPLC	4.3	6.6[b]	0.5[b]	—	—
Polarography	6.8	4.6	—	1.0	—
Coulometry	1.1	1.2	—	—	—
Electrogravimetry	3.6	4.3	5.2	6.0	12.6
Fluorescence	1.5	1.4	0.5	—	—
Total no. of pages	585	724	558	418	413

[a] Includes experimental error and statistics.
[b] Column chromatography.



A well-used fourth edition of Kolthoff's quantitative analysis text.

titative analysis texts: Kolthoff et al. (1969) (*5*); Kolthoff and Sandell (1952) (*6*); Rieman, Neuss, and Naiman (1951) (*7*); and Willard and Furman (1940) (*8*). We were unable to locate a copy of the 1936 (1st) edition of Kolthoff and Sandell (*9*), perhaps the granddaddy of quantitative analysis texts (*10*). The results are compared in Table IV. Although there was far greater emphasis on gravimetric analysis and applications of redox titrations, the distribution of pages among the other topics generally is not too different from that in contemporary texts. However, the earlier texts are qualitatively different: in particular, the experimental aspects of analysis are far more closely integrated with the theoretical descriptions. In modern textbooks the experimental directions are in a wholly separate section or even a separate manual, with some footnotes. As has been thoughtfully noted by Williams and Bromund (*10*), these earlier texts reflect what analytical chemists then actually practiced professionally: gravimetric and volumetric analyses. Contemporary quantitative analysis textbooks certainly do not reflect what analytical chemistry is, nor what analytical chemists do or are expected to know today. Rather, current texts seem to have evolved directly from their predecessors, with expanded coverage of statistical methods and the addition of discussions of some instrumental techniques, which for the most part are covered in other courses anyway.

ACS examination

We determined the percentage of questions on the ACS Examinations Committee's standardized test in quantitative analysis (*1*) that fall into each of our topic categories. The percentages are shown in Table II. Eighty percent of the questions concern the major lecture topics (those to which one or more lecture hours are devoted on the average). However, the attention paid in the standardized exam to redox equilibria, complexometric titrations, statistical methods, spectroscopy, experimental error, and solvent extraction seems somewhat out of line with the emphasis in lectures and texts.

Laboratory experiments

We requested information on the experiments performed in the laboratory portions of the respondents' quantitative analysis courses, without regard to the relative amount of time spent on

Table V. Laboratory experiments

Experiment	No. of respondents[a] performing experiment in: Quantitative analysis	Instrumental analysis	Introductory chemistry
Acid–base indicator titration	95	1	11
Spectrophotometry	87	13	4
Complexometric titration	85	4	2
Redox indicator titration	83	2	8
Acid–base potentiometric titration	82	10	3
Gravimetric determination	79	0	12
Precipitation titration	59	2	2
Calibration of glassware	51	2	5
Potentiometric redox titration	44	18	2
Ion exchange	40	9	4
Calibrate balance	30	0	3
Gas chromatography	27	52	0
Electrogravimetry	21	17	0
Grans plot titration	16	9	0
HPLC	13	52	0
Coulometric titration	12	33	1
Infrared spectroscopy	5	56	1
NMR spectroscopy	1	40	1

[a] Total no. of respondents = 95.

each. Table V lists the experiments and courses in which they are performed. Again, the traditional determinations seem to continue to be the mainstays of the laboratory part of the course. Although presumably they are emphasized less than in days of yore, gravimetric analyses still are carried out. Even more surprising to us is the number of institutions at which balances and glassware are calibrated!

Conclusion

This survey has given us a good idea of what *is* being taught in contemporary quantitative analysis courses. What *should* be taught is another question. To what extent must we concern ourselves with teaching fundamental principles and laboratory skills, and how far can we go toward showing students modern analytical practices? Are the skills taught in the labs, and the principles enunciated in texts and lectures, sufficiently fundamental to everything we do to justify the time and intellectual effort expended on them? Are we being fair to our students or to ourselves by hanging onto a curriculum outlined half a century ago? These questions clearly are worth addressing, and an appropriate forum might be found at meetings widely attended by analytical chemists. We believe a wide-ranging discussion of the content of the analytical chemistry component of the undergraduate chemistry major is long overdue.

Acknowledgment

We thank all those who completed and returned the questionnaires.

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