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ABSTRACT

A review of 132 research documents is presented for the purpose of describing and categorizing research and development in science instruction on the college level. The documents are limited to publications, dissertation abstracts, and abstracted research and development reports, primarily appearing during 1968-69. Descriptions are made concerning decision rules for material classification. Descriptive research materials are classified for the theoretical, historical, experimental, and comparative types, including case, questionnaire, and correlational studies. Documents dealing primarily with curriculum, teaching, or learning are grouped into the instructional section. Topical areas include biological sciences, chemistry, physics, integrated science, geology, general science, behavioral science, nature of science, instrument development, student characteristics, and teacher preparation. Research findings are summarized to identify current trends. The author indicates that much greater efforts are necessary in the area of research on teaching and learning science. Besides the reviewed articles, the appended bibliography also includes additional references with some isolated topics in the philosophy of science and in career patterns and projections. (CC)

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SCIENCE EDUCATION INFORMATION
REPORTS

RESEARCH REVIEW SERIES - SCIENCE
PAPER 8
A SUMMARY OF RESEARCH IN SCIENCE EDUCATION
FOR THE YEARS OF 1968-69
COLLEGE LEVEL SCIENCE

by
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SCIENCE AND MATHEMATICS EDUCATION INFORMATION REPORTS

The Science, Mathematics, and Environmental Education Information Reports are being developed to disseminate information concerning documents analyzed at the ERIC Information Analysis Center for Science, Mathematics, and Environmental Education. The reports include four types of publications. Special Bibliographies are developed to announce availability of documents in selected interest areas. These bibliographies will list most significant documents that have been published in the interest area. Guides to Resource Literature for Science and Mathematics Teachers are bibliographies that identify references for the professional growth of teachers at all levels of science and mathematics teaching. Research Reviews are issued to analyze and synthesize research related to science and mathematics education over a period of several years. The Occasional Paper Series is designed to present research reviews and discussions related to specific educational topics.

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The publications are developed in cooperation with the National Association for Research in Science Teaching. Appointed NARST committees work with staff of the ERIC Center for Science, Mathematics, and Environmental Education to evaluate, review, analyze, and report research results. It is hoped that these reviews will provide research information for development personnel, ideas for future research, and an indication of trends in research in science education.

Your comments and suggestions for this series are invited.

Stanley L. Helgeson
and
Patricia E. Blosser
Editors

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REVIEW OF RESEARCH 1968-1969

COLLEGE LEVEL SCIENCE

by

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This review of research is based on documents provided by the Science, Mathematics, and Environmental Education Information Analysis Center (SMEAC) an ERIC Center, and those additional documents resulting from the author's search of the literature. It is intended to describe and categorize research and development in science instruction on the college level which was either published during 1968-1969, or which appeared in the dissertation abstracts or as inhouse reports of research and development centers or regional laboratories during that time.

PART I. NATURE OF THE RESEARCH CONDUCTED

A total of 163 documents was examined for this review. Of this group 132 appear in this review, 31 appear in the bibliography only. Some documents reviewed in this report were published prior to 1968-69 but are included based upon the date of input to the ERIC system. The 31 references which appear in the additional references section are those which might

[1]The author wishes to express his appreciation to Ms. Anne Hays, a graduate assistant in science education whose help was immeasurable. In addition, the author wishes to thank Dr. Eugene Todd, Chairman of Secondary Education, and Mrs. Pamela Malone, secretary, University of Florida, Gainesville, for their logistical support.

be of interest to readers of this document although they may not have been produced during the 1968-1969 interval or did not enter the ERIC records at that time. Also included in the additional references section are isolated topics in the philosophy of science or "pure science" which might be of interest to some readers, and articles related to career patterns and projections which are almost certainly out of date by this time. Table 1 shows a breakdown of the documents reviewed here according to their source.

TABLE 1

NUMBER AND TYPE OF DOCUMENTS REVIEWED
COLLEGE LEVEL SCIENCE INSTRUCTION
1968-1969

Type	Number	1968	1969
Published Papers	41	17	24
Dissertation Abstracts	83	31	52
Abstracted Reports	8	3	5
TOTAL	132	51	81

A number of conclusions can be made from these data. As one might expect, dissertations outnumber other forms of scholarly production by nearly two to one. They also show a large increase in production from 1968 to 1969.

Reviewed documents were classified according to two dimensions: 1) the type of research represented, and 2) the area of college science instruction represented. The first dimension includes: 1) descriptive materials such as theoretical, historical, case studies, questionnaire types and correlational studies; and 2) experimental and comparative studies. The second dimension groups documents dealing primarily with curriculum, teaching, or learning. Table 2 provides a summary of the documents according to research type and area.

TABLE 2

A SUMMARY OF DOCUMENTS REVIEWED
ACCORDING TO RESEARCH TYPE AND AREA

	Curriculum	Teaching	Learning	
Descriptive Studies	34	21	24	79
Experimental and Comparative Studies	40	7	6	53
Total	74	28	30	132

While this classification scheme helped immeasurably in the review of the research, a number of decision rules must be described so that the reader will know what types of materials fit into each subcategory and why.

In the horizontal dimension, descriptive studies were, in the main, all those that did not include any comparison groups or manipulation of variables while others were controlled, as in an experimental context. Hence, case studies, questionnaire studies, historical accounts, philosophical materials, theoretical materials, developmental and correlational efforts appear here. When these activities centered around curriculum materials in science they were classified under curriculum, when they involved supervision or teacher behavior they were classified under <u>teaching</u>, and <u>learning</u> subsumed all documents devoted to describing instrument development and use with college students, or the achievement or characteristics of college students, and studies which related student achievement, on some instrument, with other variables. All of these were concentrated in the <u>teaching</u> or <u>learning</u> domains.

The comparative and experimental studies posed interesting topic-interaction problems which required resolution. All studies which had experimental designs which appear in the Campbell and Stanley[2] document, or hybridizations or prostitutions thereof, were grouped here. Attempts at comparative studies, although variables were uncontrolled or not clearly manipulated, were grouped here also. When studies dealt with developing and testing the effects of two curricula, they were grouped in the curriculum category even though the criterion variable was student learning. Studies emphasizing the comparison of methods to influence teacher behavior or attitude were classified under <u>teaching</u>. Learning studies differed from teaching in that they emphasized changes in student behaviors in an experimental context. All of these documents are characterized by comparison groups of some type.

Table 2 suggests some interesting trends. First, descriptive studies, as they are defined here, appear to dominate. At the same time studies dealing with curricula and their development, comparison, or evaluation,

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[2]Campbell, Donald T., and Stanley, Julian C., <u>Experimental and Quasi-Experimental Designs for Research</u>, Chicago, Rand McNally and Company, 1968.

represent over 50 percent of all the work being done on the college level. The curriculum studies are roughly half descriptive and half comparative-experimental. This entire block of work has yielded discouraging results. One reason for this is that curricula are dynamic not static. A curriculum is a composite of the interaction of students with teachers and materials. It is nearly impossible to separate out these effects. Hence, comparing curricula or curriculum components which cannot be accurately controlled during comparison, or described accurately, seems of little consequence to knowledge in the field.

If anything, descriptive studies in the curriculum area focusing on optimizing the achievement of objectives by using feedback about the curriculum would appear of greater utility and practical value than the more numerous comparative - experimental ones. One reason for this is that the former may result in an accurately described set of materials the effects of which could be widely tested and the outcomes useful in work designed to optimize the conditions for instruction using those materials. At a later time, curricula designed to achieve the same or overlapping outcomes could then be compared experimentally. Since a large percent of the comparative - experimental work is dissertation work, it represents a "one-shot" attempt with little if any "spin off" when the doctoral student becomes a professor.

Less than half of the documents reviewed represented exploration,on the college level, of teaching or learning variables. On the one hand this is understandable from an academic point of view, since a knowledge of psychological or information processing principles is essential for serious research in those areas. On the other hand, one would expect that while curricula were rapidly changing on the college level and considerable activity was taking place in the arena of developing and comparing curricula during this period, greater attention would be paid to how students learn and what teachers might do to promote this. Interestingly, the standard "array" of tests was used over and over again to "measure" the effects of curricula regardless of the objectives. For instance; the Watson Glaser instrument on Critical Thinking was used in approximately ten studies and the Test on Understanding Science was used approximately ten times. Other instruments which were frequently used were: in-house achievement tests, 16; and a wide range of cognitive and affective tests such as the Mednick Remote Associates Test, Adult Forms 1 and 2; Omnibus Personality Inventory; Welch Science Process Inventory; Kuder Preference Record; Cooperative Science Test, Chemistry Form B; Cooperative Science Test, Physics Form B; California Personality Inventory; Nelson Biology Test; Krabill Test of Biology Principles; Purdue Master Attitude Scale; Torrence Tests of Creative Thinking; Cornell Critical Thinking Test, Form 2; Guilford Zimmerman Temperment Test; American Chemical Society Test; Stanford Achievement Test for Science; Semantic Differential; and many others. More than 50 different instruments were used as both criterion measures and covariates in these studies!

The null hypothesis was tested in a large percentage of the experimental studies examined. This approach seems inappropriate for empirical work in science education. If the researcher knows so little about the independent and dependent variables to be studied that he has no idea of their possible effects, it is likely that an experimental study is premature.

Perhaps the variables in question could bear scrutiny in an effort to find relationships which eventually would lead to testable research hypotheses.

A notable trend throughout the documents examined was the inappropriate selection and use of statistics. It was not uncommon to find multiple t-tests in use when the probability of "discovering" differences after the first test increased significantly. Parametric statistics are the overwhelming choice of researchers even though such requirements as random selection of the sample, normal distribution of the observations recorded, and equal variance among groups were rarely tested for. In many of the curriculum oriented studies, methods characteristic of business and engineering research such as Bayesian Statistics would have been more appropriate and informative. For instance, if a curriculum is in use, one must have some expectations for both teachers and students. These must occur in some frequency which can be measured and optimized through repeated feedback and manipulation of curriculum factors. In view of the many non-significant differences observed between curricula, a more important purpose might be to seek to optimize the effects of a curriculum for a carefully described sample and later, if desired, compare curricula on these variables.

Finally, many of the studies examined were clearly regionally specific and totally unreplicable, even in the same region with successive samples. Comparing a junior college science curriculum with a four year college curriculum may yield useful regional data given that the curriculum, the teacher and all of the conditions are replicable. However, this is rarely the case. What was taught in the local junior college under the guise of science for the non-science student will probably never be taught again. Instructional programs are dynamic, not static and their results will be only approximate. The situation is similar for the university science course of the equivalent title. When differences are found between the two, it is likely to be attributable to basic differences in the quality of the faculty, of the students or any number of other variables. Studies of this type constitute a high percentage of the dissertation research for the 1968-1969 biennium. It is probable that the researchers will never be heard from again, since work of this type did not contribute to knowledge or theory, or, unfortunately, to the researcher's empirical skills or realization of what constitutes a significant question.

With the above reservations in mind the subsequent review of research will emphasize a description of the independent and dependent variables whenever possible and the researcher's findings or conclusions. Attempts will be made to emphasize the generalizability of findings; identify trends in research and suggest ideas for future research where the studies offer these possibilities.

PART II. SUMMARY OF RESEARCH FINDINGS: DESCRIPTIVE RESEARCH

Curriculum

A classification of the curriculum related research done during 1968-1969 by subject area is shown in Table 3. A summary of these studies will appear in order of their representation in the table.

TABLE 3

TOPICAL DISTRIBUTION OF DESCRIPTIVE CURRICULUM STUDIES

Topic	1968	1969	Total
Nature of Science Scientific Literacy	2	4	6
Teacher Education Curricula	4	3	7
Physics	1	3	4
Biology	4	2	6
Chemistry	4	2	6
Earth Science	1	2	3
Integrated or for non-science major	0	2	2
TOTAL	16	18	34

The nature of scientific inquiry was explored in two studies, Hogan (49), Languis (66). In the first, nine (AAAS) processes of science were used to classify 50 strategies that scientists reported using when doing research. A 50 percent questionnaire return from 100 American scientific researchers indicated how frequently they used each strategy. The author found no significant difference in response between theoretical and research scientists, but did find significant differences in response between the disciplines (physical, biological and behavioral sciences) in the use of 21 of the 50 strategies. Most scientists were found to define science in knowledge rather than process terms.

Using a similar questionnaire technique and similar subject categorization, Languis, studying 348 subjects who responded out of a population of 600, found that the following factors were judged to be extremely important in order to observe effectively: freedom from interruption, talking with colleagues, adequate measurement devices, becoming deeply engrossed in the problem, mental objectivity, a conviction of the importance of the project, enthusiasm, and producing good hypotheses. Over 90 percent of the respondents indicated that the following background factors were very important for developing observational skills: graduate college science, "on the job" research experience, and reading. A similar proportion of scientists reported the following types of observational judgments are made occasionally or more frequently in their work: measurement, degree or intensity, interrelationship or interaction and causative factors. Respondents in this study stressed the personal, human dimension and the intellectual and artful aspects of scientific observation as being critical.

In a study designed to measure the understanding of science and scientists by four groups of science students: freshmen and sophomores (6 classes), secondary science methods students (4 classes), elementary science methods students (3 classes), and graduate science education students (3 classes), Jerkins (53) found the following to be true: 85 percent of the classes were similar in their mean score on the Test of Understanding Science (TOUS). Comparable academic groups at the same school were similar in their scores whereas those at different schools differed significantly. The author concluded that further research was needed to devise means of increasing the understanding of science and that the TOUS instrument (form W) was a satisfactory instrument for measurement thereof.

In another study Kimball (59) compared scientists and science teachers on their understanding of the nature of science. He devised an instrument called the Nature of Science Scale (NOSS) which included items in a Likert Type format. This instrument attempted to measure a respondent's congruence with an operational model of the Nature of Science, devised by Kimball from research and philosophical literature on the subject. He found that philosophy majors in college performed better than science majors ($p. < .01$), but not better than science teachers. He did not find significant differences between science majors and science teachers on the understanding of the nature of science, although seven of eight subscores of science teachers were above those of scientists. A plea was made, as a result of this study, for incorporating instruction in the nature of science and concerns for this area in undergraduate science programs and in science teacher preparation programs. Interestingly, the understanding of the nature of science showed no change over 12 years following graduation.

Wood, et. al. (128) conducted a study to determine the extent of coverage of scientifically and technologically oriented articles for selected newspapers, in an attempt to make inferences regarding the nature of coverage and of scientific literacy. Among the findings were: newspaper themes included medicine, 38 percent; disciplines of science, 33 percent; and space sciences, 22.5 percent. Major emphasis was found to be on technology and technological applications. Interestingly, less than 25 percent of the articles examined contained a discussion of social implications and only 16 percent referred to the processes of science. Experimentation was the single most mentioned process.

An interesting study, and perhaps the only one of its type in science education, was conducted by Besch (9). He analyzed the writings of the late John S. Richardson in four domains of science education, and traced their development over time as evidenced by Dr. Richardson's publications. The following generalizations, that certainly are currently germane, were derived from these writings: 1) science education must be concerned with the sociological aspects of science; 2) science and society are interactive; 3) competency-based professional courses for teachers were advocated, modified, and implemented during the period of analysis; 4) the most effective method of problem solving was the scientific method which included the concept of method in scientific problem solving, the scientific attitude, and the role of the laboratory; 5) science education is a hybrid of the natural and social sciences; 6) science has a role in general education and all people should achieve some level of scientific literacy.

Four studies of an evaluative nature were conducted to assess the effects or effectiveness of NSF Academic Year Institutes [Welch and Walberg (125), Roye (98), Irby (51), and Slawson (107)]. In each of these studies a mass of data was gathered regarding the characteristics of the participants, the nature of the experience and the effects of AYI experiences on both the individual's development and subsequent effectiveness in science teaching. A general reaction to this work is that AYI's tend to have positive consequences for the participants and the program development of the sponsoring institution. Although measurement is often indirect and not competency based, it appears that the quality of science instruction improves in those classes taught by participants. If one were to infer the goals which NSF has for institutes, it would have to be concluded that institutes are more successful in achieving them than not.

Jensen (52) evaluated physics teachers' college curriculum in Iowa and indicated that teachers endorsed a curriculum of "traditional college physics courses," tended to evaluate their own experience in the same order as they make recommendation for desirable curricula, and tended to feel that physics teacher preparation should differ from the preparation of professional physicists.

Ricker and Hawkins (93, 94) developed and evaluated the "psychological" and instructional feasibility of an instructional module covering magnetism, electricity, heat, and "microscopic viewing in science instruction" for elementary teachers. Regarding psychological feasibility they found: students reacted positively to the module, were interested in the laboratory practicum, completed module activities, and appeared to work at their own rates to conclusion. On the instructional feasibility dimension, changes in performance from pre-tests to post-tests after the three weeks of time allotted for this module were significant, leading the authors to conclude that learning had occurred. Furthermore, students appeared able to select different combinations of learning to achieve the same objectives.

Two studies in physics were designed to determine whether "scientific literacy" was the outcome of a physics course [Stahl (114), H. L. Jones (55)] and one to determine whether "critical thinking" occurred as a result of a physics course (Yoesting and Renner, 129). The subjects in these studies were undergraduates. In the Jones study 148 subjects who had completed a non-laboratory physics course were selected. General scholastic ability of these students was measured by the American College Test (ACT), knowledge and skill in science by the Sequential Test of Educational

Progress: Science Section (STEP) and the Watson-Glaser Critical Thinking Appraisal. An instrument called the "Adapted Reaction Inventory," developed by the experimenter, was used to measure student attitudes. The author concluded that "students with the lowest critical thinking ability and attitudes show the most significant gain in these areas." (This would be a hoped for and not unexpected outcome of instruction). "The greater the student's knowledge of scientific facts, concepts and principles, the more positive will be his attitude toward science" and he will have a greater critical thinking ability.

Stahl's study was based on the assumption that difficulties encountered by undergraduates specializing in the arts and humanities, when they undertake the study of physics, are linguistic in basis and origin. Language concepts were proposed as a model for the instruction of these students in the elements of physics analysis. Stahl proposed a course "reorganization and philosophy directed toward comprehension of the inquiry by which physics evolves."

Yoesting and Renner utilized the Watson-Glaser Critical Thinking Appraisal to assess the effects of their general physical science course. Although the one-semester course under examination could probably never be replicated, they found that the particular course evaluated (with its teachers, materials and students) "contributed to the improvement of the students' ability to think critically." Science students made more improvement in critical thinking than did non-science students.

Snyder (110) attempted to evaluate an approach to physics which included three double class periods per week with no separate laboratories, information lectures, and emphasis on laboratory work. His sample was six students. His evaluation was a questionnaire sent four years after the experience. His conclusions were: This course was interesting to both students and teachers. It required a lot of work but the results seem to justify the effort. . .this approach to introductory physics should be further developed. In view of the small sample, the time lapse between experience and measurement, and the nebulous nature of the "treatments," one cannot have great confidence in these conclusions.

In the biological sciences, Mason (77) reported a set of standards for life science programs in the community colleges of New England which he derived through analysis of the recommendations of professional organizations, experts, questionnaires, and visitations. A final set of 13 standards was derived from these sources. Comparison of community colleges in relation to these standards indicated that the standards were met in areas of faculty academic qualification, workload, money for supplies and equipment, and payment of laboratory assistants. The standards were not met in the area of faculty involvement in institutional policies, library resources, and areas related to course objectives.

Three studies [Loftin (70), Hankins (45), and Soule (111)] were concerned with the nature of junior college zoology offerings, biology for freshman general education courses, and biology for non-scientists. Since the findings of these studies generally confirm current practice and "tradition" with regard to curriculum development and instructional methodology, little more will be said here. A major problem which studies of this type suggest is that of utility. Each is dissertation work focused on course development in an institution. The results are such that they could be reported from any number of institutions and programs of a similar type. In other words, not startling! However, the questions are: Programs of what type? What materials were used? What did the teacher do and say? What did students do and say? Before findings from studies of this type can be widely utilized, a much more specific system for describing the total treatment is essential. Even then, utility is limited.

A similar piece of work regarding outdoor education was done by Ferris (38). His methodology was a questionnaire and his findings inclusive. Among his conclusions were: there was a growing interest in outdoor education; there was a general agreement about purposes, objectives and outcomes among professionals in the field; and outdoor education directors appeared dedicated. This latter study has some value as a status report on outdoor education, with little to tie it to a particular program, or one-of-a-kind project, as in the earlier studies.

In another questionnaire study relating achievement in general college biology with high school background in science and mathematics, Johnston (54) found that achievement in college biology may depend on background in high school chemistry, physics, mathematics, and extracurricular activities. No differences in achievement appeared to be related to teacher preparation.

Studies in the areas of science for the non-science major and unified science were conducted by Cox (27), and Pickar, et. al. (89). The first used Science-A Process Approach materials as the basis for 27 laboratory lessons for non-science majors. Preliminary evaluation suggested the efficacy of these types of materials, particularly for prospective elementary teachers. In the latter study, biology, chemistry, and physics materials were combined in a core-course designed to span two years. The authors claimed as advantages for this approach: a decrease in time spent on conveying material by 16 percent, increased flexibility in student program planning, and greater ease in treating interdisciplinary topics.

Curriculum studies in chemical education ran the gamut of types. Barnard (3) proposed a need to identify methods of effectively and efficiently enhancing communication in the lecture room, laboratory, and out-of-class environment. His suggestions for improving the chemical education communication model included using intermittent television sequences within lectures, using films or slides in a similar manner, attempting to teach multiple laboratories simultaneously through improved media utilization, and adapting communication devices to learning objectives. Again, these conclusions appear to be standard practice in many institutions.

Studies of research in chemistry departments [Williamson and Johnson (127), Clement (22)] yield data which suggest that the volume of basic research from undergraduate schools is small and generally of an insignificant nature. A few major institutions in the nation account for the bulk of fundamental work being carried out in the country, as confirmed by a survey of 108 faculty members from 155 chemistry departments in small liberal arts, teacher, and state colleges.

Williamson and Johnson found that less than half of this sample were involved in research work and that only 13 percent of the respondents reported involvement with industry as consultants. Although the above was true, 80 percent of the respondents were faculty whose students received research experience for credit. Support for research came from the following sources: federal grants, 34 percent; college budgets, 31 percent; industries and foundations, 28 percent. The motivation for faculty research appeared to be previous research experience, and "staying alive professionally." Heavy teaching loads were cited as the most limiting factor. When one considers that a large percent of the undergraduates in the institutions surveyed will become science teachers without ever experiencing, or observing, any type of scientific inquiry, the general lack of knowledge, among teachers, of scientific processes or the nature of scientific inquiry becomes understandable.

One method of designing a curriculum is to make a job analysis of a vocational area and design instruction to prepare people to do the job. Sandberg (100) used this approach in designing a curriculum in chemical technology. After surveying large and small industrial organizations she inferred job specifications and general guidelines for curriculum development. Three major points she emphasized were that programs should be designed to integrate component skills, knowledge, and attributes necessary for performance of industrial tasks; emphasis should be placed on the development of manipulative skills; open-ended flexible programs seemed most adaptive to the wide range of necessary experiences technicians require. One fault of this approach is that a task analysis of what exists in a field is likely to contribute to perpetuating the existing model regardless of whether it is desirable or undesirable, effective or ineffective.

An alternative approach to laboratory curriculum development was proposed by Dickson (33) whose attack emphasized elements identified, in recent science education research, as being necessary ingredients of an effective undergraduate chemistry laboratory experience.

Another study which examined instructional practices and procedures in introductory college chemistry (Dodson, 34) yielded data consistent with previous descriptive studies. Interestingly, the author concluded with the recommendation that a major curriculum project be initiated for college chemistry emphasizing clearly defined objectives, employing principles of psychology and learning theory in the instructional design, and elaborating evaluation items to measure specific instructional outcomes. This systematic approach to curriculum development, instruction and evaluation would surely increase the meaningfulness of many of the studies previously described and can be seen in such programs as the elementary curriculum, Science - A Process Approach.

Downs and Henderson (35) examined student enrollment in earth science through a survey of 346 United States and 24 Canadian schools. They found that depressed employment in this field from 1957-1960 influenced a paralleling decrease in senior college classes in the field from 1961-1964. Since then enrollment of seniors has steadily increased, oceanography enrollments have increased, Master's and Ph.D. level candidates have increased.

In the junior college, Roth (95) found few institutions offering geology although there were anticipated increases in demand and few available trained instructors. He made a number of recommendations for remedying this condition.

Maccini (74) evaluated audio-tutorial laboratories in geology at Ohio State. His approach was formative, that is, gathering data which would lead to revision and improvement of the program. He found that students responded positively to AT, programmed pre-laboratory exercises were successful, and students generally rated films highest and tended to rank less difficult media as more acceptable. Revisions based on findings of this type, and of more substantive findings, may eventually lead to optimizing the instructional program.

Teaching

The descriptive studies emphasizing teaching can be roughly grouped into four types. Table 4 describes the frequency of studies in each of the four classes.

TABLE 4

TOPICAL DISTRIBUTION OF DESCRIPTIVE TEACHING STUDIES

Topic	1968	1969	Total
Teacher Preparation	5	7	12
Teacher Observation Instruments	1	0	1
Teacher Behavior	1	3	4
Teacher Characteristics	1	2	3
			20

Consistent with the overall character of the studies reported here, activity in the field increased in this area from 1968 to 1969, with the preponderance of studies focusing on some aspect of teacher preparation.

In a theoretical article, Koran (62) proposed that teacher preparation was primarily a process of behavior modification. Two psychological theories, observational learning and operant conditions, were identified as useful in this regard and were suggested as the major strategies for both the training and supervision of science teachers.

Reynolds (91) reinforced the notion of using observational learning theory and operant conditioning in his exploration of the usefulness of of the video recorder in supervising teachers of science. For both verbal and non-verbal behaviors, the video recorder provides an opportunity to recall a behavioral conception, to provide feedback on a past performance or to provide a model for a future performance.

Two status studies of science supervision [Berkheimer (8), Boehm (12)] described what that activity looked like nationwide and in New York State. An extensive questionnaire survey by Berkheimer indicated that science supervisors and teachers using NSF-sponsored science project materials differed from those using commercial materials in their perceptions of the importance of objectives and the behavior of the supervisor. Supervisors on the elementary levels K-6 perceived their role as being different from supervisors working in grades 7-12. This latter finding unfortunately suggests that perceptions of supervisory role and function are tied to content rather than to the more generalizable behavioral aspects of supervision. Role perceptions of New York State science supervisors generally were congruent with those of the rest of the country.

A series of manuscripts were examined which were concerned with science methods program development. In one, Koran (63) described a program and flexible schedule which included experiences in microteaching emphasizing the technical skills of science teaching, curriculum theory, theories of instruction, objectives and evaluation in science, and an exploration of the research literature and practical application of concept formation and discovery learning on science teaching. Cunningham (30) outlined some procedures, which could well fit into the program described by Koran, designed to improve the question-phrasing practices of prospective elementary teachers. If one considers these practices or verbal behaviors as technical skills, the procedures suggested videotaped lessons) could easily be introduced and utilized in a microteaching content.

In two studies designed to measure the effectiveness of certain science methods procedures, Olstad (84) explored attempts to influence the understanding of science, while Larson (67) explored ways to influence knowledge of concepts and processes in science and skill in manipulating scientific equipment. In the former study the procedures used did appear to influence student performance on the TOUS from pre to post, although the pretest effect was uncontrolled and unexplained. In the latter study, no significant changes were noted in the knowledge of science concepts following the methods course although interesting data were gathered on the nature of the sample.

A final report by Bruce and Eiss (14) described the nature of existing undergraduate elementary teacher education programs and arrived at the following generalizations: 1) typical undergraduate elementary majors see "science becoming real" in the methods course, if at all; 2) experiences in science methods appeared to make this impression rather than content science courses; 3) more innovations appeared to be associated with the elementary methods course as compared with the secondary course. Included in this report is a list of practices judged by the investigators to be of special interest.

Three studies were designed to investigate the preparation of science teachers. Mayer (79) described the science requirements in earth science teacher preparation programs, O'Toole and Chesin (86) described the science preparation of present and prospective teachers in Pennsylvania, and Orlich and Seeling (85) surveyed biology teacher preparation in Idaho. Both of the latter studies indicated that the preparation of existing teachers in the two states fell below the 1960 AAAS-AACTE recommendations for science course work and that more-recently produced science teachers showed little improvement over those produced earlier.

The one project to design an observation instrument for science teachers [Fishler and Zimmer (39)] resulted in a time sampling - eye witness observational instrument of class activity. Observers focused on techniques, questions and general teaching characteristics. The study described the use of binomial probability graph paper which permits a continual graphing of observers' results, allowing efficient monitoring of observer agreement. This instrument appears to be primarily for research purposes and requires a high degree of familiarity and practice for effective use. No reliability figures are given for the instrument in the document reviewed.

Several studies were explorations of teacher behavior and instructional problems focusing on teaching. Pafford (87) presented the procedures, findings and conclusions of a study designed to determine the nature and amount of activities engaged in by secondary student teachers. The time spent weekly on various activities was related to several teacher variables for 23 student teachers at the University of Kentucky. Data were collected for 14 weeks and indicated that the peak periods were: for observing, week 1; clerical duties, week 1; teaching, week 13; and conferences, week 7. Differences were found in the preceding activities between males and females and junior high and senior high assignees.

Utgard (122) studied the relationship of verbal behavior of teachers to achievement of college students. An 11-category modified Flanders interaction analysis system was developed for analyzing the verbal behavior of "graduate student recitation teachers" and 423 students. Teachers were trained in the use of the system and analyzed tapes of their own lessons. A composite score from three course examinations was used as a measure of student achievement, and an evaluation form was administered to determine students' rating of their recitation teacher. The effects of teacher verbal behavior, student rating of teacher, student sex, and SAT scores on achievement were investigated using analyses of variance and co-variance . The results indicated that SAT scores were the most important factor in determining achievement, that students with low SAT scores showed greater achievement with more direct teaching, and that achievement was related to student rating of the teachers.

In another study of student teacher verbal behavior, Matthews (78) reported that student teachers became more like their cooperating teachers in terms of the use of questions and pauses, and the use of restrictive versus non-restrictive response to student questions. They differed from their cooperating teachers in terms of their use of directions to students and pauses following such directions, and the length and frequency of student initiated comments.

Knoll (61) studied preservice teachers and their strategies in teaching vocabulary in order to formulate hypotheses relevant to an integrated language arts approach to the teaching of vocabulary which would be useful in preservice and inservice education.

Four studies explored teacher characteristics or changes in teacher characteristics. In a study of teacher attitude change, Butts and Raun (17) used the semantic differential test as the pre and post measure of the effects of a science methods course. They concluded that teachers' attitudes do change when involved in a program directed towards an increased competence in the processes of science. This change appears to be related to previous course work in science, but not to years of teaching experience or to the school at which the teacher is teaching.

An examination of personality profiles of influential science teachers, regular science teachers and science research students was conducted by Handley and Bledsoe (44). They found influential science teachers to be warm hearted, imaginative, self-confident, trusting, experimenting, and highly creative. The instrument used was a 16 Personality Factor Questionnaire with reliability of the factors ranging from .5 - .99.

In a similar study dealing with prospective elementary teachers, Shanks (102) found that high achievers of concepts in science preferred simple objective labels when presented with a classification task. These labels represented a descriptive-categorical cognitive style, as defined by the Sigel Cognitive Style Task. Those who did not perform well on the concepts-in-science achievement tests preferred memory-oriented inferential class labels. In combination with labels of the relational class, this low achieving group was broadly defined as "non-analytical." High achievers were described as "goal-oriented, self-directed women with a firmness of character and above average intelligence." By contrast, low achievers were lacking in the self-discipline and self-confidence that might have put the average intelligence to better use.

Finally, in an attempt to determine the change in teacher behavior as a result of a thirty day workshop, Blough (11) used a one group pre-test post-test design with no control. Criterion measures were the STEP Science Test, Forms 1A and 1B; Flanders Interaction Analysis, Watson-Glaser Critical Thinking Appraisal and Mednick's Remote Associates Test, Adult Forms 1 and 2. The latter two tests showed no significant gains, whereas the former instruments, particularly the Flanders Interaction system, showed changes in behavior.

Learning

Descriptive studies which emphasize college students' learning in the various sciences can be divided into three types. Table 5 describes the frequency of studies in each of the classes.

TABLE 5

TOPICAL DISTRIBUTION OF DESCRIPTIVE LEARNING STUDIES

Topic	1968	1969	Total
Student Background and achievement	2	8	10
Personality factors and achievement	4	5	9
Instrument Development	2	3	5
			24

In a study involving student background and achievement, Moran and Brouillette (82) found that critical thinking achievement was not associated with a specific discipline or major. Natural science backgrounds did not appear to make more of a contribution to critical thinking ability than did any other background.

Undergraduates who participated in an NSF research participation program seemed to be significantly superior in terms of high school academic achievement than non-participants (Astin, 2). Benefits of the program included increasing the student's chances of being author or co-author of a scientific article and increasing the student's interest in becoming a college professor.

Student background in science appeared to influence attitudes towards the other sciences and the humanities (Snow and Cohen, 109). On the undergraduate level, professions appear to be organized in one hierarchy, where students majoring in the physical and life sciences exhibited more favorable attitudes toward their own major, placing the other science in the second most favorable position. The social sciences were ranked third with the humanities fourth. This hierarchy undergoes modification as the student moves into graduate work.

In a study to determine factors contributing to success in science fields at the University of Michigan, Mallon (76) found that the student's high school percentile rank and National Merit Scholarship Selection score were the major factors in predicting success in science fields, regardless of the size of the high school from which the student had graduated.

Kruglak's (65) study, to find whether pre and post Sputnik high school physics background of college freshmen differed, indicated that 1963 male freshmen entered college with "traditional" high school physics and were superior to a corresponding 1958 (pre-Sputnik) group. No difference was found in physics achievement of 1963 freshmen with "traditional" physics background versus PSSC background.

A similar study (Armstrong, 1) focusing on freshmen biology achievement of students from two Idaho high schools indicated, among other things, that rank in the high school graduating class had a significant effect on predicting college freshman biology grades.

Garrett (40) reported yet another study of the effects of a science background, this time high school biology, on achievement in college biology. His independent variable was BSCS or non-BSCS biology in high school. His dependent variable was achievement in introductory botany or zoology. In a sample of over 1400 students, he found that when the scholastic ability of students was adjusted through the use of analysis of covariance with a scholastic ability test as the covariate, there were no significant differences in achievement in zoology or botany and no differences in attitudes towards science for BSCS or non-BSCS students. A study of a similar type in physics to determine whether a course in physics influenced student critical thinking ability, as measured by the Watson-Glaser Critical Thinking Appraisal, indicated that it did (Henkel, 47).

Two quite different studies dealing with the area of earth science appeared during this biennium. In one, Burford (16) compared the reading ability of college freshmen earth science students with the readability of "selected" earth science textbooks. He found that a majority of the textbooks sampled were rated at the twelfth and thirteenth-fifteenth grade levels while over 38 percent of the college freshmen were reading at grade levels below these. Although all of the researcher's suggestions for a remedy revolved around the adjustment of the reading materials to correspond with student reading abilities, one could legitimately ask why such a large percentage of college students are unable to read at a college freshman level, and indeed, what are they doing in college?

The second study attempted to measure student learning of geologic time and evolution from a Computer Assisted Instruction (CAI) program (Young and Stolurow, 131). The authors reported that students who took longer on the terminal made fewer errors (r = -.56) and that no relationship was found between gain made in knowledge from the lesson and the time a student spent to make that gain (r = -.03). Those students who had high Welsh SPI test scores and biology achievement scores, took more time to learn than those whose scores were lower. Attitude toward content and number of errors made while learning were significantly related (r = -.60), although attitude and gain were not correlated significantly.

A number of interesting studies were conducted during this period yielding evidence of relationships between personality factors and achievement. Some of the major relationships that can be drawn from this work are:

1) High computational and mathematical placement, with somewhat less general intelligence, was related to personalities characterized by introvertedness and compulsiveness, lacking somewhat the qualities of depression, schizophrenia and asociality. High intelligence and science ability tended to indicate somewhat sensitive, anxious behavior, combined with literary and musical interests, but lacking in qualities of accuracy with factual material and compulsiveness, indicating that the person with a positive science attitude and high intelligence may tend to "hang loose" defensively (Hedley, 46).

2) The size of the high school or college from which a student came did not seem to be related to the student's success. But, high school teacher's graduate hours in science were positively correlated with college achievement of students. Science interest scores were randomly related to science achievement in college (Mallinson, 75).

3) Significant relationships were found between the semantic differential and criterion scores in physics and chemistry (Rothman, 96).

4) Personality and achievement in physical science are related. For males, five California Psychological Inventory (CPI) scales correlated with physical science achievement; four CPI scales related to verbal achievement and one to numerical achievement. For females, eleven significant correlation coefficients occurred between CPI scales and achievement. Six related to verbal achievement and five to numerical achievement (Saunders, 101).

5) College biology achievement was affected by the prior biological education of the student as well as by his intelligence and reading performance [Spurlin (113), Welker (126)].

6) Student achievement in audio-tutorial genetics could best be predicted by using a multiple regression incorporating the following factors: SCAT-Q scores, student sex, word fluency scores, dependency needs scores, ideational fluency scores, SCAT-V scores (Haakonsen, 43).

7) Neither ACT scores nor psychological factors measured by the California Psychological Inventory appeared to be of value as predictors of success in an audio-tutorial biology program (Welker, 126).

8) Verbal aptitude and prior science achievement were related to final grade in the traditional college biology course, but high school social studies average was related to final grade in the independent study course (Szabo, 118).

9) The American Chemical Society (ACS) high school achievement test (1963 edition) was a valuable instrument for predicting success of college chemistry students. Grouping of students into homogeneous ability grouping as determined by their predicted chemistry grade provided more participation, interest, and chemistry achievement than did heterogeneous grouping (Sieveking and Savitsky, 105).

Five studies were devoted to the development and testing of instruments to measure student characteristics. Carr (20) constructed and determined the validity and reliability of an instrument to measure problem-solving ability in physical science for use with non-science majors and established a set of norms for the test.

Another researcher, Cummings (29), developed an instrument to measure attitudes toward science and scientists for students in elementary science methods courses and used this instrument to measure differences between an Academic Year Institute Group and an elementary science methods group. The reliability of his instrument was 0.915.

Butzow (18) reported the development and validation of a behaviorally defined interest instrument for science which was patterned after the semantic differential, but instead of using words or noun phrases which name a static entity such as chemist or father, phrases which describe a behavior were employed. Butzow observed that the relationship displayed between interest types and achievement types were extremely weak. He felt that a small relationship between cognitive domain measurement and the affective domain measurement as made by the semantic differential instrument would show it to be a fairly pure form of affective domain instrument.

Jutila (57) developed an objective instrument for the evaluation of scientific maturity in electrical engineering called the CPM-2. The developmental procedure and application to instruction were discussed.

Milligan's study (80) using the semantic differential for predicting science achievement in community colleges indicated that high school average was the best predictor of achievement in college, but the semantic differential was also helpful.

An overwhelming question which cannot be avoided when studies of the type just reviewed are examined is, "Why don't beginning and accomplished researchers search the literature before initiating a study?" With the exception of a small number of studies, one could say the same study with the same instrumentation was repeated over and over. One major reason for this is that many of the studies reviewed were done in "science education" programs at universities where science education research was supervised by biology, chemistry, physics and earth scientists who are just not familiar enough with educational research methodology and literature to know what is a significant question, what constitutes an appropriate method of research, and what instrumentation at what time in the study measures what is being explored. The specter is similar to an educational psychologist doing research in mycology.

In addition, few of the studies reviewed show evidence of researchers who know learning theory and/or instructional design rudiments. For instance, it is not enough to explore the relative effects of an audio-tutorial treatment or a "traditional one." Aside from the fact that neither can be operationally described precisely enough to constitute distinct treatments, it is frequently apparent that the treatments used have varying amounts of practice, feedback, reinforcement and social learning characteristics which may be randomly, but probably unequally, distributed over treatments. The fact that no significant differences are found may be attributed to the cumulative effects of varying, and different amounts of the above, factors which go undetected on the type of global instrumentation used. Other apparent difficulties with interpreting the aforementioned research have been discussed earlier. This all adds up to the reality that generalizability of the findings for a large percent of the studies and manuscripts must be done with caution, or perhaps not at all.

PART III. SUMMARY OF RESEARCH FINDINGS: EXPERIMENTAL RESEARCH

Curriculum

The studies in this section are generally of a type where curriculum x is compared with curriculum y and/or a control z. Criterion measures vary from relatively direct measures of the phenomena the curriculum is designed to influence to somewhat remote measures by available standardized instruments. Whenever possible these studies will be grouped according to topic. Table 6 below gives an overall breakdown of the studies in this group according to the subject area considered. Consistent with earlier data, there were more publications in the area of curriculum research in 1969 than in 1968. Studies dealing with biology, chemistry, and physics achievement as criterion variables also predominated with very little attention being given to integrated science, geology, and general science

TABLE 6

TOPICAL AREAS OF EXPERIMENTAL CURRICULUM STUDIES

TOPIC	1968	1969	TOTAL
Biological Sciences	5	6	11
Chemistry	3	4	7
Physics	6	8	14
Integrated Science	1	1	2
Geology		1	1
General Science	1	1	2
Teaching Methods	1	2	3
			40

for the non-major. Although there were meager data in this regard, there was an increase, though small, in these latter areas from 1968 to 1969 which may signal the beginning of interest in these areas in 1969.

In the biological sciences, two studies dealt with the comparison of two methods of laboratory instruction [Calentine (19), King (60)]. The first study compared the achievement of groups of students using microscopes and slides with another group viewing photographic transparencies and microscopic slides. Surprisingly, students using only the microscope slides performed better than the group getting that stimulus plus other materials. The author speculated that time parameters might have forced the latter group to scan slides and transparencies. It also appeared that the criterion test emphasized knowledge about slides to the relative exclusion of information that might have been learned from transparencies. The second study compared a demonstration laboratory method with an individual laboratory method No difference in the treatments was detected on a standardized achievement test in biology.

Bessler (10) attempted to study the effects of an electronic student response system in teaching biology to the non-major, using nine group-paced linear programs. The results indicated no significant differences between the achievement of students taught in control discussion sections and in treatment sections. A significant interaction was found between time of day of discussion and achievement in control and treatment sections.

Some interesting findings occurred when audio-tutorial instruction in biology was compared with traditional instruction (Weaver, 124). The criterion measure used was the Nelson Biology Test, Form E, and the Otis Quick-Scoring Test of Mental Ability, Gamma Form BM was used as a co-variate.

The author posed nine research hypotheses regarding the effectiveness of the audio-tutorial method, all of which resulted in rejection (non-significant results). It is probable that the Nelson Biology Test did not measure the cognitive or other types of benefits supposedly resulting from audio-tutorial instruction, or was too narrow a measure.

Russell (99) found similar nonsignificant results in his comparison of A-T with conventional biology. He also used the Nelson Biology Test as a criterion along with the Purdue Master Attitude Scale and a questionnaire to gather categorical data about the subjects. The fact that the control group surpassed the experimental group on overall achievement as measured by the Nelson Biology Test may suggest that perhaps the achievement benefits of A-T programs, if indeed they exist, are not in the areas measured by the criterion instrument. Surprisingly, the author concluded that the "terminal outcomes of the two methods were similar" even though the traditional method excelled on overall achievement.

After testing and accepting 29 null hypotheses, Durst (36) came to a similar conclusion. However, Hoffman (48) found, when he compared audio-tutorial instruction using "direct and indirect" methods on objective tests and attitude questionnaires developed by the investigator and the Watson-Glaser Critical Thinking Appraisal, a significant difference in favor of the indirect group with respect to problem solving abilities. No differences were found between the two groups with respect to total achievement, critical thinking abilities, or retention. There were significant positive changes in attitude for both groups exposed to audio-tutorial instruction.

Chanin (21) evaluated the effectiveness of two scheduling patterns in biology. Laboratory sessions were either in the form of three one-hour sessions per week or as two one and one-half hour session, one after each lecture. Again the Nelson Biology Test and the Watson-Glaser Critical Thinking Appraisal tests were used as criterion measures and administered pre and post. Twelve instructors taught one section of each pattern with no control groups. The author concluded that the two laboratory sessions per week pattern was significantly better than one long period in the area of applying biological knowledge in problem solving. There was no significant difference between the groups with respect to critical thinking ability and attainment of biological knowledge. There was a significant teacher effect and an interaction between teacher and scheduling pattern in terms of biological knowledge attainment, but not on other variables.

Two studies were designed to look at particular aspects of biology courses: Smith (108) examined the effects of TV instruction at a midwestern university and Stock (116) explored the effectiveness of critically analyzing Scientific American papers in a biology course. In Smith's study, television instruction made a significant difference over conventional means in student achievement in Botany but not Finite Mathematics. In Stock's study, analyses of Scientific American papers in biological science in lieu of related portions of a textbook appeared to be more effective than student use of a textbook alone with respect to student growth in critical thinking ability. There was no significant difference between the two methods of instruction with respect to student growth in mastery of biological content and interest in the fields of science.

Tolman (121) compared student performance in college biology programs of four year institutions with that of two year community colleges. He found that four year institution students received a superior educational experience in terms of the development of critical thinking ability. The reasons for this appear to be legion, two which the author ignored are quality of faculty and overall quality of course offerings in fields other than biology, which would contribute to critical thinking development. A carbon copy of this study was done at the same institution, using similar criterion measures in chemistry (Denney, 32). There were few significant difference found in this study and generalizability was limited to a one-college sample.

Walker (123) conducted a study to determine if a set of programmed laboratory experiments would affect the performance of general education chemistry students with respect to selected objectives related to the methods of science and descriptive chemistry. He found that programmed instruction was effective in achieving selected methods-of-chemistry objectives, but not effective in teaching the descriptive chemistry of certain elements. This result most likely was a function of the emphasis in the program on methods-objectives. Descriptive chemistry was not highly emphasized.

In a similar programmed chemistry study, J. W. Barnes (4) compared two programmed lecture sections with one taught in a traditional fashion. The programmed lecture was an attempt to introduce the principles of a learning program to the teacher's presentation, by presenting questions or statements to students at particular times during lecture and giving reinforcement and feedback subsequent to response. Apparently in the traditional fashion, no reinforcement or feedback occurred during the teaching act. The author concluded that "it was obvious that students in the experimental method were more attentive and asked more questions than the class taught by the traditional method." Students achieved at a higher level when programmed lectures were used, and in some cases this level was significantly higher than control groups taught in traditional ways. (It is interesting to note that in studies of this type the control group is frequently a treatment in its own right.)

Another study using computer-assisted instruction in organic chemistry (Culp, 28) found significant effects in favor of the CAI group over a traditionally taught group on some topics of organic chemistry ($p < .05$) while student achievement in the areas of stereochemistry and skeletal isomerism did not reach significance over the control.

Three studies focused on other types of instructional variations in chemistry. In one, Richardson (92) compared an inquiry-discovery method with a control. His findings, obtained from the comparison of laboratory examinations and post-test comparisons showed that the "experimental groups" achieved significantly more than the control groups.

Another study (Kent, 58) explored the effects of laboratory procedure and ability grouping on achievement in an introductory chemistry laboratory. The author reported significant differences in achievement ($p < .05$) due to the effect of ability and a significant interaction ($p < .05$) between ability and method such that able students did well regardless of treatment.

Milne (81) compared laboratory-tutorial groups with control groups in chemistry. He used three criterion measures: recall of information, application of principles, and problem solving ability. For recall of information there were no differences in favor of the experimental groups. However, there were differences in favor of the experimental groups for the higher levels of learning. Again, one can only guess how much practice, reinforcement, and feedback went uncontrolled in the treatment groups and in the control.

A series of comparative studies yielded the following findings:

1) When manipulation of laboratory apparatus was compared with no opportunity to do this, with the criterion measure being ability to interpret experimental data correctly, no meaningful differences were noted (Spreadbury, 112).

2) When team learning was compared with the lecture method, with teams randomly composed of 3-4 students, no difference between groups was noted on immediate achievement and the lecture approach was superior to the team approach on retention of subject matter (Young, 130).

3) When programmed laboratory physics was compared with conventional laboratory physics, using six in-house cognitive and affective criterion measures, no differences between the two methods were noted on any of the instruments (McLendon Jr., 73).

4) When lower ability students experienced programmed instruction in applied mathematics, they significantly improved their achievement in mathematics, astronomy and physics. Experimental subjects completed this program in eight weeks instead of the control group's ten weeks (Collagan, 24).

5) When inductive and traditional laboratories were compared in college physical science on author-constructed criterion measures, immediate gains favored students using programs, while there was no significant difference in retention (Zingaro and Collette, 132).

6) When a three week programmed unit in atomic theory and chemical bonding for non-science students was compared with a lecture-demonstration method on author constructed criterion measures, the results confirmed the previous studies (Moriber, 83).

7) When programmed materials were used in a university physical science laboratory as compared with non-programmed or traditional materials; a) students achieved equally well in both treatment and control; b) higher ability students (as measured by the SAT) were more successful in laboratory work than lower ability students; 3) students and instructors preferred programmed to conventional materials (M. R. Barnes, 5).

8) When a multimedia approach to teaching physical science was utilized for elementary education majors it appeared superior to conventional materials in promoting achievement on criterion measures astronomy, but not on the TOUS (Siemankowski, 104).

9) When an audio-tutorial laboratory and a traditional laboratory in physical science were compared, with college freshman subjects, there were no significant differences on a course final examination, a Laboratory Knowledge and Understanding Test, and a Test of Science Reasoning and Understanding, Form A (Rowbotham, 97).

10) When three types of laboratory experiences were compared: a) traditional, where the student was asked to do a workbook type experiment; b) the student was given a chance of doing a prepared experiment, or designing his own; c) no experiments were done; no differences were found on four different instruments (Simpson, 106).

11) When students in a general education physics course and those in a professionally oriented course were compared on their understanding of scientists, the scientific enterprise, and the aims and methods of science using the TOUS test as the criterion measure, the general education course produced significantly greater gains than did the professional course (K. M. Jones, 56).

12) When two groups were compared in which one introduced students to each new topic through demonstration before being exposed to the topical content through programmed materials in dynamics, while the other used programmed materials first and then instructor-led demonstration and discussion, it was found that: a) the group with demonstration followed by programmed instruction was better at problem solving, but less positive toward instructors; b) the classes exposed to demonstrations of application first, and a programmed theory instruction second, showed significantly better ability to deal with new problems; c) students seemed more comfortable with the lecture first method even though they did better under the other sequence (Plants and Venable, 90).

13) When science classes of science and non-science majors were compared to control classes receiving no science instruction, with the Watson-Glaser Critical Thinking Appraisal (Forms YM and AM) and the Stanford Achievement Test in Science (Forms W and X) used as criterion measures, significant differences ($p < .001$) were noted in achievement in knowledge and understanding of the science group. No such differences were detected in the achievement of critical thinking once the effects of aptitude and prior achievement were

controlled for non-science and control groups (Brouillette, 13).

14) When three methods of instruction were compared: 1) subject matter centered approach; 2) historical, social, cultural science content approach; and 3) historical approach with a laboratory; the approach emphasized tended to show up strongly on criterion measures keying on that approach. These criterion measures were the TOUS Form W and subject matter tests (Baxter, 6).

In the area of integrated science, two studies were completed. Mc Intosh (72) compared student achievement in general chemistry with that of students in integrated physics and chemistry. Criterion measures were the Watson-Glaser Critical Thinking Appraisal (CTA, Form YM), and the American Chemical Society (ACS) Cooperative Examination in General Chemistry, Form 1965. As one might expect, the chemistry-only experimental group was superior to the integrated chemistry-physics course on the two chemistry criterion measures. Unfortunately, no measures were used that would assess the unique effects, if any, of the integrated course in the areas of interest, motivation, or special topics where integration would be useful. Bundy's findings (15) generally confirm the above with students in the non-integrated courses excelling in the special content area they studied on an array of criterion measures designed to measure the special content area.

In an attempt to evaluate the effectiveness of an independent study course in earth science, students experienced either this method or a traditional method. The same teacher taught randomly selected sections of each. The criterion measure was the New York State College Proficiency Examination in Earth Science. No significant differences were found (Shaver, 103).

General education courses focusing on curriculum comparisons were studied by Grozier (42) and by Peterson (88). The first explored the effects of the laboratory as it related to developing positive attitudes toward science and the acquisition of interpreting factual information skills. Grozier found that groups not having laboratory improved their attitude toward science, but not their performance, on a post-test proficiency measure of factual material. In the second study, using case history presentations of the nature of science and scientific research and using as criterion tests: Test of Scientific Information (TSI), Test of Scientific Methods (TSM), Test of Scientific Attitude (TSA), evidence was gathered to support the use of case studies.

Three experiments were designed to assess the effects of various program arrangements in teacher education. Lehman (68) studied the effects of role playing in the preservice preparation of science teachers. He reported that role playing was useful in helping student teachers develop skills in the use of the inquiry method of teaching science and to develop nonauthoritarian interpersonal relationships in the science classroom and laboratory.

In another study, Leonard (69) used a small sample (treatment = 17, control = 5), not randomly selected, of methods students versus experienced teachers who never had a methods course. The experienced teachers were the control group. Leonard found that student teachers completing a methods course behaved in a manner reflecting the objectives of the methods course. This behavior was significantly more apparent for the methods students than for experienced teachers not having a methods course.

A final study exploring independent study as part of a science methods course compared this circumstance with a regular classroom situation. Criterion measures were the Watson-Glaser Critical Thinking Appraisal, Test on Understanding Science, and the Minnesota Teacher Attitude Inventory. The data indicated no significant differences between the groups in critical thinking, science understanding, or teacher attitudes (Combs, 25).

Teaching

Koran (64) described a study utilizing two treatments and a control to test the relative effects of observational learning of the skill of asking observation and classification questions as compared with equal time devoted to manipulating observation and classification kit materials and teacher instruction. The two stage design resembled a post-test only design with the first trial testing the effects of manipulation compared with a control (no difference) and the second stage assessing the effects of a videotape model versus a control. The model was found to produce significantly greater frequency ($p < .05$) of the criterion behavior than the control.

Another modeling study (McDonald and M. L. Koran, 71) compared the effects of film-mediated and written models with a control group of randomly assigned teacher trainees. The criterion variable was the frequency and quality of asking analytical questions during a microteaching session. Both film-mediated and written models produced significant increases in the criterion behavior ($p < .05$) over the control, with the film-mediated model having significantly greater effects than the written model ($p < .05$). At the same time, certain cognitive characteristics of the teacher trainees were found to be related to the treatment from which they learned best. Hence, a preliminary suggestion for individualizing instruction is to assign trainees to treatments congruent with their personal characteristics. The sample in this study was randomly assigned from a pool of science and non-science subjects who were working on their MAT's. There appeared to be no difference in the trainees' ability to learn and use the criterion behavior, regardless of whether the trainee was a science or non-science major. In the above two studies, time, lesson materials and treatments were controlled, the criterion measures focused on measuring what was modeled, and subjects were randomly selected and assigned to treatments.

In a similar study, Steinbach and Butts (115) compared the effects of microteaching with peers, and microteaching with children. They found that preservice teachers who taught peers developed competencies and attitudes similar to those who taught children. Students who taught children were significantly better at pacing their lessons and interacting with the children, using questions and classification techniques. A significant relationship was found between feedback and the skills of pacing lessons and clarity.

Another study, focusing on what the researcher called "microsimulated teaching," which sounded like microteaching, gathered evidence to support the procedure of using interaction analysis as a means of influencing certain teacher behaviors (Sweeney, 117).

Beard (7) sought a relationship between the style of presentation used by a science teacher and the effectiveness of that teacher's teaching as measured by student achievement. He found that videotapes of teachers presenting the same lesson can produce significant differences in average student achievement. A two-week workshop focusing on teacher technique and effectiveness in teaching a particular type of lesson did not produce significant differences among teachers. Significant differences on question sets requiring computational ability were related to expanding an idea, presenting concepts over data, emphasizing skills over content, using analogies, and comparing ideas, rather than to direct presentation of the content tested. Effectiveness in this type of videotape presentation was related more to visual pictures presented in the lesson than to any other factor.

Two curriculum type studies which emphasized teacher behavior were done by Holcomb (50) and Cook (26). In the first of these, course learning and retention of learned material were significantly increased ($p < .05$) by giving less teacher direction versus more direction in laboratory instruction on qualitative analysis. The amount of direction had no significant effect on transfer of training in the performance of related tasks. The second study emphasized teacher elicitation of student participation versus videotape lectures and demonstration without any teacher-student interaction. The Flanders-Amidon interaction analysis techniques were used to describe interaction in the teacher taught class. Criterion measures consisted of in-house midterm and final exams, the TOUS, General Attitude Towards Science (Vitrogan), and Test on Evaluation of Scientific Information (ESI). Null hypotheses were tested, with significant differences ($p < .05$) between groups taught by different methods found only for mean final exam scores, with the discussion group averaging higher than the TV group counterpart.

Learning

Only six studies reviewed were experimental learning studies carefully designed to manipulate clearly defined variables while other variables were controlled, resulting in the kind of theory and results that contribute to further research and knowledge. In the first study, Gilman (41) assigned 75 university upperclassmen to one of five feedback types as they were exposed to 30 general science concepts by means of a computer-assisted adjunct auto-instruction program. Treatment groups differed only with respect to feedback modes related with instruction. Group A had no feedback; Group B, feedback of correct or wrong responses; Group C, feedback of the correct response choice; Group D, feedback appropriate to the student's response; Group E, a combination of feedback modes. Results indicated that subjects who received feedback guiding them to the correct response learned more effectively and performed better than those who were forced to discover the correct response.

In another study, Tanner (119) attempted to assess the extent to which the college instructor was able to influence the opinions of his students in evaluating a familiar task. Science methods students were presented with a television lesson in science (familiar task) which the instructor introduced with positive or negative comments. The instructor was able to exert a significant influence on the students' evaluations of the lesson. Support for the instructor's influence was provided by a student confidant. The researcher concluded that this study demonstrated the relative ease with which an instructor could manipulate the judgments of his students.

Dwyer (37) reported a study which was part of a line of research on learning from visual illustrations. He randomly assigned 108 subjects to three types of visual illustrations used to complement oral instruction. He used criterion tests designed to measure pecific educational objectives. He found that the realistic photographic illustrawas the least effective of visual media used in complementing oral instruction (no more effective than oral instruction alone). The abstract linear presentation proved to be the most effective medium, the detailed shade drawing being second. One of his conclusions was congruent with the theory underlying aptitude interaction with instructional treatment research reported by McDonald and M. L. Koran (71) in this review. Students, because they are continually being explosed to oral instruction, have developed their ability to learn from oral presentations. They have not been taught how to learn effectively from realistic photographs, their previous exposures being merely to acquaint them with reality. The area of learning from pictoral stimuli in science and the exploration of areas such as order of pictures in written discourse, and spacing and type of pictures appears to be a very fruitful area for further exploration.

Dallas (31) explored the effects of two hierarchal structures of knowledge on the application of science concepts by preservice elementary school teachers. Two treatments presented the content of a methods course either hierarchally or non-hierarchally, and these were compared with a control on a Concepts Application Test. The findings indicated that the hierarchal organization approached significance over the non-hierarchal (probability approximately .1), hierarchal was significantly better than control ($p < .001$), non-hierarchal significantly better than control ($p < .001$).

Although somewhat global in nature, studies of this type with small segments of content, over short periods of time under controlled conditions, should yield important data about the structure of content of various types of effective instruction.

Cole and Raven (23) report a study examining principle learning as a function of instruction on excluding irrelevant variables. Subjects included 97 seventh grade students, 259 eighth grade students, and 38 college students. They found that teaching for the exclusion of irrelevant concepts and the statement of the correct concept for determining flotation properties increased college and eighth grade students' performance, but not seventh graders' performance. They concluded that this was consistent with Piaget's and Inhelder's findings.

Taylor (120) studied the effects of positive and negative instances when used in an inductive-deductive approach to concept learning in a classroom setting. One instructional program used mostly positive instances to illustrate the classification scheme of Bloom's Taxonomy. A second mixed relevant negative examples with positive instances, and a third program mixed relevant negative instances and positive instances. All examples in all three programs were appropriate examples to illustrate the conceptual classification of Bloom's Taxonomy. It was found that student performance was not significantly affected by treatments differing in composition of positive and negative instances. A mixture of positive and negative instances could be used successfully. This latter suggestion is consistent with other concept formation research which has found that negative instances can be used effectively if learners are taught how to use them.

PART IV. SUMMARY

Some final comments remain to be made regarding the research reviewed. A good percentage of this work used questionnaire or correlational data. Extreme caution must be taken when making inferences from questionnaire data. For one thing, one might ask about the difference between respondents and non-respondents. If there is a sixty percent return, what was the nature of the forty percent non-respondents? This is vital information. To a very great extent this type of data lends reliability and validity to the returns tallied and reported. Without it few if any inferences can confidently be made. Recent comments by Edwin C. Lewis, Educational Researcher, Vol. 1, No. 11, November, 1972, describe additional pitfalls. Frequently the items on questionnaires are poorly worded, requiring the respondent to guess at meanings. Few if any questionnaires reviewed here have been pretested with a comparable sample to aid in formative development. Still fewer have reliability data. Finally, many items on questionnaires that require a judgment of number, kind or relationship just cannot be counted upon for accurate data.

Correlational studies abound with significant correlations proudly declared. However, many relationships are extremely complex and meaning cannot be inferred from a set of correlations unless considerable exploration of the correlates has preceeded. Statistically significant correlations may be practically insignificant. One needed direction which the aforementioned research suggests is a definite need to pay careful attention to some of these details. Only when sound research is done will it contribute to meaningful practice.

Much has been said earlier in this review regarding the curriculum research, both descriptive and comparative. Again, a needed direction is to exercise care and common sense in this research. Limited studies with carefully selected criterion measures which show evidence of being directly affected by a treatment are essential. Operational definitions of treatments will permit replication and the development of banks of data on various topical areas.

Finally, it appears that a much greater effort is necessary in the area of research on teaching and learning science. While many of the studies reviewed herein emphasized manipulation of organizational, administrative or technical variables, beneath these global variables were variables such as amount, kind and spacing of practice, amount, kind, and distribution of reinforcements, feedback characteristics, contingencies and the like. Only 15 studies reviewed did a respectable job of controlling and manipulating variables. It seems that after a decade of reckless curriculum development it is time to ask such questions as, "What are the conditions necessary for learning concepts, principles and search heuristics in college science?" "What should teachers be doing and saying to influence these things?" "How can we train teachers to do and say these things?" "If we train teachers to criterion, what are the effects on college students?" "How can we arrange stimulus presentation using media to most effectively promote certain learnings?" "How should books and reading stimuli be arranged?" "How should the prompts, cues, pictures, and advanced organizers be arranged?" We have barely scratched the research surface. This review is being written three years after most of the reviewed research was completed and much of it published, yet the current research activities seem to have changed little. We still seem to be asking relatively meaningless questions and pursuing meaningless problems. But, we can hope that future reviews of research in science education will show promising attempts to ask and answer critical instructional questions.

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