A COMPARATIVE STUDY OF THE CHEM STUDY METHOD VERSUS THE CBA METHOD

APPROVED:

C. A. Hardy
Major Professor

James H. Marshall
Minor Professor

Swartz Kinsley
Dean of the School of Education

Roberts Foulds
Dean of the Graduate School

The purpose of the study was to conduct documented research on two of the recently designed teaching methods of high school chemistry, the Chemical Education Material Study (CHEM Study) and the Chemical Bond Approach (CBA). Both were developed in the late 1950's, and each of them was supported by the National Science Foundation.

An attempt was made to answer certain questions concerning differences in the two methods.

Various researchers have pointed to those aspects of one method which appear superior or inferior to the other. A comparison of teaching results between the CBA and the CHEM Study method definitely favors the latter. The view that the CHEM Study method has a much more far-reaching effect on present high school chemistry is borne out by the fact that it has received much wider acceptance and adoption than have the CBA materials.

The research suggests that the CHEM Study method will do the most good for the largest number of students by appealing to them on their "natural practical approach." In conclusion, the writer supports the CHEM Study method completely with very few reservations.
A COMPARATIVE STUDY OF THE CHEM STUDY METHOD VERSUS THE CBA METHOD

THESIS

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By

Joseph S. Chimeno, B.S.
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CHAPTER I

INTRODUCTION

During the early 1960's, following the advent of Sputnik, it became evident that serious shortcomings existed in the teaching of chemistry at the secondary school level. These shortcomings appeared not only in the content of chemistry courses but in sequence of presentation of the subject matter and, in fact, in the very approaches used by educators.

A large number of curriculum improvement projects have been undertaken in the United States within the past decade. Physical Science Study Committee (PSSC), Chemical Bond Approach (CBA), and Chemical Education Material Study (CHEMS or CHEM Study) are examples of the many such projects. The above examples have some of the following features in common:

1. All were developed for the secondary school level.
2. They were worked up by teams of educators and scientists.
3. The teams consisted of university and high school teachers.
4. Each project was tried on an experimental basis in various high schools.
Purpose of the Study

The purpose of this study was to conduct documented research in two of the recently designed methods of teaching high school chemistry: The Chemical Bond Approach and the Chemical Education Material Study. These two teaching methods were compared and contrasted, with the objective of determining whether there were any substantial differences in their presentation of the subject of chemistry.

Specifically, certain questions were important elements in the comparative analysis of the two chemistry-teaching methods, such as:

1. Do CBA and CHEM Study contain the same material?
2. Is this material developed to the same degree?
3. Is the fundamental approach the same in the two methods?
4. What major emphasis is placed on the CBA and the CHEM Study approach?
5. What are the philosophies of the two courses?
6. Although both courses have as their major aim, the producing of well-educated chemists, do they go about achieving this aim in similar ways?
7. How does the average student react to the two teaching approaches?
8. How do the courses go about integrating such other subjects as economics and history with the study of chemistry?
9. What are the basic differences in the two courses?
10. Is there any distinct advantage in teaching one of the methods in preference to the other?

Background of the Study

Chemical Bond Approach.—In 1959, a group of nine high school and nine college chemistry teachers set up the Chemical Bond Approach Project. Under grants from the National Science Foundation, the group prepared a preliminary draft of an introductory chemistry course which regarded the study of chemistry as a process of weaving ideas and facts that should occupy the student of chemistry, a process in which the student would take an active part. Throughout the project, emphasis was placed upon ideas and experiments, both of which are necessary, of course, in an effective study of chemistry. Stress was placed on operational and conceptual definitions and on how to think about chemical reactions. The group felt the need for a chemistry course which would present chemical reactions in the light of modern ideas. Chemical Systems, the CBA textbook which evolved from the project, was believed by its authors to be "the first thoroughgoing effort to show the interrelated roles of ideas and facts in chemistry" (1, p. vi). An experimental procedure was used in the development of Chemical Systems. Members of the CBA staff prepared trial versions of the text and laboratory guide, and placed them for use by over 200 co-operating teachers and over 10,000 students.
Much of the science studied in the CBA course was taken from the work of noted scientists. The main objective was to get the student involved in the process. Reading about science allows one to be only a spectator, according to the CBA staff. The more personally the student could become involved in the chain of experiments and ideas as he studied, the more he would be proceeding as a scientist.

The staff felt further that science is both experimental and mental—both doing and thinking—both observation and imagination. Therefore, the CBA study method aimed primarily at raising questions, some of which were supplied with answers, others of which were raised for the student himself to answer, and still others of which were raised to point out aspects of chemistry for which chemists do not yet have satisfactory answers (1, p. vi).

The CBA project has its headquarters at Earlham College in Richmond, Indiana, and is directed by Dr. Lawrence E. Strong. The CBA course includes the following features as its primary departures from the traditional methods of teaching chemistry:

1. CBA employs a systematic presentation of laboratory work.

2. It involves a closer tie between text and laboratory.

3. It follows a more logical approach to atomic and molecular structure.
4. It undertakes a more intensive use of energy concepts.

Chemical Education Material Study.--The CHEM Study method, first used in 1960, was developed at Harvey Mudd College, Claremont, California, with Dr. J.A. Campbell as the Study Director and Dr. Glenn T. Seaborg, U.S. Atomic Energy Commissioner, as Chairman of the Executive Committee for the study. The committee attempted to staff the study with the nation's most able university scientists and high school teachers. According to Pimental,

University professors were drawn from all over the United States on the basis of demonstrated understanding of science and recognized leadership in teaching it. An equal number of outstanding high school teachers contributed, each one individually selected on the basis of enthusiastic recommendation by his peers (2, p. vii).

The National Science Foundation supplied grants for the CHEM Study as well as the CBA project. It is interesting to note that nearly 2,800,000 dollars was expended on CHEM Study, and that more than 4,500,000 dollars has been returned to the National Treasury through royalties accrued by the project work (5, p. 5).

A student who studies the CHEM Study course will spend the first class day and most of the first week of school in the laboratory rather than in discussion. He will devote most of his time to an extensive study of the chemistry of a candle and its flame. The intent is for him to raise questions about a familiar object which he
thinks he understands. In this way, he will become familiar with the complexities of apparently simple systems and will begin to comprehend how relatively simple ideas may be used to interpret the behavior of these systems.

The textbook for the CHEM Study assumes that the student believes in atoms and molecules but that he does not understand the reasons behind these beliefs. Introductory chapters present an overview of chemistry in terms of the atomic molecular nature of substances. These chapters develop concepts of chemical behavior in terms of atomic theory and chemical information. The second section of the book deals with some of the most basic concepts of chemistry from an experimental point of view. Chapters are also devoted to energy reaction rates, equilibrium, acids, bases, and oxidation-reduction. These are tied together in terms of the mole concept, kinetic theory, and the atomic molecule concept of behavior in matter.

The second semester begins with a discussion of atomic and molecular structure and of structural relationships in the various states of matter. These are discussed in terms of their influence on chemical reactivity. The chemistry of carbon, which involves organic chemistry, is studied in the later chapters. Also, other typical elements are studied, with the emphasis in these sections being on the experimental approach. The authors' intent in these later sections is to utilize the materials and ideas presented earlier so as to tie the chemical knowledge together.
Need for the Study

Various studies have been made which point to those aspects of one chemistry-teaching method or approach which appear to rate superior over those of another. Ridgway, for example, comments on the far-reaching effects of the massive secondary school curriculum improvement projects and adds, "Some of this influence is attributable to CHEM Study" (5, p. 6). He fails to comment on any similar influence exerted by the CBA method.

Pode has compiled a worthy survey of appreciation of both methods, making his stand quite clear when he states, "I would like to say at once that I regard both courses as a great step forward, a breakthrough in science education." (3, 8). Although Pode presents some valuable comparisons and contrasts of the two teaching methods, he comes to the conclusion that a definite choice must be made between the two because of the philosophical framework in which the analogies and experiments are displayed. At the same time, he makes no such choice.

Strong and Wilson fervently support their Chemical Bond Approach because they realize that not every student taking high school chemistry will go to college nor will all of those who do go to college take further work in chemistry. An effective high school course, therefore, must be one in which the teacher can assume responsibility
for students of different interests. Their attitude is expressed clearly in the following statement:

Although the proposed course (CBA) may represent an increased emphasis on abstract ideas, this is the result of limiting major attention to a single concept with varied illustrations. This should give greater possibilities for interpretation and clarification to aid the student whose main interest may be centered outside the physical sciences (6, p. 58).

Troxel, by means of four instruments used on a pre-test and post-test basis, determined that students enrolled in CHEM Study developed a greater preference for science than did those enrolled in CBA. He discovered, however, that both CHEM Study and CBA course materials develop a better understanding of chemistry, a better understanding of science, and a greater ability for critical thinking than do other comparable modern chemistry courses (7, pp. 79-81).

Rainey attempted to evaluate the effectiveness of the kinds of laboratory approach offered by the two methods without attempting to measure the CBA program against the CHEM Study program. His observations, subjective though they were, indicated that CBA students (a non-directed group) were able to recall the specifics about each laboratory experiment better than could the members of the CHEM Study group (a directed group) (4, p. 290).

Although it is obvious that both the CBA approach and the CHEM Study approach have some very dedicated
proponents, it appears that the majority on both sides are hesitant to criticize adversely the opinions of one another. A significant need is thus revealed for research that will come to a definite conclusion as to the actual differences in the presentations of the two teaching methods. Only when these differences are determined, revealed, and evaluated can a prospective (or presently active) chemistry teacher choose between the two methods for use in the classroom. Even then the instructor will have to use his own discretion as to the amounts of theory and practical emphasis needed for his students' best interests, as stated in the quote from Vricheck, "It is the author's opinion that it is the teacher who primarily determines the success or failure of a course, not the methods" (8, p. 5).
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CHAPTER II

REVIEW OF RELATED LITERATURE: CBA AND CHEMS

That there is a need for increasing the productivity of teachers is a circumstance that can hardly be ignored. Current educational problems have been summed up, in fact, in the following manner:

The world faces a simple fact: It may not long survive as we know it. The fact is a complex of problems which have never been experienced, collectively, before. No nation and no aspect of life can escape their pressure. The problems fall under six broad headings: the expansion of population, the burst of technology, the discovery of new forms of energy, the rise of new nations, and world-wide rivalry of ideologies (4, p. 269).

Much time and effort have been devoted to discovering teaching methods that will enable teachers to do their work more productively. It is becoming more and more apparent, indeed, that undue stress has been placed on the imparting of knowledge rather than on the development of those qualities and characteristics which enable youth to solve their problems in a scientific manner. Although factual knowledge is, of course, a prerequisite to practical thinking, good teaching procedures involve the thought processes, which require motivation and guidance for development to their highest potential.
Survey of Literature Regarding the Chemical Bond Approach

Completely in line with the ever-growing belief that youth should be taught to solve their problems in a scientific manner is Feifer's analysis of the Chemical Bond Approach to teaching high school chemistry. He deprecates the teaching method referred to as the "cookbook approach," characterized by the student's attempt to follow printed laboratory instructions by alternating reading and performing directed steps, the whole of which constitutes an experiment completed with little or no understanding.

Feifer expresses the belief that the CBA method, when properly implemented, "promises to provide a most fruitful setting for teaching the student the methods and nature of science as well as facts and principles of chemistry" (2, p. 111). Taking an example of a CBA experiment of the open-ended, problem-solving, discovery type, he describes the one entitled "The Movement of a Gas Through an Orifice," which is set forth in a CBA textbook as follows:

Problem 1. What type of apparatus could be constructed and used to study the leak rate of gas?

Problem 2. What experimental data can be obtained to establish the relationship between the molecular masses of two gases and their leak rates?

Pre-Laboratory Assignment. Suggest a practical apparatus and a procedure which may be used to study the leak rate of gases.
Laboratory. Using the apparatus and procedures which you designed, determine the leak rate of gases assigned to you by your teacher.

Post-Laboratory Assignment. From the data obtained in the laboratory, make the necessary calculations to determine whether there is any relationship between molecular masses and leak rates of the gases studied. State this relationship in a mathematical equation. (2, p. 111).

The experiment, taken verbatim from the CBA textbook is regarded by Feifer as being a real challenge for the student, who, he says, has little opportunity in such work to blindly pursue an incomprehensible "recipe." Like the actual scientist, the student must devise his own experiment, a process which should lead him to think through the entire investigative process he must resolve in terms of meaningful procedures, relevant observations, and cogent conclusions.

Certainly, such a procedure will give more significance to the study of chemistry as well as help the student to develop his thought processes and his ability to reason creatively. The entire situation, however, may be far from ideal. The ordinary student may not be capable of performing such an experiment. According to Feifer, the extent to which such an "ordinary" student can meet the difficulties to be found in the experiment as it is outlined will depend upon the amount of guidance he receives from his teacher. Still another problem arises in this context; that is, if too much guidance is given, the experiment ceases to be
open-ended and problem-solving. There is a considerable danger when the teacher attempts to judge the proper amounts and kinds of guidance a student should receive. Although too much detailed assistance from the teacher may remove entirely the element of discovery, making the student a mere robot following directions; at the same time insufficient guidance will leave most students totally lost and bewildered.

Feifer, although he believes strongly in the CBA method, warns that it will not automatically eliminate the cookbook approach. No matter what type of manual the student uses, he will engage in meaningless activities unless he is adequately prepared and guided by the teacher. (2, p. 114).

On the subject of preparation, Westmeyer has made some interesting observations regarding the CBA. He emphasizes that it is more prominently a thinking course than a memory course. The emphasis, he explains, is upon ideas, and the theme of the ideas discussed is chemical bonding. To follow this theme consistently, the course omits a considerable body of material that has always been used in more traditional courses. In fact, almost half of the material presently found in introductory chemistry text books has been left out of the CBA course. (11, p. 318).

Westmeyer expresses particular interest in the "black box" section of the course. After presenting some introductory material designed to raise questions and inspire the students' curiosity, the teacher lays a brief foundation
related to the electrical nature of matter. The first of two structural models is then begun, but prior to this time the students have done an experiment with the "black box." It is simply a box containing some object whose nature is to be ascertained without opening the box. The student is allowed to tilt, shake, sniff, weigh the box, thus obtaining data concerning the unknown object. He then constructs a mental model of the object and tests the model by observing whether predictions based on it hold true.

Now the student is asked to accept certain assumptions about electrons and protons, to build a model of atomic structure based on these assumptions, and to test the model by asking questions about it. This model, and the "black box" experiment are used deliberately to impress upon the student that science is manmade, not divinely revealed (11, p. 319).

A great deal of preparation, it is seen, goes into the "leading up" to experiments in the CBA course. To make it even more elastic (as opposed to static), the close of the course may consist of three possible alternatives:

1. A section in which the concepts developed are applied to selected organic systems

2. A section which raises further questions not considered in the course, or

3. A laboratory study (11, p. 319)

To accusations that the CBA course is too theoretical in nature, Westmeyer explains that the students' laboratory guide is very brief, but the Teacher's Guide is much more
detailed, containing a theoretical discussion of each experiment, background information that the teacher may find useful, and suggestions for class discussions before and after the experiment. The amount of theoretical emphasis placed upon teaching, then, is entirely up to the teacher.

Strong, director of the CBA Project, strongly supports the "idea" aspect of the course. Throughout all the material of the course, he says, much emphasis is placed on the distinction between facts and ideas or operations and concepts. Ideas, he adds, provide students with the means to interrelate certain phenomena. Such distinction between facts and ideas, further represents a point of view about science and material phenomena which is of great significance to all human understanding. Strong comments that other viewpoints, of course, are held by logical positivists and operation- alists, but the unified view in the CBA course provides an excellent basis for preliminary discussions of how humans achieve understanding. He sums up the values of the Chemical Bond Approach in the following way:

A good course for the general student emphasizes the nature of science and its contributions to the process of human understanding. By study of the CBA course, a student can see some of the major steps to our present understanding of the nature of chemical reactions. If the teacher chooses to emphasize how ideas provide interrelations among disparate phenomena, the general student can be rewarded by insight (9, p. 60).
A refreshing view of CBA is given by Morlan, who was interested in finding out his students' reactions to the course. Much has been written on teacher opinions and those of other authorities, but little has yet been discovered as to how those taking the course feel about it. Morlan reports the following findings:

Almost 65% of the students believe that the textbook is very rigorously written, which is quite difficult for the average student. However, they like its organization; one boy recently said, "It's more like a mystery story. They say something and we get to figure out what is meant." Another has said, "In this course one must want to learn more than in most courses because the text is hard to understand and a great deal of thought is required" (5, pp. 425-6).

Morlan feels, too, that the text is "a tough bit of scientific writing." Sometimes, he says, it seems to go to an extreme in an effort to be complete. It is important, however, for students to learn to settle down and concentrate on what they are reading. He believes that the CBA text is one which the above average student cannot simply read and then make excellent grades on all examinations. This aspect of CBA is the most favorable one, in Morlan's opinion. The student must pay attention in class, because the teacher has to develop every topic taken up. The teacher, then, is the focal point, and here Morlan certainly agrees with all other opinions thus far expressed regarding the Chemical Bond Approach.
Education is badly in need of teachers who like to teach and who are dedicated to doing a good job of it. CBA gives them that opportunity. In Moran's words:

The text must be reinforced not only by developing some of the concepts more clearly, but some areas need more drill than is provided. I have added, for example, more mass-mass (weight-weight) problems, using several mimeographed sheets. And yet these materials are not so tightly organized that there isn't room for some personal freedom. Although using CBA, I still teach. (5, p. 426).

Related Literature on CHEM Study

Proponents of the CHEM Study Approach also feel that chemistry students should become able to solve their problems in a scientific manner. It is interesting to discover the aspects of the course which are impressive to various persons who have taught by the CHEM Study method. Torop, for example, places great stress on the importance of written laboratory reports, which, he says reflect to a high degree the student's understanding of a chemical experiment. In addition, such an exercise provides understanding and structure to the laboratory experience, forces intellectual organization, and provides feedback and reinforcement of the principles of science. If a student reflects about the experiment as he writes his report, he will undoubtedly improve his understanding of chemistry as well as science in general (10, p. 335).
Surely Torop's interest in written laboratory reports is indicative of the attitude of most CHEM Study proponents. Part of the philosophy of the CHEM Study program is to establish laboratory evidence in order to deduce the principles operating in chemistry. Deduction, of course, can be made only when a spirit of inquiry is present. From the beginning of the CHEM Study course, when the lighted candle experiment is used, the students are encouraged to suggest reasons for everything they see and do. If Torop is correct in his belief that written reports are a vital part of the CHEM Study course (or any other method of teaching chemistry), then it becomes obvious that writing down the experiment reinforces the fact that laboratory evidence has been established and is being recorded as such.

Laboratory work, of course, is the most emphasized part of the CHEM Study course. Its stress on learning by doing—the "practical" approach—depends to a great deal on knowledge gained in the laboratory. Rainey has found that CHEM Study students enjoy their laboratory work more than chemistry students ordinarily do. On a student reaction sheet given to his classes after a CHEM Study course was completed, the students consistently stated that the laboratory work was the most enjoyable part of the course (7, p. 544).

Osborn feels that the CHEM Study Approach provides an excellent background for future study of chemistry. Students
who have completed such a course, he states, will be able to think as chemists should think. He has one reservation about the course, however, and it applies to the study's value for the non-college orientated student. He suggests that CHEM Study may be a little too mathematical in its approach. Another interesting comment reveals his attitude toward the CBA course. He believes that the average teacher will be able to adjust to the CHEM Study Approach more readily than to the CBA because the material is somewhat more familiar (6, p. 550).

Silber, on the other hand, remarks that CHEM Study is designed for the "average" high school chemistry student and not directed at a particular group. Such an opinion implies that the CHEM Study Approach is for non-college orientated as much as for any other group. Too, the course is designed so that built-in or automatic devices, such as the monograph program, take care of the gifted students. Silber's overall reaction to CHEM Study may be seen in the following revealing remarks:

The text material is also written in such a way that the student cannot always obtain the answer from the textbook and must rely on his ability to seek the answers from other sources. This is entirely different from most textbooks on the market. Also, the course is closely integrated with the laboratory and actually carries out the theme of being an experimental science. The course was developed so that a broad understanding of the principles of chemistry is obtained with sufficient depth to enable the student to cope with new problems presented in college or later life. (8, pp. 117-118).
Sibler's remark about the CHEM Study method being nondirected at any particular group is confirmed by the research done by C.A. Hardy. Hardy summarizes in his research that:

...there is no significant interaction between program and mental ability as far as achievement in chemistry and as far as level of critical thinking are concerned. Therefore, it cannot be concluded that the CHEM Study approach is superior for high ability students but not superior for low ability students (3, p. 276).

Another opinion of the CHEM Study Approach expresses much the same thoughts, somewhat more enthusiastically worded. Fast calls CHEM Study an "exciting" approach filled with fresh ideas. He adds that it "is an adventure in a curriculum change at the high school level when compared with more of the so-called traditional high school chemistry courses " (1, p. 147). He also is particularly impressed with the laboratory part of the course, describing it as "psychologically sound." According to Fast, CHEM Study contains the following "ingredients":

1. A discovery approach
2. A search for regularities
3. The use of models as explanations
4. Problem-solving using laboratory data
5. A de-emphasis on descriptive material
6. Real experiments without the possibility of "dry" labbing
7. Excitement and fun (1, p. 156)
Summary and Remarks

In this review of the literature concerning the Chemical Bond Approach to chemistry and the CHEM Study method, it is plain to see that most teachers highly prefer either one or the other. Very few "in-between" opinions have been found. It appears that when one becomes an actual part of one of the methods, he is either completely "sold" on it or turns completely against it.

Some differing opinions on each course have been accumulated, quite naturally. Certainly it is a part of America's growing concern with good teaching that one is entitled to draw his own conclusions. Such has always been an important ingredient of the Democratic Way.

It is now—and will be throughout the entirety of these pages—the objective of the present writer simply to offer a comparative study of the CBA and CHEM Study approaches to the study of high school chemistry.
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CHAPTER III

COMPARISON OF TEACHING RESULTS GAINED FROM
THE CHEMICAL BOND APPROACH AND
THE CHEM STUDY METHOD

While it is valuable to get differing opinions on the merits of CBA and CHEMS, even more significant to the purposes of the present study is a survey of the teaching results of each method. Feifer, for example, is particularly enthusiastic about the interest stimulated in his students by the three different kinds of laboratory experiments in the CBA manual. The first group is fairly traditional in context. The second and third types are quite different. In the second group of experiments, suggestions are given only to help the student get a start in a useful direction toward solving the problem. In the third group, only the problem is given; no directions are included.

According to Feifer, the laboratory exercises in CHEM Study are less liable to get good results. For example, in the experiment entitled, "Reactions Between Ions in Aqueous Solution," a detailed account is given of the procedures to be followed, indicating all of these:

1. Materials
2. Quantities
3. Concentration
4. Techniques
5. Pertinent observations

This list is followed by a guide designed to help the student interpret his results. Feifer states that there is no opportunity for creativity or originality, however, at the end of the experiment these remarks are made:

1. Examine your results and propose explanation that will account for the fact that a precipitate was observed in some cases and not in others.
2. Propose a further experiment to test your ideas (6, p. 113).

Feifer concludes that original investigation constitutes only a small fraction of the CHEM Study Laboratory manual, and instead the student is limited to short and simple experiments. When each step of a procedure is carefully spelled out, the format of a manual very closely resembles that of a "cook book" (6, p. 113).

Morlan also found that the CBA laboratory program has been highly successful with his students. Students enjoy the chance to discover and develop more than ever before. Even the longer and more involved laboratory reports, he says, do not receive much student resistance.

The students enjoy the sophisticated manner in which data is handled; for example, even most of the "less able" students develop the ability to build and analyze graphs. The laboratory guide is generally easier to read than the text, although in some of the pre-lab sessions procedure must be developed in more detail (7, p. 426).
The results of questionnaire distributed to CBA students showed that bright, average, and "less able" students find satisfaction in the CBA method. After the course was over and all final grades recorded, Morlan found that the below average student could learn as much chemistry with CBA as with previously taught traditional materials, and that they had become more enthusiastic about chemistry (7, p. 426).

College students who participated in CBA while still in high school have reported two effects the CBA study has had on their college chemistry work:

1. They are particularly strong in orbital theory, equilibrium, concepts of bonding, the use of models, and energetics.

2. A lack of nuclear chemistry, however, has hindered them somewhat (7, p. 426).

Morlan's conclusions after his first year of teaching by the CBA method were as follows:

It does keep students of all abilities "off balance" in a creative and challenging manner. And equally important, it gets students excited and teachers enthused. The student does learn to analyze new situations; and many catch the satisfaction of developing ideas for themselves. As one student said, "It's a very good course because it gets your mind working for itself." (7, p. 427).

It was very interesting to the present writer to discover that many more teachers appear to have written in
praise of the CHEM Study than the Chemical Bond Approach. From their very beginnings, both courses have attracted a great deal of attention. In the 1960-61 school year, directly following the first publication of the CHEM Study books, a preliminary try-out was made with a group of participating students. A series of five sequential achievement tests was developed and administered throughout the academic year. The tests were deemed to sample the kinds of learning consistent with the overall objectives of the CHEM Study, and results of the tests showed an inordinately low correlation of the CHEM Study scores as compared with similar correlations of aptitude against the multitude of traditional achievement tests in high school chemistry. It was decided that, given a group of students such as those who were enrolled in the CHEM Study course during 1960-61 and teachers with equal capacities, the course most certainly would produce dramatic results (3, p. 17).

Another research study undertaken in January of 1966 made use of the Cognitive Preference Examination: Chemistry (CPEC). Atwood was attempting to test the following hypothesis: "There is no significant difference in CHEM Study achievement as measured by the course semester examination, among groups of eleventh grade students classified on the basis of frequency of choice on the CPEC." The CHEMS achievement test and the CPEC were administered by
each of ten cooperating teachers as he or she completed the first twelve chapters in the CHEM Study test. The author felt that a preference for memory of facts and terms (M) should be at a disadvantage in CHEM Study when compared with a strong preference for fundamental principles (Pr), a critical questioning of information (Q), or practical application (Ap). Using data for 775 subjects, correlations between CHEM Study achievement and each of the four cognitive preferences were obtained. The consistency with which the CHEM Study students preferred Pr over M was quite marked. There was, as the hypothesis had assumed, an apparent negative relationship between CHEM Study achievement and the M preference. It was concluded, indeed, that students who showed a strong preference for memory of specific facts were at a disadvantage in the CHEM Study course relative to those who showed a strong preference for fundamental principles, critical questioning of information, and practical applications. The data suggested that a strong preference for practical applications in combination with a preference for fundamental principles or critical questioning would be most advantageous (1, p. 159).

A total of 1333 students and twenty-three teachers took part in a study in Iowa and Illinois. Troxel attempted objectively to analyze the effectiveness of the CBA, CHEM
Study, and Modern Chemistry course materials by utilizing and comparing student achievement of various common objectives of the three courses of study. He felt that the results might help teachers to make their choice between the two new programs and the more conventional approach to chemistry (12, p. 79).

For the study, Troxel used four instruments on a pre-test and post-test basis to determine if there was any difference in the attainment of the courses' objectives. The objective instruments were as follows:

1. **ACS Cooperative Examination in General Chemistry, Form 1963 (ACS)**
   - a. Recall of Information
   - b. Application of Principles
   - c. Quantitative Application of Principles
   - d. Total Test Score

2. **Test on Understanding Science, Form W (TOUS)**
   - a. The Scientific Enterprise
   - b. The Scientist
   - c. Methods and Aims of Science
   - d. Total Test Score

3. **Watson-Glaser Critical Thinking Appraisal, Form Ym, (WGCTA)**
   - a. Inference
   - b. Recognition of Assumption
   - c. Deduction
   - d. Interpretation
   - e. Evaluation of Arguments
   - f. Total Test Score

4. **Prouse Subject Preference Survey (Prouse)**
   - a. Total Test Score (12, pp. 79-80)
Results of the study were as follows:

1. The students in CHEM Study and/or CBA classes scored significantly higher than did students in the Modern Chemistry classes.

2. On the ACS total test score both CHEM Study and CBA students scored significantly higher than did students in the Modern Chemistry course. There were no statistically significant differences between the CHEM Study and CBA students.

3. On the TOUS total test score as well as all subtests, CHEM Study and CBA students scored significantly higher than did students taking the Modern Chemistry course. In addition, CBA students scored significantly higher than CHEM Study students on all of the TOUS measures except the subtest, "The Scientist," on which there were no significant differences.

4. On the WGCTA, the CHEM Study students scored significantly higher than did the Modern Chemistry students, on all measures except the subtest, "Recognition of Assumptions," in which case the CBA students scored significantly higher than did the CHEM Study students.

5. On the Prouse, the CHEM Study students rated their subject significantly higher than did the Modern Chemistry or CBA students. Also, the Modern Chemistry students rated their subject significantly higher than did the CBA students (12, p. 81).
Troxel came to the following conclusions in regard to the effectiveness of the CHEM Study and CBA courses:

The results of this study indicate that the Modern Chemistry, CHEMS, and CBA courses are not meeting their objectives with the same degree of effectiveness. In general, students who use the CHEMS and CBA course materials develop a better understanding of chemistry, develop a better understanding of science, and develop a greater ability for critical thinking, as measured by the instruments used in this investigation. Students who are enrolled in Modern Chemistry and CHEMS develop a greater preference for science than do students enrolled in CBA, as measured by the instruments used in this investigation (12, p. 81).

In late 1966, Pye tested some 695 high school students from 100 high schools in Southern California. The examination given was a general chemistry test, not planned for the specific evaluation of any one of the four chemistry approaches: Conventional, CBA, CHEM Study, or OTHER (an advanced placement course). The examination consisted of four parts:

Part I considered general principles of chemistry.
Part II contained numerical calculations.
Part III consisted of questions on special applications.
Part IV, regarded as the most difficult, was designed to test the student's ability for logical reasoning (8, p. 30).

The 98 examination questions represented what 35 research, industrial, and academic chemists, with widely varying backgrounds, felt were some of the more important aspects of chemistry with which a good beginning student
should hope to be familiar. The results of the examination showed, not surprisingly, that the OTHER students led all of the groups in all parts of the examination with only one exception: The CHEM Study students outperformed them on Part I. The students in the OTHER group, however, were screened, selected, and given an Advanced Placement chemistry course (8, p. 32).

Another notable result was that the Conventional group, with few exceptions, made a better performance than did the CBA group, with the CBA group doing better only on Part IV (8, p. 32).

Only in Part III did the Conventional students have a performance superior to that of the CHEM Study students (8, p. 32).

CHEM Study students in general outperformed both Conventional and CBA students. Only in the logical reasoning portion of the examination did the CBA students excel noticeably; and generally, the CBA group fell behind the Conventional group (8, p. 32).

Another investigator, Rainey, was impressed with the CHEM Study laboratory method. Using as subjects the students enrolled in four classes of chemistry in Minneapolis High schools, Rainey followed this procedure: Two of the four classes were taught by the CHEM Study method; the other two classes were taught by a conventional method. Two null hypotheses were tested:
1. There is no significant difference between the mean test scores of the two groups at the start of the year.

2. There is no significant difference between the mean test scores of the two groups at the end of the year (9, p. 541).

While it was concluded that neither of the teaching approaches showed superiority in student learning as measured by the tests mentioned on page 30 of this paper, certain subjective observations were made, which included:

1. Students in the conventional classes consistently produced better write-ups of experiments than did the CHEM Study classes. A possible explanation might be that the students in the CHEM Study classes believed they were merely repeating the detailed directions of their laboratory manuals, although the format included their own interpretation of the facts.

2. Students in the CHEM Study classes seemed to enjoy their laboratory work more. On a student reaction sheet given to all classes at the conclusion of the course, the CHEM Study students consistently stated that the laboratory work was the most enjoyable of the course, while those in the conventional classes were less consistent with this kind of comment.
3. Students in the CHEM Study classes felt more hurried in their laboratory work because of a more rigid time schedule imposed on them to finish all the material during the year. Students in the conventional classes were not under any pressure to finish and were allowed to explore other things related to a specific assignment in the laboratory within a reasonable time limit.

4. On the basis of the experience of the investigation, the CHEM Study course offered a reasonable and workable approach to teaching high school chemistry. The laboratory work did the teaching, and it was concluded that the CHEM Study curriculum offered an excellent alternative in paired and group laboratory work (9, p. 544).

Some special attention has also been given the importance of CHEM Study films as an integral part of the course. Trinklein, for example, comments on the film, "Bromine--Element From the Sea." The subject matter on bromine is not presented elsewhere in the CHEM Study course, he says, and the film can be excerpted to provide single concept sequences dealing respectively with:

1. Correct handling of bromine
2. Reactivity of bromine and solubility of bromine compounds.
3. Preparation of aqueous bromine
4. Laboratory extraction of bromine from sea water,
5. Commercial extraction of bromine as compared with the laboratory method (11, p. 235).

Trinklein was interested in testing the relative effectiveness of using a full film and excerpts from that film to teach factual information to high school chemistry students. The student population was 382 students in CHEM Study courses involving 18 different Southern Michigan teachers. Three film treatments were used: One group saw the film only; another saw the film excerpts only; and a third group saw a combination of film and excerpts. Each class saw the film material twice but not necessarily in the same order or the same time sequence. The investigator wrote a summary for the film and for each excerpt. These were used by the teachers as the only introduction to the film or excerpts. A series of questions based on the fundamental principles in the excerpts was used as the only basis for discussion of both the film and excerpts.

The finding of the study was that a combination of a whole film and excerpts from that film produces greater achievement gains in factual knowledge within the film than either the film or the excerpts alone. Trinklein's investigation also proves another valuable point, however, to the present writer. The enterprising science teacher can go a long way toward making a success of his course no matter what course materials he uses (11, p. 238).
Another similar investigation was made by Brandou using a set of 27 CHEM Study films. A major concern of this project was the selection of useful segments from the films. Subjects for the study were the 56 participants in the 1964 CHEM Study Institute at Michigan State University, and the following conclusions were reached:

1. The films prepared by the CHEM Study curriculum were highly rated by the subjects for use in the classroom.

2. A number of segments from the films were cited as potentially useful short format clips.

3. More experienced teachers and teachers with more extensive backgrounds in chemistry selected more film locations as potentially useful (2, p. 191).

Brandou concluded that the selecting of excerpts is not difficult and that there are many pieces of film within present educational films that could serve a useful purpose on their own. An experienced teacher can pick out a number of such items in a single viewing of a film, and experienced previewers frequently select the same sections, even after several screenings (2, p. 191).
Personal Observations

A wealth of material exists on the subject of the CHEM Study course. Fewer writers appear to be concerned with the effects of teaching by the CHEM Study method. This is not really surprising, however, when one considers that the CHEM Study text, Chemistry: An Experimental Science, has been adopted for use by close to 50 per cent of the high school chemistry students in the country (10, p. 217).

Clader comments on CHEM Study's progress by saying:

Progress . . . has been made not only in terms of numbers involved but also with respect to clarity of concepts and principles of chemistry as embodied in the laboratory experiences for student and in the textual readings (4,p.378).

In the present writer's opinion, progress has indeed been made. While little effort has been made to revise and adapt such courses as CBA, the CHEM Study Steering Committee decided that three publishers would be chosen to produce revisions of the original CHEM Study text. The Committee chose this unique path in order to maintain CHEM Study's influence and, at the same time, to avoid perpetuating itself. In 1968-69, Houghton-Mifflin, D.C. Heath, and Prentice-Hall published their revisions. Each of the publishers paid to CHEM Study a fixed amount, with the provision that there would be no royalty to CHEM Study on sales nor would the Study have any financial interest in the books produced. Further, CHEM Study exercised no supervision of any kind
over the content of the revisions (10, p. 219).

Hodgway and Pimentel have conclusively proven to the present writer that theirs is a far-reaching goal, that is, to present the best possible chemistry teaching methods and materials without allowing their course, over the years, to become static and too much influenced by the personal views of its perpetrators. In the revisions of their text, for example, they looked for and found creative and innovative departures from the initial materials. They found, too, that the inquiry approach and the philosophy and spirit of the original text were maintained in all three revisions (10, p. 219).

In addition, the CHEM Study films, which were originally directly integrated into the CHEM Study program, have been retained by the three revised texts, which all suggest the use of the films with their courses. Other chemistry texts, too, have found that many of their concepts can be effectively taught through the use of the CHEM Study films. Even universities, in their introductory courses, are finding the CHEM Study films to be useful (10, p. 221).

There can be no doubt of the impact of CHEM Study as a new approach to the teaching of high school chemistry. While such methods as CBA have obvious value and have also contributed to the increasing interest in knowledge of their
subject, CHEM Study appears most definitely to have had a much more far-reaching effect on present high-school chemistry teaching. Certainly, this investigator must agree whole-heartedly with Fast's evaluation of the CHEM Study approach:

... the student learns chemistry by the discovery approach through guided laboratory experiences designed to draw conclusions and to establish regularities which lead to the generalizations of present day concepts and principles of chemistry. Great emphasis is placed on the experimental nature of chemistry. One learns chemistry rather than learning about chemistry (5, p. 147).


CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

To summarize, in the first chapter of this paper ten questions were listed. Answers to these questions were to be provided by research. Taking the answers to these questions now, one by one, the answers provide a summary of the overall objective herein, namely, to determine whether there are any substantial differences in the CBA and CHEMS presentations of the subject of chemistry.

To the question of whether they contain the same materials, the two courses treat the same nine major topics: stoichiometry, atomicity, kinetic-molecular theory, periodicity, energy, rates of reaction, equilibrium, bonding, and acids and bases. The CHEM Study course, however, does not develop the materials as extensively as does the CBA. The first six chapters of the CHEM Study textbook, for example, present an overview of the course with heavy stress laid upon the experimental approach.

At the same time, the fundamental approach of the two courses is the same. The theme of the CBA, "Chemical change is structural change," can also be seen quite plainly in CHEM Study's treatment of the atom as a unit of structure. Further, the major emphasis in both courses is firmly laid
on chemical principles rather than on descriptive chemistry. Perhaps nowhere is this fact more evident (in the case of CHEM Study) than in the results of Atwood’s research (pp. 25-26, this paper). Students who showed a strong preference for memory of specific facts were at a disadvantage in the CHEM Study course in comparisons with those who showed a strong preference for fundamental principles, critical questioning, and practical applications. As regards CBA, Troxel (p. 28, this paper) discovered that CBA students ranked even higher than CHEM Study students in their ability to recognize assumptions.

The philosophies of the two courses are very different. CBA is primarily theoretical, a reflection of the idealism of Dr. Strong. In its text, alternative theoretical interpretations of the same phenomena point up the dynamic character of modern chemistry as a developing intellectual discipline. As Feifer has said, like the actual scientist, the CBA student must devise his own experiment, a process which should lead him to think through the entire investigation process he must resolve in terms of meaningful procedures, relevant observations, and cogent conclusions (p. 12, this paper). And, as Strong points out, "A good course for the general student emphasizes the nature of science and its contributions to the process of human understanding." (p. 15, this paper).
While the CHEM Study course also stimulates the spirit of inquiry, its philosophy takes on a more practical (and practicable) aspect. It is most important for the CHEM Study student to establish laboratory evidence in order to deduce the principles operating in chemistry (p. 17, this paper). For this reason, the laboratory portion of CHEM Study gives much fuller instruction for the experiments than can be found in CBA.

Although both courses have as their major aim the producing of well-educated chemists, they go about achieving this aim in differing fashions. CBA is rather overwhelming in its elegant presentation of logic; the student is required to give intensive thought to each topic, because Strong makes no concessions in this respect. Morlan has stated that the CBA text is "a tough bit of scientific writing," and, even though he is a CBA proponent, he feels that the text sometimes goes to an extreme in an effort to be complete (p. 16, this paper).

CHEM Study, on the other hand, reflecting the practical but cheerful viewpoint of Pimentel and Carpenter, prefers to oversimplify if this will lead the student through the difficulties of the study of chemistry. The practical nature of CHEM Study can be seen in Sibler's statement quoted earlier in these pages:
The course was developed so that a broad understanding of the principles of chemistry is obtained with sufficient depth to enable the student to cope with new problems presented in college or later life. (p. 19, this paper).

How does the average student react to each course? This is a question not easily answered, for it is difficult even to define "the average student." There is little doubt, however, that students in general regard the CBA text as a "very rigorous" one. (p. 16, this paper) At the same time, Sibler says of the CHEM Study text that it is written in such a way that the student cannot always obtain the answer and must go to other sources. (p. 19, this paper) Students of both courses, indeed, seem to prefer the laboratory portion. This is hardly surprising, as most students prefer activity to mental effort alone. Feifer and Morlan both found that their students thoroughly enjoyed their CBA laboratory experience, and the CBA laboratory guide admittedly is easier to read than the text (p. 23, this paper). Rainey, a CHEM Study teacher, found that his students, too, preferred lab work to class work (p. 18, this paper).

CHEM Study shows more of an inclination to bring other school subjects into its discussion than does CBA. As previously stated, CBA emphasizes chemistry as an academic pursuit. CHEM Study students, on the other hand, are encouraged to suggest reasons for everything they see and
do. (p. 18, this paper). Such deductions will naturally raise questions, the answers to which lie outside the realm of pure chemistry. In the present writer's opinion, no high school subject should be completely isolated from a consideration of other subjects. History and economics both have a great deal in common with chemistry, and when possible and relevant, such linkages should be made.

The primary differences in the two courses are their order of presentation and the philosophy underlying the courses. Another area of difference that is of special significance to this investigator is the integral part played by the CHEM Study film.

Conclusions

As a result of extensive research, several conclusions have been reached in regard to the CBA and CHEM Study courses:

1. The philosophy of the CHEM Study course is more adapted to what the average high school student needs. Very few students, in all likelihood, will profit greatly from the idealistic theories which form such a major portion of the CBA course.

2. Although both methods rely heavily on the laboratory work as an experimental approach, CHEM Study is more helpful to the average student in that the details of the experiments are more fully presented. Regardless of Dr.
Strong's fervent desire to stimulate the philosophical spirit, most high school students have little respect for semantics. The broader, less inclusive and dogmatic approach for CHEM Study is more apt to appeal.

3. Likewise, the majority of high school students favor the forthright method to be found in CHEM Study. Few of them are sophisticated enough to fully appreciate Strong's sometimes pedantic working and the extent to which he goes in many of his rigorous definitions. Surely the personalized, informal style found in CHEM Study is more likely to reach more students who fall in the so-called average group. At the same time, the CHEM Study course does provide for the above-average student who wants to take advantage of, for example, the available monograph program.

4. The CHEM Study course can be assimilated better by the average chemistry teacher. No special "training" period is necessary for it, as has been found to be the case for many CBA teachers.

5. Since far less than one-half of high school students will go to college, it is important that they receive the practical knowledge taught in the CHEM Study course. It may well be their only experience with chemistry as a school subject, and it is impossible to overstress the need for educating America's young people to an ever-changing way of life. The basically simple to complex type of coverage in the CHEM Study method appears to be the better answer.
6. Further, only a small percentage of those who do go on to college will be interested in science as a career. The CHEM Study course appears to be exactly what the student needs when, as in most cases, his career will be in a non-scientific field.

7. The excellent films used in CHEM Study show up a corresponding lack of audio-visual aids in CBA.

Recommendations

On the basis of the above conclusions, the present writer feels that, if required to make a choice between teaching the CHEM Study course or the Chemical Bond Approach, he would definitely choose the former. All high school students, no matter what their future may bring, are entitled to a working knowledge of chemistry, presented in an enjoyable way and with eminent future advantages. For the college-bound, whether they elect to become elementary school teachers, businessmen, nurses, technicians, or whatever, the CHEM Study course provides a good background.

The present writer further recommends the teaching of CHEM Study on the ground that it is a much less revolutionary course than CBA. While a change in traditional chemistry-teaching methods was (and is) greatly needed, it must be the task of the instructor to blend the new and the old
methodology into an approach which is best suited to his individual situation. Certainly, such a prospect is infinitely more likely with the CHEM Study than with the CBA course.

Although both courses emphasize greatly the laboratory work, CHEM Study is recommended over CBA for this reason: The Chemical Education Materials Study Course presents the student with an excellent sequence of experiments carefully designed to point out to the beginning student all the variables he must account for by listing the things he must and must not do, and by directing him step by step through rather detailed experiments. Leading a student toward a superior ability to make correct assumptions is all well and good, and certainly CHEM Study as well as CBA has that goal in mind. A large amount of direction is needed, however, by most students, and CHEM Study provides this where CBA does not.

Finally, CHEM Study is recommended as a superior method of teaching high school chemistry because theory, so much more emphasized in CBA, can equally well be included in a CHEM Study course—-at the teacher's discretion. The instructor, after all, is the vital link between the student and what he hopes to teach the student. Regardless of whether CHEM Study, CBA, or any other method is used in the classroom, the teacher will add to and subtract from
the materials offered by the course itself. No two teachers are alike and no two teaching situations are identical. The teacher who follows by rote the textbook and the manual he has selected is not deserving of the name "teacher." Every experiment performed will give the "growing," the "constantly searching" teacher additional means of emphasizing the continually changing universe and the necessity of man's adapting himself to it. Chemistry, as a science, cannot be a static subject. This statement has never been more true than it is today. In this era of space age achievements, a large emphasis must be placed on the value of science in everyday living. CHEM Study presents an opportunity for the teacher to prepare the average student for a fuller life. Since there is such a majority of average teachers and average students, surely the CHEM Study course can be of infinitely more value. What more important objective, after all, can any course on any subject hope to achieve than to impart enjoyable and lasting knowledge of practical value?

Surely, it is seen that there are differences in the CBA and the CHEM Study methods of teaching high school chemistry. There are differences which make it vital for all teachers who hope to be involved in high school chemistry to weigh the values of each course with a steady, careful hand. Such has been the procedure in these pages. Some
advantages have been seen for each course, but taking the overall value of CBA and comparing it with that of CHEM Study, it is judged that the Chemical Educations Material Study Course will do the most good for the largest number of students, a true and valid and most important consideration in a democratic world.
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