KIMIKA 17 (1) 27–33 (2001)
Printed in the Philippines

The Teaching of Analytical Chemistry in the Philippines

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Analytical chemistry has undergone a number of changes during the past decades. However, the teaching of analytical chemistry in Philippine colleges and universities has not coped up with the developments in this branch of chemistry. A survey of the curriculum for analytical chemistry in sixteen major Philippine universities offering an undergraduate degree in chemistry revealed that the course is still being taught in the traditional manner. Almost all of the universities followed the traditional division and nomenclature for the courses. Even though the instrumental methods have been incorporated in the curriculum, a major part of the course is still devoted to the classical methods of chemical analysis. Very few universities are equipped to provide an adequate training on the instrumental methods. The paradigm shift presently pervading in analytical chemistry as an information science has still to find its way in the curriculum.

Keywords: Chemistry teaching; analytical chemistry education; Philippines

INTRODUCTION

A number of changes have taken place in the field of analytical chemistry. The classical methods of chemical analysis, especially the gravimetric methods, have become scarce, and instrumental methods of chemical analysis have become ubiquitous. The working principles behind chemical measurements have extended beyond chemistry, and have involved physics, biology, electronics, and computer methods. The contact between the analyst and the sample has diminished, as instrumentation and computer systems intervened and automated the analytical procedure. Analytical chemistry has shifted its paradigm from data collection to information generation, and has focused serious concern on the quality and reliability of its methods and of their output. The demands of society for chemical information have created a unique niche for analytical chemistry, which has consequently been recognized as a distinct field of science—the science of chemical measurements.

Are these developments reflected in the academic framework for the education and training of chemists in Philippine colleges and universities? Does the curriculum for analytical chemistry provide students with adequate contemporary knowledge and experience that will enable them to confront the situation in the real world? To what extent is the teaching of analytical chemistry in our country harmonized with that in other nations so that we can participate in a global flow of information and manpower?

This paper reports on a study that aimed to provide answers to these questions. It involves a comparative study of the analytical chemistry courses offered in the B.S. Chemistry curriculum of several Philippine universities. It presents and assesses the present state of the teaching of analytical chemistry in the country and offers recommendations for a relevant and updated training and education of analytical chemists in the Philippines.

Survey instrument and respondents

The data required for this study was gathered through a survey form that was distributed to educational institutions with a B. S. Chemistry degree offering. The survey form requested for the following information: (1) the analytical chemistry courses offered and the number of lecture and laboratory units for each; (2) the course outline for each subject offering, together with the time allotment for each topic, the textbook used and the highest academic degree of the lecturer; and, (3) the experiments performed in the laboratory course, together with the number of hours allotted for each and the major analytical chemistry equipment available for this course.

The survey forms were sent to forty colleges and universities which were listed in the CHEd Database [1] as offering a B. S. Chemistry course. Sixteen institutions responded and sent back the requested information. Even though the response rate was low, the respondents included the major colleges

and universities in the country. Seven of the respondent institutions were state universities, and nine were private universities. Excluding the six respondents from the Metro Manila area, the regional distribution of the respondents was quite uniform: three from Luzon; three from Visayas and four from Mindanao. An alphabetical listing of the respondent universities is provided in Table 1.

Table 1. The institutions included in this study

- Adamson University, Metro Manila
- Ateneo de Davao University, Davao City
- Ateneo de Manila University, Metro Manila
- Central Mindanao University, Musuan
- De La Salle University, Metro Manila
- Far Eastern University, Metro Manila
- Mariano Marcos State University, Batac
- Mindanao State University, Marawi City
- Mindanao State University – Iligan Institute of Technology, Iligan City
- Pablo Borbon Memorial Institute of Technology, Batangas City
- University of the Philippines at Diliman, Metro Manila
- University of the Philippines at Los Baños, Los Baños
- University of the Philippines –Visayas, Iloilo City
- University of San Agustin, Iloilo City
- University of San Carlos, Cebu City
- University of Santo Tomas, Metro Manila

CHEd Curriculum for Analytical Chemistry

The Technical Panel on Policies and Standards for Chemistry of the Commission for Higher Education (CHEd) recommends a minimum of two one-semester courses for Analytical Chemistry. Each of these courses has a total academic credit of five units, three units for the lecture course and two units for the laboratory course. The first course provides a description of the analytical process, a discussion of the classical methods of analysis and a brief introduction to the instrumental methods of chemical analysis. The second course focuses on analytical separations and on the instrumental methods of analysis. Tables 2 and 3 summarizes the topics included in these two courses and the percentage time allotment for each topic.

Analytical Chemistry Curriculum

Only two universities follow the minimum requirement of the CHEd Technical Panel, the other institutions offer from three to six semesters of Analytical Chemistry courses, with the total units ranging from 11to 20 units. Figure 1 presents a distribution graph for the number of semesters and the total number of units for these courses.

Table 2. Major topics in the Analytical Chemistry I, as recommended by the CHEd Technical Panel for Chemistry

Topic	% Allotment
Introduction	3%
Analytical Processes	3%
Chemical Reactions used in Quantitative Analysis	9%
Stoichiometry	14%
Gravimetric analysis	10%
Volumetric analysis	47%
Introduction to instrumental methods	14%

Table 3. Major topics in the Analytical Chemistry II, as recommended by the CHEd Technical Panel for Chemistry

Topic	% Allotment
Analytical separations	28%
Spectrophotometric methods	14%
Electrochemical methods	14%
Chromatographic methods	14%
Automated analysis	4%
Basic electronics (optional)	19%
Computer methods (optional)	8%

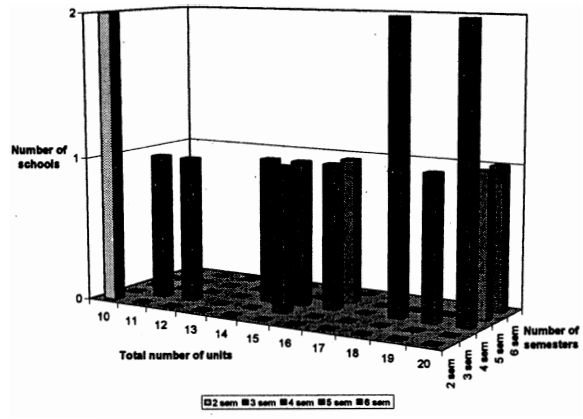

Fig. 1. Frequency distribution of the total number of semesters and total academic credit unions of analytical chemistry courses in the colleges and universities surveyed.

The universities offering three semesters of analytical chemistry had one-semester courses for Quantitative Analysis, Instrumental Analysis and Technical Analysis. Those with four semesters had added either a one-semester course for Qualitative Analysis or a second semester for Quantitative Analysis. It was noted that almost all the universities follow the traditional division and nomenclature for the analytical chemistry courses.

Two universities had three semesters of Instrumental Analysis, allotting one semester each to Spectrophotometric Methods, Electroanalytical Methods and Chromatographic Methods. One of these institutions also offered one semester of Qualitative Analysis, and therefore had six courses for analytical chemistry. One university had an extra semester for Food Analysis, and another university offered one semester for Organic Analysis.

QUALITATIVE ANALYSIS COURSE

The classical approach to the teaching of analytical chemistry starts with a course on Qualitative Analysis. Only seven out of the 16 respondent institutions offered this course. Those who did not include this course in their curriculum commented that the topics normally taken in this course have been incorporated in the General Chemistry course. All of the colleges and universities allotted three units for the lecture class and two units in the laboratory class.

The course was intended to provide an in-depth treatment of the basic principles of chemical equilibrium in solution. It is usually the second course wherein chemical equilibrium is presented, the first time being in the General Chemistry course. More complex equilibrium systems are discussed and more difficult numerical problems are presented. A listing of the topics included in the lecture course, as well as the average percentage of the total hours allotted for each, are presented in Table 4.

Table 4. Percentage coverage of topics in the course on Qualitative Analysis

Topic	% Coverage
Review of basic concepts	16%
Chemical equilibrium	16%
Acid-base equilibrium (including hydrolysis)	31%
Solubility equilibrium	15%
Complexation equilibrium	9%
Oxidation-reduction equilibrium (electrochemistry)	14%

The course outline was based on the classical course on Qualitative Analysis, as further indicated by the textbook adopted for this course by most of the colleges and universities. All of these schools cited the books "Qualitative Analysis and Chemical Equilibrium" (4th edition) by T.R. Hogness and W. Johnson and "Qualitative Analysis" by E. S. Gilreath as either their textbook or reference for this course. The latest editions of these textbooks were made in the before 1970. Some schools supplemented these books with the recent versions of Analytical Chemistry books (e.g., by G. Christian and by Skoog and West) or with the latest edition of General Chemistry books (e.g., by R. Chang and by Robinson and Holtzwic).

For the laboratory course, all of the schools offering it included experiments on the analysis of cations and anions. Almost all, except for one, school had experiments on the reactions and schematic analysis of the different groups of ions, followed by the analysis of unknowns. One school gave unknowns directly, devoting only half of the semester to qualitative analysis and the rest to quantitative analysis.

It can be seen from the syllabus for the lecture and the laboratory course that the approach being used is based on the classical course on Qualitative Analysis. The CHEd curriculum follows a movement started in the United States of eliminating this course and integrating it with the General Chemistry course. However, in the preparation of the new Eurocurriculum for Analytical Chemistry, Kellner [2] asserted that the Qualitative Analysis course is essential in the training of analytical chemists since the lecture portion presents the principles for the unit operations (e.g., precipitation, neutralization, complexation, oxidation-reduction, extraction, etc) involved in chemical analysis. He also stressed that the laboratory course provides an experience in control experiments and an awareness of the need for reproducible results.

QUANTITATIVE ANALYSIS COURSE

The course on quantitative analysis constitutes the main course for analytical chemistry. All, except one, of the respondent institutions offered a one-semester course on quantitative analysis with three units for the lecture and two units for the laboratory. The exception required two semesters for the course on quantitative analysis.

This course presents the principles involved the different methods for chemical measurements. All the colleges and universities included in this survey covered exactly the same topics in this course, following perhaps the emphasis provided in most textbooks. Table 5 tabulates the main topics and the average percentage of the lecture time spent on each topic. Clearly, this course focuses on the classical methods of chemical analysis and provides only brief introduction to the instrumental methods of analysis. More than half of the lecture time is being devoted to the volumetric methods, which include several types of titration methods such as acid-base titration, oxidation-reduction titration, complexiметric titration and precipitation titration. Gravimetric methods are allotted

Table 5. Percentage coverage of topics in the course on Quantitative Analysis

Topic	% Coverage
Introduction	7%
Errors and statistical treatment of data	6%
Gravimetric methods of analysis	17%
Volumetric methods of analysis	59%
Instrumental methods of analysis	14%

less than one-fifth of the lecture time. The instrumental methods, especially spectrophotometry, are briefly discussed in this course.

More than half of the respondent institutions used the book authored by Skoog and West as their textbook. This is actually a recent development brought about by the increase in the local availability of the international edition of this book at an affordable price. Previously, most colleges and universities were confined to the textbooks which were locally reprinted and widely distributed in the bookshops. Among these books were the old editions of the books by Christian, by Day and Underwood, by Fritz and Schenk, by Hargis and by Hamilton and Simpson. These books apparently have remained a favorite among the lecturers who still continue to prescribe them as a lower-cost alternative textbook or reference book for the students. Table 6 lists the textbooks used in the quantitative analysis course, in the order of decreasing popularity.

Table 6. Textbooks used in quantitative analysis course

Textbook Authors	% of Respondents Using the Book*
Skoog and West	56%
Day and Underwood	50%
Christian	31%
Hamilton and Simpson	25%
Fritz and Schenck	25%
Harris	18%
Hargis	18%
Kennedy	6%
Blaedel	6%

*Several schools use more than one textbook.

Table 7. Laboratory experiments done in the course on Quantitative Analysis

Topic	Experiment
Weighing techniques	Variation of weights of coins
Gravimetric analysis	Determination of moisture; soluble chloride; soluble sulfate; iron
Acid-base volumetric analysis	Determination of organic acid; soda ash; Double titration: carbonates Potentiometric titration
Redox volumetric analysis	Permanganate: iron, oxalate; calcium, manganese; Dichromate: iron Iodine: copper, vitamin C; dissolved oxygen
Complexiметric volumetric analysis	EDTA: calcium, water hardness
Precipitation volumetric analysis	Mohr/Volhard method: chloride
Spectrophometric analysis	Iron; phosphate

Table 8. CHEd-recommended experiments done in the laboratory course on Analytical Chemistry 1

Topic	Experiment
Calibration	Volumetric Apparatus, buret
Weighing techniques	Variation of weights of coins
Gravimetric analysis	Determination of nickel (DMG method)
Acid-base volumetric analysis	Determination of HCl and KHP, aspirin
Redox volumetric analysis	Iodine: vitamin C, copper Permanganate: available oxygen in manganese ore
Complexiметric volumetric analysis	EDTA: calcium carbonate in chalk
Chromatography	Ion-exchange chromatography of calcium
Potentiometric titration	Determination of KHP
Spectrophometric analysis	Determination of iron

The laboratory course in quantitative analysis is also focused on the classical analytical techniques. All the respondent universities covered the same topics in the laboratory course they offered on Quantitative Analysis. Table 7 presents the experiments performed during this one-semester course. As in the lecture course, much time is given in the laboratory course for the different titration methods. The traditional experiments continue to be the mainstays of the laboratory course, not only because of their simplicity and low cost, but also because of their practical importance in the real world. It is worth noting that at least one laboratory activity is still being devoted to gravimetric analysis, even though this technique has become less popular because of its tediousness. Many teachers maintain that an experiment on gravimetric determinations has to be included in this course, since it provides a good opportunity for the student to learn the techniques of quantitative precipitation and complete recovery of the precipitate. Only a few universities include an activity on the instrumental techniques, deferring the experiment for the succeeding course on Instrumental Analysis.

The range of topics covered in the laboratory course in the institutions included in this survey almost coincides with the set of experiments recommended by the CHEd Technical Panel, except for the experiments involving potentiometry and chromatography (see Table 8). As mentioned above, most of the schools have these two experiments done in the laboratory course on Instrumental Analysis.

INSTRUMENTAL ANALYSIS COURSE

The course on Instrumental Analysis is regarded as Modern Analytical Chemistry or even Advanced Analytical Chemistry. Only 15 out of the 16 respondent universities offered Instrumental Analysis as a one-semester course. In four of these institutions, the course involved only lectures, and no laboratory classes. In the other institutions, there was a three

Table 9. Percentage coverage of topics in the course on Instrumental Analysis

Topic	% Coverage
Introduction (instrumentation)	8%
Molecular spectroscopy	24%
Atomic spectroscopy	10%
Potentiometry	8%
Voltammetry	6%
Coulometry	5%
Gas chromatography	11%
Liquid chromatography	11%
Mass and NMR spectroscopy	14%
Radioanalytical methods	2%
Process analytical methods	2%

Table 10. Textbooks used in instrumental analysis courses

Textbook Authors	% of Respondents Using the Book *
Skoog and West	63%
Ewing	2 %
Day and Underwood	9%

credit unit lecture course and a laboratory course with either one or two credit units. The lone respondent university which does not offer this course actually has the topics integrated in the courses on Quantitative Analysis and Technical Analysis.

This course deals with the instrumental methods for chemical analysis. In all the institutions surveyed, about one-third of the lecture time is spent on the different optical methods of analysis. Mass spectroscopy and nuclear magnetic spectroscopy are also presented at some length in several institutions, especially because of their application in the elucidation of the structure of organic compounds. The electrochemical methods are not given as much emphasis as the optical methods, while the chromatographic techniques are adequately discussed in the course. Table 9 gives the average percent time coverage of the different topics included in this course.

About two-thirds of the respondents make use of the book authored by Skoog and West for this course. It should be remembered that this is the same book used in the previous course on Quantitative Analysis. Several schools prescribe the book written by Ewing as their textbook since this book has been locally reprinted and costs much less compared to the book by Skoog. Table 10 lists the textbooks used by the various respondents in the course on Instrumental Analysis.

Many universities find it difficult to offer a comprehensive laboratory course in Instrumental Analysis because of economic constraints. This is the same reason why four of the

Table 11. Laboratory experiments done in the Instrumental Analysis course

Topic	Experiment
UV-VIS spectrophometric analysis	Determination of iron (4) Determination of phosphate (2) Simultaneous determination of components in a binary mixture (3) Spectrophotometric titration (2) Stoichiometry of a complex ion (6)
Atomic absorption spectrometry	Determination of a metal: Cu, Ca (6)
Gas chromatography	Determination of hydrocarbons Parameters (5)
Liquid chromatography	Column efficiency; method development Determination of caffeine (5)
Potentiometry (ISE)	Determination of fluoride, lead (3)
Voltammetry	Determination of heavy metals, lead (2)

respondent schools do not offer a laboratory course on Instrumental Analysis. The experiments performed in this course are presented in Table 11, together with the number of institutions wherein the experiments are being done. All of the respondent universities have several experiments involving UV-VIS spectrophotometry, but less than half of the respondent are able to include an experiment on atomic spectroscopy in this laboratory course. A number of the institutions had "dry experiments" that involve the interpretation of IR, NMR and MS spectra for the elucidation of the structure of organic compounds. As in the lecture course, the electrochemical techniques are not adequately emphasized in many of the institutions, even though the equipment involved in these measurements are not as expensive as the spectrophotometers. Only one-third of the respondent schools are able to afford the instruments for the two chromatographic techniques and incorporate chromatography experiments in the laboratory course.

TECHNICAL/APPLIED ANALYSIS COURSE

The course on Technical Analysis is the final course in the traditional analytical chemistry curriculum. This course, which is also named as Applied Analysis or Industrial Analysis, aims to provide the students with training and experience in the analysis or real or complex materials such as those which are encountered in industry.

Only 12 out of the 16 respondent institutions offered this course to the students majoring the Chemistry, with ten universities requiring one semester for this course and two allotting two semesters for the course. All the institutions gave the same emphasis for the laboratory course, which had two credit units; but they differed in the credit units for the lecture

Table 12. Percentage coverage of topics in the course on Technical/Applied Analysis

Topic	% Coverage
Steps in chemical analysis	5%
Treatment of analytical data	4%
Water analysis	11%
Analysis of ores and cement	11%
Soil analysis	5%
Food analysis	16%
Analysis of fats and oils	14%
Analysis of fertilizers	11%
Analysis of metals	3%
Analysis of textiles and paper	7%
Analysis of soap and detergents	5%

Table 13. Laboratory experiments performed in the Technical Analysis course

Water analysis
Analysis of ores and cement
Soil analysis
Food analysis
Analysis of fats and oils
Analysis of fertilizers
Determination of air quality
Analysis of metals
Analysis of textiles and paper
Analysis of soap and detergents

course, ranging from one unit (for four institutions) to two units (for four institutions) to four units for (four institutions). One of the respondent universities allotted an extra separate semester for a course on Food Analysis.

The topics in the lecture course on Technical Analysis in almost all universities are usually grouped according to the material being analyzed. These materials are the samples commonly encountered in an industrial analytical laboratory where most of the students are expected to work after graduation. The analysis of food, fats and oils, water, fertilizers, ores and cement are discussed at some length, each of these topics taking up more than one-tenth of the lecture time. A few institutions allotted time for a discussion on the treatment of analytical data. Table 12 shows the various topics included in the course and the relative amount of time allotted for each topic.

One university had an entirely different set of topics in the lecture course on Technical Analysis. The lectures focused on the various aspects of practical chemical analysis, such as data evaluation, sampling, method development and validation, calibration and quality assurance.

The laboratory course in all the respondent institutions followed the same set of topics as in the lectures. The methods employed involved both the classical and instrumental techniques, with the titration methods being widely used. A few gravimetric analysis, such as moisture measurement and determination of oil content (Sohxlet method) are performed. Among the instrumental methods, UV-VIS spectro-photometry is the most commonly employed because of the ease in acquiring the instrument required. The other spectrometric methods, such as AAS, are used only by the few schools who could afford to purchase the relatively expensive instruments. Table 13 lists the topics of the experiments performed in the laboratory course on Technical Analysis.

CONCLUSION

This survey reveals that in almost all of the Philippine universities, analytical chemistry is still being taught in the classical manner. The course content has undergone very little change in the span of several decades. This is reflected in the way Instrumental Analysis is being dealt with, as Advanced Analytical Chemistry when it is at present the bulk of fundamental chemistry. The courses on Technical or Applied Analysis persist even though its relevance has been outgrown.

Courses in analytical chemistry have been criticized as involving materials that have little connection with the analytical procedures used in the chemical industry, in clinical chemistry or in environmental chemistry [1,3]. There is a discrepancy between the analytical chemistry being taught in the universities and that being employed in practice to solve problems. Most of the courses offered seldom show the role of analytical chemistry in the real world. While the undergraduate training focuses on the classical methods particularly those involving the volumetric techniques, the industrial laboratory employs much of the instrumental methods of chemical analysis. Furthermore, the analytical chemistry courses do not include the diverse and exciting topics of research in analytical chemistry, such as bioanalytical chemistry, thermal analysis, surface analysis, chemical sensors and chemometrics.

Based on the data gathered from the survey, it appears that the objective of the courses in Analytical Chemistry is to train the students be analysts rather than as analytical chemists. The training provided by these courses, particularly in the laboratory, is devoted solely to the development of good analytical techniques, with the students made to follow procedures well. Very little opportunity, if any, is given for the students to gain experience in the development of analytical methods. Thus, the students have little appreciation for the parameters specified in the analytical procedures and are content in simply doing what the procedure says.

The paradigm of analytical chemistry has shifted from data collection to information generation. Unfortunately, this paradigm change is not reflected in the training provided by most colleges and universities to the students of analytical chemistry. There is still much emphasis given to the gathering of data in the analytical chemistry laboratory, and very little attention, if any, is devoted to the generation of information

from analytical data. The experiments and exercises in the laboratory course make the student focus on the measurement procedures and on the calculation of the required data. The student perceives the result of his calculation (e.g., analyte concentration) at the end of his experiment as the goal of the analysis. The *raison d'être* of the chemical analysis, i.e. the information provided by the analytical data about the system from which the analytical sample originated, is never emphasized to the student.

The paradigm shift in analytical chemistry has resulted in a greater importance given to statistical methods. Statistics is employed not only in the evaluation of the reliability of the analytical data on which information are based and but also in the extraction of information from a body of analytical data. Though most of the Analytical Chemistry textbooks contain at least one chapter on statistical methods, most teachers do not spend sufficient time to discuss the relevance of these methods in "real life" analytical chemistry. The application of significance testing and linear regression is not usually included in the undergraduate course in Analytical Chemistry.

Indeed, there is a need to update the teaching of analytical chemistry in our universities in order to make it relevant to the present needs of analytical chemistry laboratories. The two semester minimum requirement of the CHEd Technical Panel is insufficient to cover the important fundamental topics to make the course relevant to the current status of analytical chemistry as "a scientific discipline that develops and applies methods, instruments and strategies to obtain information on the composition and nature of matter in space and time" [3]. There should be a wide-ranging discussion on what should be taught in the Analytical Chemistry courses. Reference has to be made to the Eurocurriculum which was formulated by the Working Party on Analytical Chemistry of the Federation of European Chemical Societies.

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