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ABSTRACT

The CHEM Study literature reviewed consists of (1) the "subjective" literature, as evidenced by project newsletters, position papers, and open sources and (2) the "objective" literature, which consists of research studies related to CHEM Study. The "subjective" literature provides many suggestions regarding the use of the CHEM Study materials, the kinds of learning outcomes to be expected, and the differences in instructional procedures between conventional chemistry teaching and CHEM Study teaching. The reviewer points out the lack of research into some of these aspects. Instead, most research has been directed at (1) comparing student outcomes from the CHEM Study course and those from some other chemistry course, (2) investigating cognitive processes of students in CHEM Study classes, and (3) investigating the effect of CHEM Study content on students without using a pre-post test design. The areas which the reviewer suggests need research include that of determining (1) how the CHEM Study materials may best enhance student outcomes, (2) how closely the objectives of the course are actually achieved in the classroom, (3) which students, and teachers are best suited to the CHEM Study program. An extensive bibliography of CHEM Study references is included. (LC)

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A REVIEW OF THE RESEARCH AND LITERATURE ON THE CHEMICAL EDUCATION MATERIALS STUDY PROJECT

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Gregor A. Ramsey

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for Science Education
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Research Reviews are being issued to analyze and synthesize research related to the teaching and learning of science completed during a two-year period of time. These reviews are organized into three publications for each two-year cycle according to school levels--elementary school science, secondary school science, and college science.

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A REVIEW OF THE RESEARCH AND LITERATURE ON THE CHEMICAL EDUCATION MATERIALS STUDY PROJECT

by

Gregor A. Ramsey

The CHEM Study literature was reviewed in two stages. In the first, the subjective literature as evidenced by project newsletters, position papers, and open sources was reviewed. In the second stage, the objective research related to CHEM Study was reviewed. To provide a common reference point for examining the literature, it was decided to focus on the implications for instruction and the development of chemistry content suggested by these sources. An exhaustive bibliography of CHEM Study references is included.

Aims and Goals of the Course

The CHEM Study Course was developed initially in 1959 as one of the curriculum projects sponsored by the National Science Foundation. Reference to the National Research Council Guidelines gives some insights into what one of these courses should be:

> Concepts may be regarded as complexes of cognitive factual information, laced together by experience in problem solving, and overlaid with substantial involvement. These components - the facts, experience with the analysis and solution of problems, and a sense of emotional excitement - seem to be essential ingredients for a school science program if concept development is to occur even to a moderate extent. (60, pp. 7, 8)

The aims of the CHEM Study Course have been reiterated many times since 1959. Statements by Seaborg (105), the first CHEM Study Newsletter (26), Campbell (20), and the description in each edition of the International

Clearinghouse Report, Lockard (71), all explain the aims and goals of the course. Richard J. Merrill, former executive director of the project, defines the two major aims as being:

> (1) to stimulate and prepare those high school students whose purpose it is to continue the study of chemistry in college as a profession.
>
> (2) to further in those students who will not continue the study of chemistry after high school an understanding of science in current and future human activities. (82, p. 2)

Merrill goes on to describe the philosophy and approach recommended:

> . . . important concepts and generalizations should be developed inductively by being based on evidence which the student can understand . . . He then is encouraged to develop one or more explanations or 'mental models' to explain phenomena and regularities he has observed. The student tries this first on his own, and then with the help of reading assignments and class discussion. (82, p. 2)

The "charge to the students" made in the preface of the CHEM Study text (90) emphasizes understanding rather than memorization. The following points summarize briefly the preface:

1. An understanding of principles removes the need for endless memorization of innumerable chemical facts.
2. Principles grow out of observation.
3. Students become practiced in making unexpected observation, in weighing facts, and in framing valid conclusions.
4. Questioning and seeking understanding should become a habit.
5. Students will no longer be satisfied with dogmatic assertations.

These comments place an emphasis on understanding, and suggest that students have an important role to play in the instructional process. The course was designed to be college preparatory, yet it was also designed to enhance scientific understanding in those students who will not proceed with college chemistry. Emphasis is placed on the student "finding out" rather than on the teacher "telling."

Content of the Course

The course was developed to be significantly different from traditional courses in content development. The design of the course provided an integration of the textbook materials, laboratory activities, and visual aids.

Merrill describes how the course differs from more traditional ones:

> The content of the course differs principally in that the fundamental, unifying concepts of chemistry are stressed at the expense of much of the history and descriptive technology commonly included in high school textbooks and courses. (83, p. 71)

The intent and approach of the CHEM Study Course may best be seen from the comments in the extensive teachers' guide. Its organization shows that there is a heavy emphasis in the course on the content and concepts of chemistry. This content is intended to be developed inductively by obtaining experimental evidence and conceptualizing through classroom discussions and student exercises. Students are expected to consider questions like "Where do the 'facts' come from?" "What does it mean to 'explain' facts?" Answers to these questions constitute "the most abstract message of the course." (77)

Each chapter of the text is extensively treated in the teachers' guide. On the average, two-thirds of a page is devoted to the "intent and approach" for the chapter. Also, the experimental evidence which forms the basis for the new concepts is spelled out and the general philosophy of the chapter given. The "outline" gives the general ideas to be developed in the chapter (usually about ten of them), and then any "new concepts" are listed (usually about six). As Pode quotes from an unpublished history of the development of CHEM Study by R. J. Merrill, former executive director of the project, the four criteria applied in ordering ideas for the course are:

1. Is the idea so important that no first course is complete without it?

2. Can the idea be developed honestly at a level comprehensible to high school students?

3. Can it be developed out of experimental evidence that high school students can gather, or at least understand?

4. Does it tie to the other parts of the course so that its use can be reinforced by practice? (93, p. 100)

As Pode points out, "these are educational considerations, not technical ones" (93). If these criteria are also to guide a teacher in the classroom situation, then a method must be found for determining how closely these criteria are met. These four criteria are not only imperatives for the construction of textual materials, they are instructional imperatives as well.

Little has been written on areas of difficulty found in teaching the course to students. Merrill, who taught the course in its trial phase, outlines some of these:

1. A continuous stress on mathematical manipulation skills throughout the course.

2. A "changing of rules" for achievement using open book tests which stress principles rather than the factual recall of more traditional courses.

3. A rapid over-view of many chemistry concepts which are dealt with later in great depth. (82, pp. 5-6)

Unfortunately the pedagogical implications of these or other difficulties experienced when the course is taught are not discussed, nor are suggestions given to help the teacher cope with them.

Instructional Procedures

A course as different in content and approach as the CHEM Study program should be taught in the classroom in a way quite unlike that used to teach conventional courses. The course was to be based on experimentation, ideas were to be developed inductively from evidence, and the emphasis was to be on understanding principles rather than knowing facts. Yet a search of the literature has revealed no definitive description of how these ideas were to be accomplished in the classroom. How does one teach inductively? How does a teacher integrate the laboratory into classroom experiences? What techniques are needed to develop understanding? Little attention has been directed to these urgent instructional questions, and the newsletters or teachers' guide seem to leave them largely to the teachers' intuition.

One direct reference to the kind of instruction was found in a CHEM Study Newsletter which outlined recommendations for facilities and class size.

> Class size and arrangement should be conditioned by the kind of teaching for which CHEM Study materials were designed. This involves a minimum of lecturing and a substantial amount of real discussion in which ideally all members of the class should be actively involved. (37)

The traditional lecture session apparently should be de-emphasized in the CHEM Study programs, and in any discussion of content, students will be active participants, not passive listeners.

The development section in the teachers' guide to the course outlines a detailed approach to each chapter. Stress is placed on experimental evidence and on models and analogies to help students understand the concepts being considered in class. Although the teachers' guide is extremely detailed, the emphasis is on what to develop, and which models or experiments to use during development, rather than on describing teaching strategies which are known to be successful. There are many hints regarding what may be used in an instructional sequence, but few suggestions for blending the hints into a coherent whole to describe successful teaching strategies. It seems from the teachers' guide that it is left to the individual teacher to express his own mode of instruction in the classroom (78).

There have been several reviews of the CHEM Study program, including those by Bennett and Pyke (9), Ashmore (3), and Pode (93). These have concentrated on objectives or content of the materials, rather than on how these materials are used in the classroom. For example, Bennett and Pyke in their discussion of the CHEMS and CBA chemistry programs and traditional programs state that the CHEMS materials encourage a "scientific method of enquiry as opposed to learning the facts," and that they make "significantly greater use of analogy" than either CBA or traditional chemistry (9). The materials may, but this does not necessarily mean that teachers in their classrooms do. This aspect seems to have been ignored by reviewers.

Much of the relevant literature describing the CHEM Study program has attempted to show how different the program is from traditional chemistry courses. A quick reference, two column comparison of CHEM Study and a traditional chemistry course has been outlined by Peterson (89). He compares objectives, criteria for selecting content, actual content, organization of text, laboratory work, evaluation and testing, teaching materials, and method of teaching implied. For example, under Method of Teaching, Peterson draws the following comparisons:

TRADITIONAL	NEW
METHOD OF TEACHING IMPLIED:	METHOD OF TEACHING IMPLIED:
1. A problem approach, stressing methods of inquiry as the means through which understanding and mastery of subject matter will be achieved, is suggested.	1. The CHEM Study Course is strongly based in experiment and is, in organization as well as in philosophy, laboratory-centered.

2. Conventional classes in chemistry are most frequently subject-centered and teacher controlled (dominated).

2. The teaching of facts, while important, is secondary to an understanding of broad summarizing principles which can be applied to new and varied situations. The teaching is conceptual.

3. The acquisition and retention of factual information (product) is stressed. This leads to the presentation of many facts, usually through the lecture method, which is effective for that purpose.

3. Teaching is so organized that:

(a) Evidence from experiment is obtained.

(b) Models are proposed and tested.

(c) Class discussion and text treatment of a concept then proceed on the basis of what students have seen in their laboratory work. The concepts gained are tied with those presented earlier.

4. The teaching is strongly based in the formal presentation of materials <u>followed</u> by laboratory (verification) experiences. This provides only limited student opportunity for discovery, and interpretation. However, the better chemistry teachers (whether traditional or modern) use a wide variety of teaching techniques and approaches. No stereotyped plan can be used to the exclusion of all others. The teacher must know what he wants the student to gain in a particular time block and then choose the method(s) which will provide the most effective learning situation(s).

4. The teaching of chemistry is based heavily upon the idea of science as a process. The methods emphasized will be those which provide opportunity for student discovery, for interpretation of data, and for formulation of tentative conclusions and/or generalizations.

5. The supplemental use of integrated films provides an excellent method for the presentation and/or reinforcement of important unifying principles. (89)

If these are the methods of teaching implied by the courses, what demonstrable differences are there in procedures used by teachers teaching them? This aspect has had little research attention. Objectives, content, the nature of laboratory experiences all may be compared, yet unless differences in these are translated into different instructional procedures by the teacher, the 'new' course reverts to being the old course with new words.

The inductive method of teaching chemistry implied by the CHEM Study Course required, in the initial stages, extensive inservice education. Summer institutes were arranged to acquaint teachers with the new methods. Details of these institutes are outlined in the CHEM Study Newsletters of January and May, 1963; February, 1965; and February, 1966. Even with these summer institutes, however, it was unlikely that all teachers wishing to teach the course could be accommodated. This aspect was discussed in the October, 1962, Newsletter where it was stated that teachers without institute experience would want to teach the course. An optimistic note regarding success was expressed:

> Evidence to date is encouraging though not plentiful. Comments and test results received from the handful of teachers who taught the course 'on their own' last year revealed no unsurmountable difficulties. (32, p. 2)

Also, a series of suggestions are given for teachers who intend to teach the course without inservice experience (32).

Evaluation of what the teachers did who taught CHEM Study without the benefit of inservice was solely on the basis of limited test results and comments of the individual teachers. It is interesting to speculate on what these teachers did differently in their classrooms after electing to teach the new course. Certainly no objective attempt was made to see what they were doing.

The change in emphasis in the CHEM Study program from the products of science to the process of science, from the facts of chemistry to the principles of chemistry, from deductive to inductive teaching, and from teacher explanation to student realization should mean that what goes on in a CHEM Study classroom should be quite different from what goes on in a classroom where chemistry is taught in the traditional way. Because the two approaches are considered so different, one might expect numerous reports of what goes on in CHEM Study classrooms; however, a review of the literature shows that this is not the case. It would appear that the researchers in the CHEM Study field considered that if CHEM Study materials were being taught, this was sufficient reason to expect that different things were being done in the classroom, and these differences would show up in terms of student outcomes evaluated using conventional pre-and post-test procedures. The actual research which has been done on the CHEM Study program will be reviewed in the next section, and the findings of many of these studies discussed. They do, however, seriously call to question the idea that a significantly different kind of chemistry teaching was going on in the CHEM Study classes involved in the studies.

Research Studies

The studies reviewed may be divided into three main groups: studies which compared student outcomes for students in the CHEM Study Course with those studying a more conventional course; studies which investigated cognitive processes of students in CHEM Study classes; and studies which investigated the CHEM Study Course without using a pre-post test design.

Comparative Studies

The earliest comparative study identified was that of Heath and Stickell (61). They compared outcomes of students in CHEM Study and CBA courses with those studying a conventional course. Each group was tested using its own final examination, with the Cooperative Chemistry Test (ACS - NSTA) (48) being taken as representative for the conventional group.

Control groups of conventional students took either the CHEM Study or CBA final examinations. It was found that each group did significantly better on its own examination.

Rainey (96) and Altendorf (1), in somewhat similar studies, compared student achievement using the Cooperative Chemistry Test (ACS - NSTA) for students in CHEM Study and conventional classes. Both researchers used a matched pairs design, and found no significant differences between the groups. Rainey also compared his groups using the CHEMS Final Examination, and found no significant differences between his groups on this test either.

Pye and Anderson used a general chemistry examination to compare the performance of CHEMS students and students taking Chemical Bond Approach (CBA), Conventional, or other chemistry approaches. The examination was given to some 695 students from 100 high schools in southern California as part of a contest, so it may be inferred that these students represented the better chemistry students. The examination had four parts, relating to general principles, calculations, applications, and logical reasoning. The results of this study are difficult to interpret, although there appears to be no exceptional superiority demonstrated by students in one group compared to those in another (95).

Troxel (115) made an extensive study of the learning outcomes of students in CHEM Study, CBA, and conventional courses. In his test battery he used the Cooperative Chemistry Test(ACS - NSTA), the Test on Understanding Science (TOUS) (110), the Watson-Glaser Critical Thinking Appraisal (WGTA) (118) and the Prouse Subject Preference Survey (94). He used several criteria to establish his sample of teachers. They were required to have a minimum of 35 semester hours of chemistry course work, to have taught the course before, and to agree with the stated philosophies and aims of the course they were teaching. A random selection procedure was used to obtain the final sample. It was found that students in the CHEM and CBA courses performed significantly better than conventional course students on the ACS-NSTA, TOUS and WGTS tests. Where teachers were experienced in teaching chemistry, and agreed with the philosophy of the course, there seemed to be advantages in terms of student outcomes for students taking a new course. One uncontrolled factor in the Troxel study was that the more innovative and creative teachers of chemistry may have been attracted to the new courses.

From these comparative studies it seems that, in terms of the tests used, great gains in student outcomes were not obtained simply by changing to a new course. The teacher variable is likely to be a highly significant factor, and probably what the teacher does with the materials, rather than the materials *per se* may be more important in determining student outcomes. From the design of each of these studies it was evident that the teacher variable was only partly controlled.

Another difficulty with a comparative study is that of knowing what a 'Traditional' or 'Conventional' course is. It is now ten years since the initiation of the new chemistry projects, and it is certain that a large amount of diffusion of new course materials and methods into conventional courses has occurred. It seems unlikely that further studies which compare student achievement in new and conventional courses will produce any new knowledge, and attention should be directed at how teachers use the materials they choose in the classroom.

Cognitive Development

Many of the remaining research studies directed at the CHEM Study program investigated the cognitive processes used by students taking the course. This was most often done by comparing cognitive processes of CHEM Study students with those of students in traditional classes.

Studies by Anderson (2), Herron (64), and Schaff (102) used the comparison technique to investigate whether or not the CHEM Study program had influence on the cognitive processes of students. Anderson compared cognitive processes under the headings Knowledge, Comprehension, Application, and Analysis. Information obtained from a test she developed yielded no significant differences on three of the four cognitive divisions with any of three ability groups. Only on tests relating to 'Analysis' were any differences found, and these favored the conventional course for low ability groups.

Herron used the Bloom taxonomy (10) as a classification for cognitive processes and a factor analysis technique to compare three ability groups of CHEM Study and conventional students. His findings indicated that conventional course students relied more on lower level cognitive abilities than CHEMS students, and that CHEM Study students received more training in making application of their knowledge than did conventional students.

Schaff (102) used a comparative design to investigate student performance on the cognitive ability 'Evaluation.' Students taking conventional chemistry courses were compared with those taking the 'Modern' CHEM Study and CBA courses on investigator prepared tests designed to measure student outcomes in the Knowledge and Evaluation cognitive levels.

Performance on the 'Knowledge' test showed no significant differences between the groups while performance of the modern course students was superior on the 'Evaluation' test. From this Schaff inferred that students taking the two kinds of chemistry differed in the complex cognitive ability 'Evaluation.' The Schaff study appears to equate text and curriculum, and by inference assumes that the course materials per se, rather than the teacher, determine what goes on in the classroom. In a simple comparative study between groups of students it is difficult to equate teachers and classes for the groups compared and it is difficult to know whether differences detected are a function of the materials, the teacher, or the class.

One of the difficulties with studies like those of Anderson, Herron, and Schaff is that the investigator can never be certain that all the questions on a test identified as relating to higher thought process (e.g., of analysis or application) actually are that to the students. An 'Application' question to one student may be simply a 'Knowledge' question to another because the teacher of the second student may have taught the 'Application', thus rendering it 'Knowledge'.

Cleare (46) extended his investigation of the interaction of student cognitive ability patterns to include those of the teacher. He compared the gain in chemical knowledge made by students with cognitive patterns similar to those of their teachers with students whose patterns differed. He used seven cognitive factor tests (verbal comprehension, visualization, syllogistic reasoning, general reasoning, semantic redefinition, flexibility of closure, and induction) to establish cognitive patterns and match teachers and students for his sample of 13 teachers and 917 students. The CHEM Study mid-term and final examinations were used to measure student achievement.

Cleare found that some student-teacher cognitive interaction occurred, for there was a significant gain on tests favoring students whose cognitive patterns were similar to their teachers. The study indicated that performance related to how closely the cognitive patterns of students and teachers were matched, and evidence is given that cognitive patterns for teachers and students can be identified using pencil and paper tests.

Atwood (5) investigated achievement in CHEM Study chemistry among students classified on the basis of cognitive preferences. Four preferences exhibited by students were identified. These were memory of specific facts, practical applications, critical questioning of information, and fundamental principles. Students showing strong preference for memory behaviors were at a distinct disadvantage on tests compared to students preferring the other three cognitive behaviors. Also identified in the study were certain combinations of these four basic cognitive preferences which could be correlated with increased student performance.

The study indicated that students who relied on memory for success on tests were at a disadvantage in the CHEM Study course. Students who questioned information initially, or preferred fundamental principles, or a combination of principles and application performed better than students with other cognitive preference patterns.

If success on tests is a criterion, students preferring levels of cognitive thought higher than memory do achieve better, and the CHEM Study course may be considered to appeal to this kind of student. This study gives evidence that the CHEM Study course maybe more suited to students with certain cognitive patterns than to others. The question is raised, what sort of chemistry should be taught to students who have a cognitive preference opposed to that which is likely to bring success in CHEM Study?

These studies of Atwood and Cleave raise important instructional questions. Which students should take CHEM Study chemistry? Which teachers should teach it? How should the students in CHEM Study classes be grouped? What effect does the course have on students whose cognitive patterns are not congruent with those of the teacher, or whose cognitive preferences are such that they are certain to achieve less than other students?

Non-Comparative Studies

One study was identified which assessed the effect of CHEM Study content on students without resorting to a comparative design using a conventional course. Swartney (109) used a clinical technique to investigate learning difficulties encountered by students studying the CHEM Study program. She examined the items on CHEM Study achievement tests to determine the skills and concepts required for success in the course.

She investigated the lower 20 per cent (based on achievement) of chemistry students in one school, and the lower 30 per cent in another (smaller) school over a series of four individual interviews. She obtained a list of skills and concepts given incorrectly by these students and used this list to test the top 20 per cent of students in the one school and 30 per cent in the other. A total of some 70 students were individually tested.

Her findings were very interesting though only a few will be reported here. She found that more than half the students in low groups:

1. did not enter the chemistry course with a prerequisite knowledge of the particle nature of matter.
2. could not interpret tables and graphs.
3. could not perform long division, solve algebraic equations, or solve ratio problems.

4. were unable to define terms like atomic weight, atom, chemical change, heat (she lists 63 terms without an understanding of which the complete course in chemistry deteriorates to some form of gibberish.)
5. were unable to verbalize and/or use concepts like ionization, equilibrium, acid-base, model (she lists 32).

Things were much better for the top group of students. The lists of difficulties were reduced in length, although more than half of these students:

1. were unable to define heat, isotope, boiling.
2. were unable to verbalize or use concepts like energy, dissolving, catalyst.
3. were unable to balance oxidation-reduction equations; write an equilibrium constant expression or calculate a heat reaction. (109, pp. 4-7)

Swartney's study produced findings of immediate instructional relevance. Student weaknesses were identified, and from these, some of the difficulties associated with class instruction come out clearly. Students have widely divergent chemistry backgrounds, common scientific terms are likely to mean different things to different students, and mathematics is likely to be a problem when quantitiative work is being carried out. Swartney used a relatively small group of students in only two schools. How typical the results are of other CHEM Study classes cannot be decided until a much broader study is undertaken. This kind of study does seem to be a profitable line to pursue to help gain insight into the improvement of classroom instruction.

One study investigated the instructional process in CHEM Study classrooms not involving individual laboratory. Ramsey (97) investigated the development of CHEM Study content in the classrooms of seven teachers. He used an audio tape recorder and extensive hand written notes to record the lessons and categorized the content communications occurring according to a three dimensional category system.

The results of the study suggest that the teachers adopted a deductive teacher-oriented approach to teaching content, and they acted as givers of information rather than guiders of learning. More than 90 per cent of content events occurring in class were initiated by the teacher, and only for inferring events did the students supply the content of the event more often than did the teacher. There appeared to be wide differences between teaching procedures employed by this group of teachers and practices described by the writers of the CHEM Study materials as being the most conducive to learning.

Laboratory Procedures

The newsletters and teachers' guide have stated on many occasions that the laboratory is an integral part of the CHEM Study program. This aspect has been neglected by researchers, and only one study has been identified which investigated laboratory teaching.

Torop (114) investigated the effectiveness of four methods of laboratory reports in the teaching of CHEM Study and their effect on CHEM Study outcomes. The four methods chosen consisted of:

1. writing paragraphs under the formal titles of objectives, procedure, results, and conclusion.
2. filling the blanks on investigator prepared sheets (these had a highly structured format).
3. answering the questions in the laboratory manual.
4. no written report by the student.

Some 75 students were divided into the four groups for the study, and the only instructional difference between the groups was the method of writing the laboratory report. Each student was given a battery of pre- and post-tests for evaluating outcomes. These included the Watson-Glaser Critical Thinking Appraisal, The Test on Understanding Science, CHEMS Semester Achievement Tests, and Laboratory Techniques and Apparatus Tests.

The investigator-prepared laboratory sheets and the reports relying on questions from the laboratory manual proved most effective in terms of outcomes on the tests administered.

This study directed attention to what methods should be employed in the classroom. Write-ups of laboratory experiences do seem to improve student performance in CHEM Study. An interesting extension would be to investigate which kind of laboratory report is best suited to a particular laboratory experience. There seems to be no good reason why the lab reports of all students for all experiences should be written up in exactly the same way, and research into innovative ways of handling the recording of laboratory experiences could well be undertaken.

Summary

The CHEM Study literature reviewed was of two kinds:

1. General statements regarding the aims of the course, descriptions of materials, and discussions of the approach to be taken - the <u>subjective</u> literature.
2. Research studies which have investigated outcomes of the CHEM Study program - the <u>objective</u> literature.

The subjective literature provided many suggestions regarding how the CHEM Study materials should be used, what kinds of outcomes should be attained by students taking the program, and what differences might be expected in instructional procedures between traditional teaching and CHEM Study teaching. A review of the objective literature leads to the conclusion that the investigation of some of these aspects has been largely overlooked. For example, very few studies were discovered which investigated objectively what occurs in the CHEM Study classrooms or whether teachers teaching CHEM Study materials use different methods of instruction than other chemistry teachers.

Most research was directed at some kind of comparative study between student outcomes from the CHEM Study course and those from some other chemistry course, and few significant differences were detected. More recent studies broke new ground and made some attempt to investigate what does occur in chemistry classrooms, or at least look at methods of enhancing student outcomes within the broad framework of the CHEM Study materials.

It seems unlikely that more studies comparing student outcomes when conventional or CHEM Study chemistry is taught will yield useful knowledge. Research should now be directed at how the CHEM Study materials may best be used to enhance outcomes, and the focus should turn to the active instructional process in the classroom.

Some areas needing investigation include:

1. How may laboratory, classwork, and films be integrated?
2. How should inductive discussion sessions be conducted?
3. What different ways can the CHEM Study (or other) materials be used in the classroom?
4. What are the instructive processes used by teachers in the classroom?
5. Which students (and which teachers) are best suited to the CHEM Study program?

The research on the CHEM Study program is sparse and in general not well conceived, especially when it is compared to the extensive research into the BSCS Biology program. The subjective literature should be a springboard for the research effort on CHEM Study. This does not seem to be the case, and future studies could well be directed to determining how closely the aims and objectives of the course are actually achieved in the classroom. There is some evidence that the actual classroom situation is quite different from that implied in the subjective literature.

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