CHEMISTRY EDUCATION AT THE INTERMEDIATE GRADE SCHOOL LEVEL

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ABSTRACT. — A completely new approach to the teaching of chemistry has been developed over a period of eleven years at the Lake Villa [Illinois] Consolidated Grade School. As a result, it can be said that chemistry can be as effectively taught in the grade school as any other subject.

Chemistry is a subject that can be effectively taught in the grade school. This conclusion is based upon a program of research now entering its twelfth year at the Lake Villa [Illinois] Consolidated Grade School. As a result of this study, a system of six-week units of instruction in the field of chemistry for the third through the eighth grades, with a final quantitative unit for students showing exceptional ability and aptitude, has evolved. Experience with units for the sixth, seventh, and eighth grades has been reported (Midgley, 1958). The present report is concerned with the overall objectives of this work and the techniques we have used to achieve them.

OBJECTIVES OF GRADE SCHOOL CHEMISTRY

1.—To fill a serious deficiency in the science curriculum. An inspection of the standard textbooks of general science selected by individual teachers on a preferential basis and used during the 1961-2 academic year at our school from the third through the eighth grades shows that of a total of approximately 1800 pages in these books, only 70 are devoted to purely chemical concepts. A major part of the experimental demonstration of these concepts is noted to be limited and repetitious from grade to grade, for example, extinguishing fire with carbon dioxide.

2.—To feed, nourish, and guide the natural curiosity most children have in matter and its changes. To the young, inquiring mind, the many kinds of matter and the thousands of possible changes they can undergo, that is to say the subject of chemistry, should be at least as interesting and important as any other scientific subject. Even without formal training, many children acquire an interest in chemistry which becomes most intense when they are ten to twelve years old. A formal course before a student reaches this age level may prevent the student from attempting dangerous experiments with commercially available sets.

3.—To psychologically prepare a student for future study of chemistry. The young mind is receptive to new concepts. A course at the grade school level creates a familiarity with the concepts of chemistry which should make the subject more appealing in high school or college. As a consequence, the number of science-oriented citizens, as well as scientifically trained workers, would be increased.

PEDAGOGICAL CRITIQUE

A completely new approach to the subject of chemistry has been developed for presentation in the elementary grades. We are of the opinion

that the systems developed for secondary and collegiate levels made the subject unnecessarily difficult and completely unsuited to grade school instruction. A résumé of the chief obstacles which we have avoided follows.

1.—Excessive emphasis upon theory without first establishing facts. In our curriculum, the facts of chemistry are first qualitatively given. Theoretical and quantitative aspects are then secondarily introduced when, and only when, they can effectively serve to explain or add to the facts thus established.

2.—Pure memorization of concepts without any real understanding. In our course we have tried to unfold the study in a natural manner, introducing no new concept without the student being ready to understand it by what has already been learned in the course. The type of technique which is avoided, for example, is that of presenting the standard preparation of oxygen from potassium chlorate without any prior mention of the halogen compound. If a student's curiosity is aroused, it may be thwarted, for some elementary textbooks make no further reference to the starting compound.

3.—Chemistry as an abstraction. The immature mind is not prepared to absorb concepts in the abstract and should the subject be thus presented, the student may obtain the impression that chemistry is a subject of signs and symbols alone with no relation to real matter. In this course every attempt has been made to illustrate by actual experiment each and every principle taught. In order to do this, rapid procedures, using primarily microtechniques to illustrate a point, were worked out. A simple apparatus was also designed to quickly illustrate all of the gas laws and to serve as well as a barometer or a gas thermometer.

4. Complex organization with subtle interdependence. The standard textbooks for the presentation of chemistry at a secondary or collegiate level present a format with no obvious order or connection between the units to one untrained in the field of chemistry. We reasoned that, if grade school children are to be taught chemistry by grade school teachers, there must be a simpler organization of the material.

The Curriculum

The complete outline of our curriculum is given in Table 1. The details of the work for grades 6 through 8 is given since it has been found beneficial to modify the original presentation (Midgley, 1958). The subdivisions of the quantitative unit are given separately in Table 2. While Unit 1 is the correct prelude for an integrated elementary course in chemistry, the remaining units could be presented without it, providing one avoids the obstacles previously mentioned. Even Unit 5, if necessary, could be presented with little reference to the preceding units. Such independence is important in the grade school, where instruction is necessarily piecemeal, as contrasted with the continuity of a subject taught in high school or college.

1.—Unit 1. Writing a textbook of any kind for the lowest grades requires a different language and technique than would be used for the

TABLE 1.—Grade School Curriculum Outline.

I. *Unit 1. Matter in General* (3rd, 4th, and 5th Grades)
- A. Matter, the subject of chemistry
- B. Changes in matter, physical and chemical
- C. Kinetic Molecular Theory of matter
- D. Nature of pure matter
- E. Mixtures of matter
- F. Separations of mixtures of matter

II. *Unit 2. Elements-Building Blocks of Matter* (6th Grade)
- A. "Student's Periodic Table"
- B. Classification of the elements and their properties
  - 1. Metals
  - 2. Nonmetals
  - 3. Hydrogen
- C. Direct means of identification of the elements
  - 1. Color of solutions
  - 2. Color of flames
  - 3. Bead tests
  - 4. Spectroscopic Analysis
- D. Theory of the structure of the atoms of the elements

III. *Unit 3. Compounds-Chemical Combinations of Elements* (7th Grade)
- A. Classification of compounds
- B. Formation of compounds
- C. Properties of compounds
- D. Theory of the formation of compounds

IV. *Unit 4. Families of Elements and Their Compounds* (8th Grade)
- A. Hydrogen and its compounds
- B. Metal families and their compounds
- C. "Cousins" and their compounds (Group VIII metals)
- D. Nonmetal families and their compounds
- E. Organic Compounds

V. *Unit 5. Quantitative Measurement of Matter*

higher grades. The material must be related to the experience of the pupil. While the overall outline as given serves the purpose of defining the subjects to be covered, the language and method of presenting that material must necessarily be suited to the age group being instructed. It has been found that words, however difficult they may seem to grownups, are not in the least disturbing to the youngster of any age, providing he has the meaning given to him first. If this meaning of a concept is provided in terms with which he is familiar and can understand, and then related to some common experience of his, a label that will be easily remembered can then be attached to the meaning. Thus, in this unit, such concepts as the meaning of chemistry, the properties of matter, the difference between law and theory, etc., are taught with a great deal of success. Some of the subjects, which at first thought appear to be too difficult for the third grade, evoked the most spirited discussion in the first trial use of this material.

2.—Units 2-4. Several important changes have been made in the original order of presentation (Midgley, 1958). The theory of the structure of matter has been taken from the last of these units and placed in Unit 2 as the final lesson. It was independently discovered by several

TABLE 2.—Quantitative Unit Outline.

I. *Methods of Counting and Recording Units of Matter*
   A. Numbering systems
   B. Recording of numbers
      1. Decimal system
      2. Significant digits
   C. Manipulating of numbers
      1. Logarithms
      2. Slide rule

II. *Measurement of Matter Generally*
   A. Dimensions of matter
      1. Size
      2. Weight
   B. Density of matter
      1. Solids and liquids
      2. Gases
   C. Metric units used in the measurement of matter
      1. Units of length
      2. Units of volume
      3. Units of weight
      4. Energy units used in the measurement of matter

III. *Measurement of Pure Substances-Formulas*
   A. Subscripts and coefficients
   B. Atomic weight and gram atomic weight
   C. Formula or molecular weight and gram formula or gram molecular weight
   D. Formula fractions and percentage composition
   E. Simplest formula from percentage composition
   F. Avogadro's Number

IV. *Measurement of Gases*
   A. Avogadro's Law
   B. Boyle's Law
   C. Charles' Law
   D. Dalton's Law
   E. Guy Lussac's Law
   F. Density of Gases
   G. Kinetic theory of gases and Graham's Law of diffusion

V. *Measurement of Molecular Solutions*
   A. Molar solutions
   B. Molal solutions
   C. Percent solutions
   D. Density of solutions
   E. Percent compared to density
   F. Dilute from concentrated solutions

teachers that this theory could be easily taught, with considerable interest, once the student had an understanding of the Periodic Table as given in Unit 2. The theory of the formation of compounds has been added to Unit 3, and concepts related to nuclear energy have replaced the deleted lesson on the theory of the structure of matter.

3.—Unit 5. The initial trial of the quantitative unit has proved particularly pleasing. Members for this class were selected from the 7th and 8th grades on the basis of interest shown in the other units and their superior standing in their respective classes in mathematics. The class was held after school and was well attended throughout the six-week course.

It may appear that we are cover-

ing some material that would ordinarily be too difficult for a grade school youngster. However, we never have prejudged what concepts the youngsters will be capable of assimilating. We have tried every concept ordinarily given freshman college students and have then formed the units, finally, by including only those concepts which were found most teachable and useful, keeping the prescribed objectives constantly in mind.

We were agreeably surprized by the enthusiasm with which these exceptional students learned to use the slide rule. This was facilitated partly by making use of a mechanical method of finding the decimal point instead of attempting the mental survey method commonly used by older students in high school and college. Though we taught them the use of the C and D scales only, many were not satisfied and wanted to know about the use of the other scales as well.

As part of their course of instruction, the students of this class prepared solutions of prescribed molarity for use in the next year's classes. It is our belief, because of the success of this year's trial, that we will not need to be so strictly selective in setting up future classes.

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Literature Cited

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