RECENT DEVELOPMENTS IN CHEMICAL EDUCATION[1]

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A CASUAL survey of our membership roll shows that the Oklahoma Academy of Science is largely composed of college teachers. I thought that you would be interested in seeing a spot map (Figure 1) showing the location of the 317 members of our academy. Outside of Norman, Stillwater, Tulsa and Oklahoma City, the Academy is hardly represented in Oklahoma.

The second map (Figure 2) shows the location of the 219 teachers of science in the highschools who are members of the Oklahoma Educational Association. Of these members seven are also members of the Academy. On the third map an attempt has been made to show the location of more than nine hundred teachers of science in the schools of Oklahoma If my count is correct, only eleven persons are members of this association. Yet in consideration of the new ideas in the teaching of science, particularly chemistry, these teachers should be vitally interested.

Edwin E. Slosson,[2] so well known among scientists, speaking of science teachers in the secondary school, states that they "occupy a strategic position for influencing the thought of the nation. They give all the instruction that most people ever get and they have the first chance at those who go on to the university."

In speaking of the recent developments in chemical education, I wonder how many of you who took chemistry twenty years ago can remember more than one text book in general chemistry. There were those written by Ira Remsen of Johns Hopkins, Alexander Smith of Chicago, Victor von Richtor of Germany, A. F. Holloman of Holland, and H. P. Cady of Kansas. A check of texts on the shelves in my office disclosed twenty-five different college texts on general inorganic chemistry and written by as many as thirty-five authors. All these texts are being used today and were written or revised during the past ten years. They vary in size from 354 pages to 1074 pages. With the exception of about a half dozen of the more recent books the table of contents and order of presentation of the subject matter is the same as that used some twenty years ago. During this period, intensive research on the chemical frontier has accumulated a tremendous amount of factual material. The ionic theory and the new theory of the constitution of matter became generally accepted; physical chemistry grew up and these facts and theories filled the pages of books to overflowing. Our well meaning instructors administered it all in allopathic doses. The patient students suffered acute chemical indigestion and toxaemia, and becoming thoroughly discouraged, held up their hands and declared "No more chemistry for me." Today homeopathic doses are the style. Thus the recent college texts are shorter, more logically and pedagogically arranged, didactic and less encyclopedic in nature.

About this time the World War came and the American people awoke to their amazement to find that the appropriative and the adaptive periods

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[1]Presidential Address, Oklahoma Academy of Science, Nov. 30, 1928.
[2]Slosson, Jr. Chem. Edu.

of our forefathers were passing and that we were forced into mortal combat with a people most highly skilled in the creative arts, heretofore unnoticed by the general public and the military forces. Military and peace time equipment simply fashioned or fabricated by the mechanical and electrical engineer from easily won raw material were inadequate, obsolete and inefficient. New hitherto uncreated material came into being. The genii of the Arabian Nights were overshadowed in their magical powers. Poison gases used were so toxic that a few pounds became more effective than tons of old fashioned bullets and charges of cavalries. Serums, antigens, active principles, vitamines administered in infinitesimal amounts protected

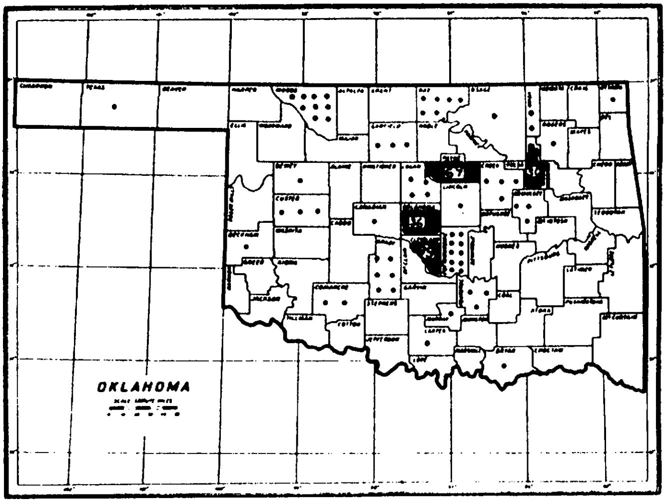

Figure 1

man from dreaded disease and nutritional disorders. In the air floated ships of hydrogen, helium and duraluminum; in the depths of the oceans crude crafts made their way propelled by stored chemical energy, with crews sustained by "canned oxygen"; and on land monster armored machines met charges of chlorine and sprays of mustard gas. These armaments of war and blessings of peace are the products of fertile brains and long hours of patient, confining investigation in the libraries and laboratories of the synthetic scientist. The creative age is here. Wealth is elsewhere than in the gold fields of Alaska and the diamond mines of Kimberley. The miner of today digs in the research laboratories of enterprising industrial concerns, trade organizations and educational institutions.

In the immigration of the young of this century, they will not wrest gold from the ice laden water of the Yukon or make fortunes from the timbers of the West; but they will undergo just as many difficulties, overcoming the forces of nature and wresting from her such secrets as finding an economical method of producing aluminum from the clays of our streets, obtaining rubber from crops annually planted and harvested, producing diamonds and jewels not garnered from the four corners of the globe, and even acquiring power by harnessing the tremendous atomic forces of the elements.

The immigrants to the gold fields of science in this creative age crowd our halls of learning. Each and every student craves his share in the opportunities and visions of the future. This horde is seeking the hidden power, the new lumber, the undreamed of materials of commerce. And like the gold seeking caravan, some lacking will power, determination, finances, and physical strength, will turn toward home never tasting the joy of discovery. The many who were not destined to discover will remain satisfied to serve, cook, sew, minister, transport and assist those few who will create this new wealth. Since the tasks of the many who serve are so different from the tasks of the few who discover, so should the instruc-

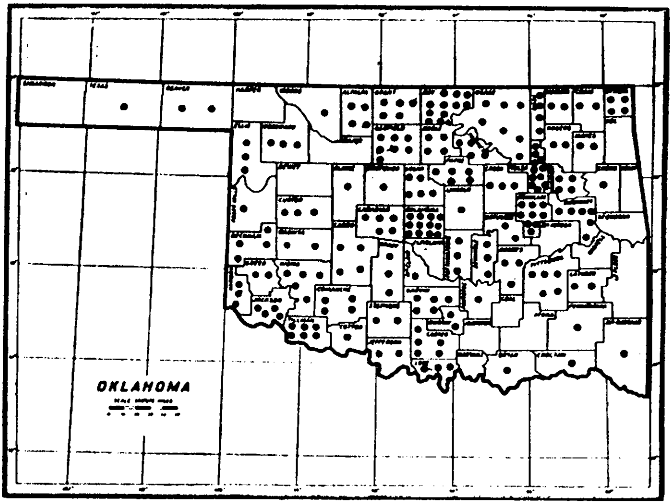

Figure 2

tion, guidance and equipage given to the many be different from that provided for the research worker or the pioneer of today.

The old idea of training everyone for college for a specialist's knowledge and skill no longer rules. In most subjects taught in the high schools and in some colleges there has arisen a new ideal, a training for service for a life rich in appreciation and for the great worth while experiences. To the many, we should give an inspiration and appreciation for those arts and skills, fundamental knowledge, principles and theories. To the few we should give professional courses designed for specialists and not laymen, largely built around certain accepted minimum essentials and presented in a logical manner as regards material, theories, skills, facts, and data.

Now digesting in an alembic in the laboratories of the chemical educational plants of America is an unknown. From this unknown educators hope to crystallize a new improved "exactly fitting the needs" course in chemistry whose aim, contents and limitations are now beginning to be determined. On this Bancroft[1] of Cornell only two years ago said, "What we need as a cultural course in chemistry is a course which will cover all the ground in chemistry given in the university without going into too

[1]Bancroft, Jr. of Chem. Edu. 3 396.

much detail, primarily for the benefit of the man who is expecting not to go on in chemistry. The course will be called pandemic chemistry (Pandemic—of or pertaining to all the people)." This idea of Bancroft's met with hearty enthusiastic support in certain quarters; in others with severe criticism. The chemical fraternity today is divided between those who believe in pandemic or cultural chemistry and those who do not; and to whom there is only one chemistry—the traditional course of today. Bancroft further states that, "Before that can come to pass we shall have to have a textbook for the students to study ..... teachers competent to give instructions in the subject, and we shall have to educate the colleges to the point

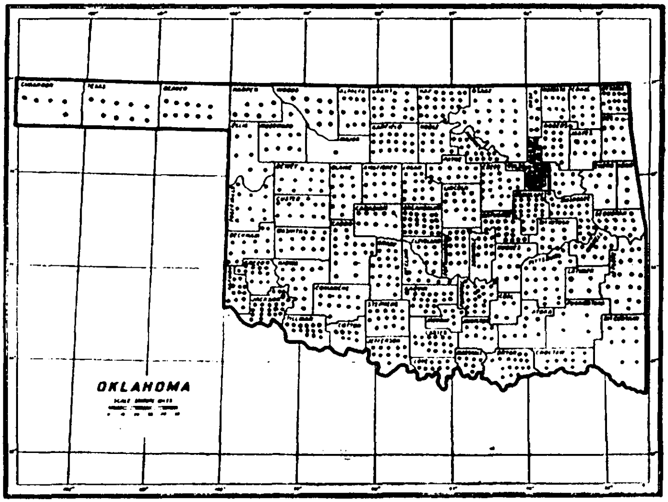

Figure 3

of accepting this unit for college entrance. This will take much time, although a textbook must be written at once for the benefit of the college student."

We believe that the chemist has not been negligent in his educational problems—perhaps he has been following the wrong ideal. For over twenty-five years the New England Association of Chemistry Teachers has been meeting without a break from four to twelve times yearly and printing full reports of their meetings, but are they not more interested in the material of their science than in boys and girls whom they teach? Teachers of chemistry have certainly not been napping if we are to believe Earl R. Glen[1], who, in a Bibliography of Science Teaching in Secondary Schools, found that out of 2117 titles of articles appearing between 1900 and 1925 in journals of science education alone, five hundred were in the field of chemistry. "These articles are the results of practical difficulties met by teachers in classroom teaching. They show the widespread interest in problems of improving instruction and the real effort that has been put forth to solve them."[2] This interest has been so keen that in 1921 the members

[1]Glen, Earl R., U. S. Bureau of Edu. Bul. 1925, No. B.

[2]Horton, Ralph E., Measurable Outcomes of Individual Laboratory Work in High School Chem. p. 1, Contributions to Education, Teachers College, Columbia University.

of the American Chemical Society, a body of over 16,300 members, organized a section for the study of chemical educational problems. In the past seven years the membership of this educational division has increased until it is next to the largest of any of the society. The official organ of this division is the Journal of Chemical Education, now in its fifth year.

Through the activity of this group of educators there has been organized what is known as the Senate of Chemical Education. This senate is made up of three representatives from each state, a college teacher, a high school teacher and a business man who is a chemist or an employee thereof. It is hoped through such an organization to obtain a much better understanding and perspective of the whole problem in all its various angles.

Some of the objectives set up by these two organizations are:

(a) To decide upon what question should engage the concentrated attention and money of the Division of Chemical Education of the American Chemical Society.

(b) To keep the state organizations in tune with the national organizations.

(c) To bring about closer cooperation between high schools, colleges, and industries and to unify the efforts of all those interested in chemical education.

(d) To plan for the future development of chemical education in the country.

Twenty-two problems are under consideration, one fourth of which are being actively attacked. These cover such subjects as,

Nomenclature
High School Research
Women's Club Study Courses
Research on Problems of College Chemistry Instruction
Aids to Visual Chemical Instruction
Minimum Equipment for High School Chemistry
Vocational Education in Chemistry
Organization of Work of the First Year of High School Chemistry
The Order of Presentation of Laboratory Work and Recitation
The Preparation of Teachers of Chemistry
Material for Chemistry and Science Clubs
Outstanding Problems in Chemical Education, etc.

One of the notable yet most difficult pieces of work has been accomplished by the Committee on Minimum Essentials for High School Chemistry.[1] In their report, which is fairly well accepted, they recommend an essential syllabus which should be covered and around which the year's course is to be built. Sufficient latitude is given to enable any teacher to teach these points and in addition adapt the subject matter and teaching to the local conditions. This syllabus was planned for high school chemistry. yet exceptions to these recommendations on the grounds that the syllabus does not conform to the aims of secondary schools are being taken by Morgan,[2] Stone,[3] and others who claim that the committee, consisting largely of college teachers, has built an outline designed more for the

[1] A Standard Minimum High School Course in Chemistry, Jr. Chem. Edu. I, (1924).
[2] What are our Objectives in Teaching Chem., Jr. Chem. Edu. 2 971, (1925).
[3] High School Chemistry Course Versus the College Requirement, Jr. Chem. Edu. I, 55, (1925).

training of prechemists or professional men than for students who will not go on to college. It appears to many that this syllabus was written along the old traditional lines and that high school chemistry is just a vest pocket edition of college chemistry for the professional. If we are to accept this opinion and Bancroft's idea of an appreciation course, then this minimum essential syllabus should be rewritten so as to conform to the new ideals and objectives.

Another important activity is the movement to obtain an adequate endowment to establish a chemical educational center for investigation of these problems. The present idea is to organize this work along the lines now being followed by the many national groups, as the Cleaners and Dyers Institute and others. Johns Hopkins University has recently established a chair in chemical education. This chair is now filled by Neil E. Gordon, formerly of the University of Maryland and now editor of the Journal of Chemical Education.

Of all the recent developments, we believe that the majority of scientists will concede that the new appreciation course in chemistry is outstanding in the educational field. What are the aims and the essential criteria in such a course? How much time should it take? What should be the proportionate amount of time devoted to laboratory, lecture and recitation? Should the same type of course be offered in college as in high school? Will the high school appreciation course be accepted as complying to the science requirements for entrance to college? Must the colleges alter their general chemistry to meet this change? Is this course a good starting ground for the professional scientists? These and many more questions immediately arise in the mind of the teacher. I am sure that you will all agree that any course taught for non-professional ends should train for proficiency in the seven cardinal principles as formulated by the National Educational Association. These are: health, command of fundamental processes, vocation, worthy home membership, citizenship, worthy use of leisure, and ethical character.

Such are the aims of Arthur T. Bawden of Baylor College in his appreciation course which he has been teaching for several years. In his manuscript, now in the hands of the publishers, he says that he was guided by the following principles:

1. Chemistry must be presented from the view point of service.
2. Cognate to the idea of service, is the emphasis on the application of chemistry.
3. The scientific method must be emphasized.
4. A broad, unified view of chemistry must be presented.
5. A proper balance of theory and application is essential.

Bancroft of Columbia presents his pandemic chemistry in 67 lectures, Sampey of Howard College, Birmingham, Alabama uses the two volumes of *Chemistry in Industry* by Howe. The material in the two volumes is supplemented by frequent references to chemical magazines. He says, "These two volumes have succeeded to a remarkable degree in presenting industrial applications of chemistry to the reader, with little or no theoretical training in science; they have found a wide circulation among business executives and the cultured public; why should not these methods of presentation be adaptable to class room use? Why has it been considered sounder pedagogy to present first a mass of theoretical matter with which the student has had no previous experience and for which he can see no use after he escapes from the course? The educator who follows the plan of presentation will be surprised by the extent to which the student seeks theoretical interpretation." C. S. Adams[1] of Antioch College has been giving for the past five years two courses, one a technical course for the professional students who expect some day to become pure scientists, engineers, nurses, doctors, students in specialized home economics and the allied professions; the other a cultural course for students interested in journalism, law, ministry, literature, business, and allied professions. Speaking of the cultural course, Adams says,

"it offers an opportunity to sell chemistry to a class of students who, in many colleges, would not be required to take chemistry; it will correct certain preconceived prejudices and unwarranted doubts as to the value of chemistry in general education, and will eliminate much of the bigotry and narrow-mindedness so often exhibited in the field of religion, economics and politics.

"The course differs from the conventional college course in the emphasis placed upon certain topics in general chemistry. For instance, much more time is spent in a discussion of the personalities and events which make up the history of chemistry. The principal laws and theories of chemistry are stressed only in so far as they enable the student to understand and handle the chemical equation. Considerable time is spent upon the periodic law and its suggestion of inorganic evolution. A little philosophizing is indulged in at this point. Approximately one-third of the year is given over to the study of organic chemistry. During the course of the year the students read, in the form of reference assignments, the following books: Moore's History of Chemistry, Slosson's Creative Chemistry, Geoffrey Martin's Modern Chemistry and Its Wonders, Geer's The Reign of Rubber, and Howe's Chemistry in Industry. While this course, of necessity, is much more descriptive and superficial than the technical course, the writer has attempted to maintain a balance between the descriptive matter, which is obtained largely through outside readings, and the theoretical work, which is confined largely to the lectures. Although this course has only been on trial for five years it has, so far, proved well adapted to the class of students to whom it is given."

Another course radically differing from the practice today, required of freshman students of the Pennsylvania State College is presented by Dean Gerald Wendt and entitled Matter and Energy. Concerning this Dr. Wendt says,

"This course differs from the usual introductory course in chemistry or in physics in two respects. As regards content it makes no distinction between chemistry and physics but uses as much of both as is necessary to understand the fundamental nature of matter and of energy and then proceeds in the second semester to analyze the things and events of daily life in terms of those fundamentals. It thus disregards the classical methods of introducing the subjects, and, indeed, makes no pretense of being a course in either subject.

" . . . We are not so much interested in the learning of the subject as we are in learning to think. The student may learn more facts by listening to well organized lectures and taking copious notes, but science is not a list of facts nor is memorizing the spirit of science. The instructor therefore presents an experiment for discussion and explanation and the lecture hour is employed in such verbal and experimental argument as will demonstrate the scientific method and will engage the class in interested and concentrated thought. The experiments are therefore not illustrations of principles already enunciated but play the part of problems to be solved and of attempts at the testing of hypotheses and the proving of theories. The course, like science itself, is an endless series of questions."

In the foregoing I have attempted to show you some of the aims and the attempts to attain these ideals. Chemistry is characterized in the minds of the most people as a laboratory course. Bawden, Wendt and Bancroft do not require laboratory work, though Wendt and Bawden do use carefully planned and appropriate lecture demonstrations. In presenting his

[1]Adams, Jr. Chem. Edu. 2, 901. (1925).

course, Matter and Energy, Dr. Wendt endeavors to open each new field with an experiment that causes the student to ask of himself why and how matter behaves as it does—in fact his lectures are largely questions put to the student.

Presumably we have considered the laboratory method to be so well established and accepted that the question it would be heresy. The large number of prominent scientists whose names grace the backs of many laboratory text books explicitly believe in the value of this method to train for scientific thinking, for learning the scientific method of attack, for independent work, and for holding the student's interest. If we recall, the laboratory in its present form, is somewhat of a new development. Only in 1824 we find this interesting statement in the directions to the board of trustees of our earliest scientific schools of higher grade: "These (the students) are not to be taught by seeing experiments and hearing lectures according to the usual method. But they are to lecture and experiment by turn, under the immediate direction of a professor or competent assistant. Thus by a term of labor, like apprentices to a trade, they are to become operative chemists." In practice, however, this took the form of lecture demonstrations by different students.

With the influx of students and the relative decrease of budgets, the objections to the prechemist courses, and the demand for courses with a service aim or objective, there have come simultaneously scientific studies in education which have devised ways of determining the efficiency of some of the methods which we have come to look upon as established. And as Lucasse[1] of the University of Pennsylvania says: "They have weighed the laboratory method on the balance and have found it wanting—at least not possessing all the advantages that we have been prone to ascribe to it." Nevertheless the educators have yet to produce consistent and conclusive proof that the present laboratory method is archaic—is too expensive and inefficient. An exhaustive series of tests and experiments carried out over a number of years and in several schools is needed in an attempt to shed more light on this, which, like Mark Twain's weather, is most discussed, but little has been done about it.

Nevertheless, out of the maze of opinions there have come several excellent researches. Powers of Columbia University and H. R. Smith of Lake View High School of Chicago have been quite active. Ralph E. Horton, working under Powers' direction, has published the result of carefully and scientifically planned experiments in an endeavor to prove the type of laboratory work most preferable. In such experiments it is difficult to determine the objectives and standards by which the laboratory work shall be judged; written tests are either invalid for detecting differences in methods of laboratory work, or the methods of doing laboratory work are not determining factors of success in written tests.

They seem to find that the so-called "problem method" produces the best results. This method is essentially the carrying out of laboratory work without explicit directions on the part of the teacher. The others in order of preference are: second, individual laboratory work following directions, but with these directions consciously generalized; third, individual laboratory work following directions from a manual, the regular method of

[1]Lucasse, The Possible Over-Emphais of Laboratory Instruction in Higher Institutions, Jr. Chem. Edu. 5, 142 (1928).

present practice; and the fourth and least preferable, demonstration by the teacher of all experiments.

In the transfer of abilities, he finds that there appears to be no evidence that these abilities and manipulative skills have any value outside of the field of chemistry. Yet if problem solving and ability to do tasks as to manipulate apparatus, to solve perplexities or projects involving the use of chemical facts in laboratory situations are important, then practice in doing similar tasks in the laboratory by self direction seems to attain this end best.

Horton does verify the opinions held by many that after a preliminary period of training the discontinuance of the individual laboratory work and the substitution of demonstration experiments should occur, which appears to be justified and feasible. Thus it seems that after a certain amount of skill has been acquired by individual application, information may be imparted more rapidly by the group or demonstration method than by individual work. Does not this mean that emphasis should be placed in the early part of a course on individual laboratory work using the problem method, and that in the second semester of the year greater progress may be accomplished by use of the group or demonstration method? It certainly does and I think agrees with what you have found to be the case with your good students. Even in the laboratory the poorer students require more individual work to get the same information across than the better students, and the brighter students after having acquired the simple elements of technique can quickly grasp the import of a demonstration and learn the lesson without the long and expensive laboratory trials with their repetition of minor details.

In conclusion Horton states that "In Seward Park High School, New York, we shall tentatively adopt the plan of presenting by demonstration the important phenomena and experimentation of which an understanding is required and on which written tests will be based. The laboratory will be used to give practice in handling apparatus and in attempting to solve problems by supervised but undirected experimentation."

The writer believes that such training constitutes to some considerable degree one of the essentials in any appreciation or cultural course. To realize the significance of some of the major developments of this century the layman should at least have tried his hand in the solving the simple problems by actual experimentation, and the student will get most out of his work when he himself determines his own method of solving a perplexity.

I hope that in my feeble way I have shown to you tonight some important trends in the field of chemical education in the United States. I have called your attention to the present organizations of chemistry teachers and their program; to the new cultural chemistry now under trial and being recommended for high school and non-professional courses in the colleges and universities, and the questioning attitude of many educators on the value of laboratory work.

Now after all has been said, of what concern is this to the members of the Oklahoma Academy of Science? In the first place your courses are built with the idea that your students have had a certain amount of information or training in chemistry. You feel that they should be able to understand many symbols, formulas, reactions, equations, laws and concepts. Now if these appreciation courses become prevalent in the high schools and colleges, and I have a firm conviction that they will, then it will mean that you must take into consideration the fact that your students have had presented to them a different kind of chemical knowledge than that which you received in your education. In the second place as broad-minded scientists we should be tolerant in judging this new move; we should realize that the individual student and his life are of more importance than the opinions of a body of scientists. Therefore, we chemists ask that you reserve judgment until this experiment has been tried and all the major factors involved carefully and accurately controlled and evaluated, and until unbiased evidence is definitely for or against this movement. Let us also add our bit in encouragement and service so that these investigators, our co-workers, will realize that these problems and tasks are important and worth all the effort they so sincerely put into them.