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RESEARCH IN THE TEACHING OF SCIENCE JULY 1957 TO JULY 1959.
BY- OBOURN, ELLSWORTH S. AND OTHERS
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RESEARCH STUDIES RELATED TO TEACHING AND LEARNING SCIENCE AT THE ELEMENTARY, SECONDARY, AND COLLEGE LEVELS ARE REVIEWED. STUDIES REPORTED WERE COMPLETED BETWEEN JULY 1957 AND JULY 1959. A GENERAL SUMMARY OF SIMILAR STUDIES ON EACH OF THESE THREE LEVELS IS PRESENTED. SELECTED ABSTRACTS ARE INCLUDED AND CONSIST OF A STATEMENT OF THE PROBLEM, AN EXPLANATION OF THE RESEARCH PROCEDURES, AND A SUMMARY OF FINDINGS. SUGGESTIONS FOR THE IMPROVEMENT OF THE QUALITY OF RESEARCH IN SCIENCE EDUCATION ARE MADE. THIS DOCUMENT IS AVAILABLE AS FS-5-229--29000-59 FROM THE SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402, FOR $0.35. (AG)

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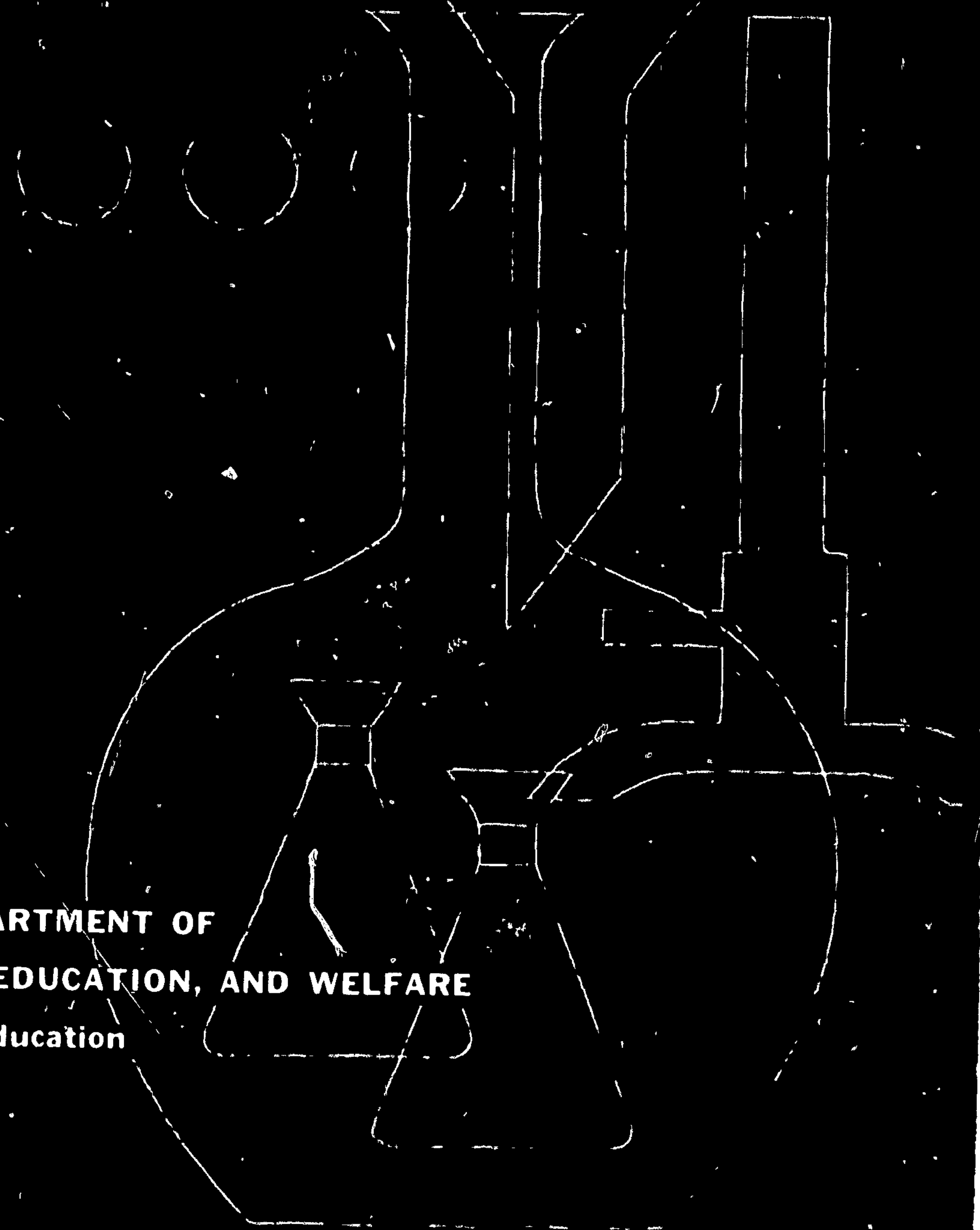

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Office of Education

Highlights

There is a growing body of evidence that a research-oriented approach to learning science facilitates not only the learning of investigative skills, but also the understanding of science principles.

The present survey reveals that science education research should focus increased attention on the unresolved, critical issues, and use modern research design and techniques.

Increasingly, studies in science education are cooperative enterprises, with scientists, psychologists, statisticians, and science educators all participating.

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IN THE

Teaching of Science

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by

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Contents

Foreword and Acknowledgments

FOR MORE THAN A DECADE the U. S. Office of Education and the National Association for Research in Science Teaching have collaborated in preparing an annual summary of research in the teaching of science. The present bulletin, under the same collaboration, begins a new series in which each successive issue covers a 2-year period; and the purpose of this bulletin, as before, is to make summaries of selected research available to school personnel and research workers.

Acknowledgment is made of the help given by the three committees appointed by the National Association for Research in Science Teaching. These committees and their chairmen were the following:

GENERAL CHAIRMAN

Cyrus W. Barnes, New York University

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Lloyd K. Johnson and Richard M. Harbeck, Specialists for Science in the U. S. Office of Education, helped evaluate the material in the present publication. Mrs. Mary W. Dinota supervised the handling of technical details.

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Research in the Teaching of Science

Introduction

IN COLLECTING, ANALYZING, AND INTERPRETING the research in science education over the biennium July 1957 to July 1959, the National Association for Research in Science Teaching and the U. S. Office of Education sought to focus on some of the areas of science education in which known problems exist. What does the research over this period indicate? Has it been concentrated in some areas to the neglect of others? Are any significant directions or trends indicated in the research findings of this period? What was the nature and design of the studies? Do they reflect some of the newer patterns and techniques of research?

It is clear that the Congress, through its support of science education over the past several years, has identified the area of science education as vital to the National welfare and security. If a long-range movement to upgrade science teaching emerges, it is certain that the improvements must be based on the findings of research. To produce excellent research, science education as a profession must become more critical—both of the design and of the findings of the studies within its area of concern.

The present bulletin summarizes published studies discovered through a careful search of the pamphlet and periodical literature of the biennium, and also unpublished studies discovered through a questionnaire jointly developed by the U. S. Office of Education and the NARST and mailed to more than 1,200 institutions offering graduate work in science education.

The three committees appointed by the National Association for Research in Science Teaching assumed responsibility for locating the names and addresses of persons who had published research in science education during the biennium. This information was assembled by each committee chairman and sent to the U. S. Office of Education. An inquiry sheet containing space for a 500-word abstract was then mailed to the author of each published study. In this way, responsibility for abstracting both the published and unpublished studies was on the author rather than on a committee member.

The studies reported in this bulletin were carefully evaluated and selected by means of criteria drawn up by the National Association for Research in Science Teaching. In most cases the abstracts were evaluated by at least three committee members and by one or more of the science specialists at the U. S. Office of Education.

The criteria, originally published under the title "What Constitutes a Research Investigation in Science Education," [1] are the following:

> In order to be classed as a research investigation, a study must satisfy the criteria in one of three categories: A. Experimental studies, B. Analytical studies, or C. Synthetic studies.
>
> A. *Experimental studies* include comparisons of learning under different methods or conditions of teaching and all other investigations that involve pupils in one or more types of learning situations. They are characterized generally by the following steps or techniques:
>
> 1. A statement of a carefully and specifically defined and delimited problem.
> 2. A thorough study of the literature appertaining to the problem, for the purpose of determining the need for the study and its possible contribution.
> 3. The development and use of an appropriate experimental design.
> 4. The collection of data and their treatment by appropriate statistical techniques.
> 5. A presentation of the findings and of the conclusions that seem justified by them.
>
> B. *Analytical studies* are systematic attempts to determine from published materials, cooperating teachers, field studies, and other sources such factors as the aims that govern or that should govern the teaching, subject-matter elements taught, the relative importance of topics, and facilities needed for teaching. Analytical studies are characterized generally by the following:
>
> 1. A statement of a carefully and specifically defined and delimited problem.
> 2. A thorough study of the literature appertaining to the problem, for the purpose of determining the need for the study and its possible contribution.
> 3. A selection or invention of a technique appropriate to the problem and also one that provides means by which the validity and the reliability of analysis may be determined and maintained.
> 4. A presentation of the findings and of the conclusions that seem justified by them.
>
> C. *Synthetic studies* are investigations in which various curricular materials, resource-use data, instructional suggestions, references, and aids to teaching are brought together into a unified pattern to be helpful

[1] *Science Education*, 37:53–54, February 1953.

in an educational situation. Synthetic studies are characterized generally by the following steps or techniques:

1. A statement of a carefully and clearly defined need or objective.
2. The development of criteria for maintaining selectivity in the use of materials and the consistent use of the criteria in thorough studies of materials appertaining to the need or objective.
3. The development of a practical pattern or technique for organizing the materials that met the criteria.
4. The preparation of a substantial publication that summarizes the results of the studies.

The present report reflects the advantages accruing to a cooperative project in which several individuals have participated. On the other hand, it reflects the obvious limitations of such ventures inasmuch as it permits a wide latitude within which individual judgments may be exercised. In addition, some studies had to be left out of the report because they were poorly represented by the abstract supplied to the committee.

The chairman of the three committees, together with the general chairman and the cooperating science specialists in the U. S. Office of Education, accept full responsibility for errors of categorizing the studies and of interpretations resulting from the application of the criteria.

It would seem advisable to make an earnest nationwide effort to upgrade research in science education. Too many studies repeat previous ones—at least in part—thus showing little awareness of what has already been accomplished in the field. Likewise, many of the problems chosen are too general, or have already been so thoroughly explored and their results accepted, that the results of the present-day research studies are almost predetermined. In addition, many studies are survey studies, basing the entire investigation on an analysis of the present status of some aspect of science education.

Challenges to the Improvement of Science Education[1]

WHAT ARE THE POTENTIALS of a research resource center? Of common concern is the improvement of research in science education, and the question is this: How might research resource centers help? To give my answer to this question I should like, first of all, to point out a few major difficulties with today's research efforts, then try to define good research and suggest possible ways of producing it, and finally examine alternative proposals for improving research in science education.

It would be easy enough to point out the technical shortcomings of present research: poor research design, improper statistical procedures, untenable assumptions, and hypotheses that cannot be generalized. Such technical shortcomings are, however, merely the result of fundamental difficulties. One of these difficulties is the fact that we seem to have to rely almost exclusively on degree candidates to conduct the research.[2] Such research is necessarily hurried and harried—the candidates do not have time either to design long-term research projects or to develop the technical competencies needed to arrive at convincing, replicable results.

Another fundamental difficulty arises from the fact that we often attack issues or problems head-on, without sufficient attention to the frame-work underlying them. We ask specific questions such as whether or not the laboratory experience should precede, accompany, or follow class discussions, rather than ask broad questions about how children learn science concepts. Our behavior is somewhat like that of the alchemists who wanted to turn lead into gold. All their time and energy was expended on repeated empirical head-on collisions. Today, by making use of the knowledge about the nature of matter, the alchemists' dream is quite possible. Similarly, our own advances in science education will come *not* from a direct attack upon the obvious issues and prob-

[1] Contributed by William W. Cooley, Graduate School of Education, Harvard University.

[2] For example, of the 420 pages in vol. 44 (1960) of *Science Education*, only 70 pages (17 percent) are devoted to research reports by members of NARST (National Association for Research in Science Teaching), and half of those pages are reports of previous doctoral dissertations. It is therefore apparent that less than 10 percent of the latest volume of the official journal of this *research* organization consists of postdoctoral research by its members.

lems, but by a slow testing of basic relationships which will become useful, operating principles.

Finally, a third fundamental difficulty is the fact that our discipline does not now possess a definite structure of criticism. If research is conducted in an area where naive and inconclusive work is published along with the good, and if poor work goes uncriticized, improvement can hardly be expected. The natural sciences which we teach give us reliable and accurate accounts of the world, in large part because of the system of checks and criticism which these disciplines have evolved, yet we fail to recognize this in our own research field.

This lack of structure of criticism in science education research is illustrated by those of our journals which have no section devoted to letters from readers criticizing specific reports for shortcomings. We all tend to deplore the general body of research, but no one is saying what is wrong with *what* research, so that we could slowly work toward research that inspires confidence. Also, at our meetings, we tend to march through a full schedule of research papers with little or no time for discussion so that *everyone* might be able to present his study. The frequent summaries of research and the "implications" papers of our organization (which made up about 20 percent of *Science Education,* vol. 44) would seem to be one avenue for research evaluation; but here only general statements are found, and criticism of specific efforts is only through omission. If a paper that is below any acceptable standards of research gets into our literature or is placed on our programs, the investigator must be told where he fell short. Otherwise, incompetent research will continue to mask the valuable research upon which our discipline should be building.

No doubt, other major difficulties might be pointed out, but if you agree that the three mentioned above are legitimate complaints, that is all I need as background for the points that follow.

Before turning to possible solutions for these difficulties, perhaps I should pause and try to give you my conception of good research. This seems a reasonable preliminary to the question, "What is needed to produce good research?"

In a recent yearbook of the National Society for the Study of Education, Fletcher Watson and I attempted to delineate areas which we felt contained worthy and researchable questions.[3] Implicit in our article is our conception of good research. First of all, good research utilizes knowledge from the frontiers of related

[3] Needed Research in Science Education. In *Re-thinking Science Education,* Fifty-ninth Yearbook of NSSE. chapter XVI. 1960.

disciplines. Too many of the previously reported studies appear to have been designed and conducted as though psychology, psychometrics, and the other behavioral sciences did not exist. Nor do the studies give much attention to philosophy in questions concerning the aims of science education. One characteristic of good research, then, is that it builds upon the established principles and research techniques of related disciplines, whenever relevant.

The use of principles and techniques developed in related disciplines, though necessary, is not, however, sufficient in itself for good research. In a current 5-year study concerning the process of becoming a scientist, we are using the psychologist's developments in personality assessment, procedures in multivariate analysis developed by statisticians within the last 10 years, sociology's techniques for measuring socioeconomic status of the family and parental expectations for the son, and the engineer's most recent high speed, stored-program, digital computer. But all of this will amount to very little if research workers should fail to build upon, derive specific hypotheses from, or confirm or modify a theoretical structure of the career-choice process. This is *not* to insist that all educational research must test hypotheses from the theories of related behavioral sciences. The essential point is that our research efforts should be directed toward a more fundamental understanding of the basic processes that occur within the domain of science education.

Having delineated a few of the characteristics of good research, we can now ask what is most needed to produce the research that seeks to understand the basic processes involved in teaching and learning science, the research that will serve as a basis to develop and improve specific methods and materials, the research that takes advantage of developments in related disciplines? What is needed? The answer is simple: good people!

In discussing the scientific enterprise we too often forget that research is done by people. The most elaborate organization ever conceived will not produce good research without good people doing the research. What we might be able to do collectively, however, is develop a program that will encourage competent people to focus their attention upon the basic processes involved in science education.

One approach might be to offer research grants to behavioral scientists for examining aspects of science education. Even if more behavioral scientists could be encouraged to use our domain as testing grounds for their hypotheses, the extent to which their efforts would modify our practice would nevertheless be question-able. Such men are usually more interested in contributing to their own disciplines and publishing in their own literature: this limits their usefulness to us within our existing structure. (We've already observed that little use is made of the developments of other disciplines. At least our published research does not reflect familiarity with their literature.) This finally brings me to my central point.

We need to develop a core of men who will serve as the missing link between the frontiers of the study of human behavior and our own specific concerns. Today the universities preparing most of the doctorates in science education number only about 12. I believe that their programs tend to be staffed with men whose primary interests and responsibilities lie in the realms of action and service: directing teacher training, conducting inservice institutes and summer workshops, writing textbooks, and preparing other new curriculum materials—certainly worthy enterprises. But missing are any faculty members—to speak of—who devote primary attention to research. We cannot expect the research in our field to improve without such persons. As the recent President's Science Advisory Committee Report [4] on basic research and graduate education pointed out, competent *graduate* research is done in an atmosphere of active *faculty* research. Research is not something that one sandwiches in between a multitude of other activities. It is a full-time job, and we cannot expect to get the competent research we sorely need until faculty researchers are on the staffs of every graduate program in science education.

Some of you are no doubt thinking that faculty researchers are neither possible to obtain nor necessary to have—impossible because of the lack of money for extra staff, and unnecessary because your university faculty has behavioral scientists to whom your candidates can turn for special help as problems arise in their dissertations.

The question as to the necessity of having a research position on a science education staff is not easily answered. If there is general agreement that our research efforts should not continue to rely almost entirely on the work of students, and if most graduate school faculty members are already overly committed with the school's necessary and important action-service functions, then the need for additional staff seems to follow. What may not seem necessary is my plea for the performance of basic, behavioral science investigations.

[4] Scientific Progress and the Federal Government. *Science*, 132:1802-15, December 16, 1960.

There are two main reasons why I believe basic research to be necessary. First, we cannot expect to utilize the frontiers of knowledge in the applicable sciences if none of us is familiar with those frontiers. The best way of knowing the frontier is to work there. The emphasis is on frontiers because the scientific advances in any field involve a process of successive approximations, so that the most recently developed principles of human behavior are generally the most reliable.

The second reason is that much needs to be done in terms of adaptation and development before the fruits of psychology and sociology become useful in the educational setting. We *must* be concerned with the sciences of human behavior because it is human behavior we are dealing with in the schools. A part of this basic research task is ours. Although the study of pigeons pecking for food or of rumors circulating in wartime may yield basic psychological or sociological principles, the task of selecting, testing, and refining such principles into educational operations involves a type of basic research not now common in our field. I call it "basic" because the focus is upon building a science of human behavior in the educational setting. It is not a disorganized empirical attack (in the manner of the alchemists) upon the obvious and immediate concerns of educators.

My remarks thus far seem to have taken me rather far afield of today's topic. How do research resource centers fit into the scheme I've presented? I believe they are potentially useful for improving the dissemination of research results, but they will not solve some of the basic problems described above. The current plan is to set up centers around issues or problem areas. This focus might serve to entrench even more firmly the head-on empirical attack on the obvious problems in our research methodology.

Another major shortcoming of the proposed center concept is the emphasis on resource rather than research. I am wholeheartedly for research centers, but differently conceived. Each research center should *evolve* specific areas for research. These areas should not be assigned from the outside, nor should the center *assign* itself any preconceived areas. But *evolving* areas are a different matter: they will necessarily reflect interests and strengths of each local faculty. I say "evolve" because research is not a process during which someone identifies a problem, defines it, compiles a relevant bibliography, performs an experiment, and thus solves the problem. It sometimes appears as though we have come to believe the all too-frequent general science textbook definition of the scientific method.

Although it is easy to be negativistic toward sincere and thoughtful proposals, it is quite difficult to develop better ones. We seem to have a common concern and desire: to improve research in science education. Research resource centers will no doubt be useful, but I would prefer not to see us place too much faith in them as a panacea. Just so much time and energy is available, and we must decide what approaches are most likely to yield the greatest improvements. The following four suggestions might be considered along with the proposal for research resource centers.

1. We should identify the more definite, organized research operations at universities preparing doctorates in education. Our research coordinator could compile and make available a summary of these activities. Only centers having a going program of research should be listed. The listings, which could be published in *Science Education*, would be useful for stimulating the establishment of more definite programs at other institutions. The listings would also make it possible for prospective graduate students to identify institutions at which they might profitably study particular aspects of science education. It is not too clear today who is doing what. This suggestion is not an attempt to establish a research elite, but rather to provide a means for recognizing those areas currently being researched on an organized basis, so that the practitioner can know where to seek competent advice and emerging centers can decide where to place their own emphases.
2. We should improve our official journal through establishing an editorial board which could pass for publication only competent research. I suggest a board because the improved screening of papers is too much to ask of any single man. If more careful editing results in too few papers, invitations should go out to behavioral scientists who are conducting research related to science education. This would bring their work into our literature and would tend to assist us in setting standards for research.
3. The official organ of this association should contain a section devoted to constructive criticism. A "Letters" section suffices in the journals of many other disciplines. If such criticism is not received on a voluntary basis, it should be actively sought—not simply for the sake of criticism, but because we have generally agreed that too much of our current research is poor. The incompetent, irrelevant, and immaterial aspects of existing studies must be clearly pointed out. We won't get anywhere until we become more specific in our critiques. This is an integral part of any scientific enterprise.
4. The Association, together with the U. S. Office of Education, might wish to sponsor special summer conferences at which the men now actively engaged in research would meet to discuss specific research problems and to share their competencies with others wishing to become more active in research. We don't seem to have much difficulty setting up big conferences for general discussions or workshops to write new textbooks. Perhaps a 6-week session on concept formation would be a good place to start.

The National Association for Research in Science Teaching no doubt might do many other things to stimulate and improve research in science education. We should remember, however, that any action must be related to *people doing research* and not to peripheral activities, which are only substitutes. To improve science education, much needs to be done in basic research; and to accomplish this, leadership and action are required. NARST is the only organization devoted to research in science education and only its membership can provide the necessary stimulus to conduct competent research. This is the challenge we face.

Avenues to the Improvement of Research in Science Education[1]

IN A POPULATION so dependent on research, it is sad to reflect how few people perceive what it is all about.

"Research," as the late Palmer O. Johnson[2] once defined it, "is an approach to a comprehension of the universe along a broad thoroughfare of organized knowledge solidly established on observation and experiment imbedded in a matrix of theory. It is a highway that is continuously being lengthened, widened, and mended."

Whether or not we agree with Professor Johnson's definition of research, his definition contains the essentials upon which good research must be based: (1) organized knowledge, (2) observation and experimentation, (3) theory. These three essentials constitute a void, or a formidable roadblock preventing the free flow of good research. All are generally necessary to the production of good research; none is sufficient in itself. How a particular academic area or discipline views them is dependent to some extent on the nature of that discipline: its breadth of coverage, its level of theory development, and its views on observation and experimentation.

In education and in science education, it is most difficult to achieve a blending of these essentials in the proper proportions, since the area of endeavor is a complex of many things. Even a casual study will show that the level of theory development in science education is low and its breadth of coverage extremely wide. These in combination have led to an arm-chair approach to the problems of education by many self-appointed experts in and outside the field whose repertoire is lacking in one or more or all of these three essentials. Experts, otherwise well equipped, have avoided observation and experimentation as a source of truth due to the remarkable breadth and complexity of educational measurement. A haphazard or arm-chair approach to the un-

[1] Contributed by Kenneth E. Anderson, Dean, School of Education, University of Kansas.

[2] Professor of Education, University of Minnesota. The quotation is from his introductory remarks at the First Annual Phi Delta Kappa Symposium on Educational Research. Report published by Phi Delta Kappa, Inc., 1960. p. XV.

resolved issues, so typical of efforts in the past, is not enough. An organized and concentrated effort such as the research resource center may be the answer to our vagueness. If properly structured, it will have the potential we are looking for.

In science education it is imperative that the researcher have a sound grasp of the organized knowledge in some scientific area, such as physics or chemistry, in which he proposes to research. He should have more than a nodding acquaintance with the philosophy of science as represented by such men as Herbert Feigl, Morris R. Cohen, Ernest Nagel, and P. W. Bridgman.[3] These in combination will add to the rigorousness of the researcher's work in terms of the method of science and afford a theoretical basis for his exploration of pertinent problems.

The above might be sufficient for the researcher in science, but there is another dimension crucial to the science educator in which the three essential conditions must be repeated if he is to conduct good research. This is the complex of education involving pertinent applications from the organized areas of knowledge, such as economics, sociology, psychology, and statistics. A fair grasp of these disciplines, coupled with a sophisticated understanding of educational philosophy, learning theory,[4] educational measurement,[5] and techniques of educational research,[6] are essential to the production of good research in education.

Research is needed also in educational measurement, since educational research has been handicapped by inadequate methods of measurement, and since the absence of feasible methods of measurement may block off entire areas from significant inquiry. Adequate methods of measurement are as essential to progress in education as they have been for progress in the scientific disciplines. Thus, the road to good research in science education is a complicated highway and the equipment must be good if one is to reach the end of the road and deliver his cargo of usable goods intact.

What constitutes good research in the field of education? Good studies are essential if research is to be implemented by action in

[3] Herbert Feigl *and* May Broadbeck. Readings in the Philosophy of Science. New York: Appleton-Century-Crofts, Inc., 1953. 811 p.

[4] Ernest R. Hilgard. Theories of Learning. New York: Appleton-Century-Crofts, Inc., 1956. 563 p.

[5] E. F. Lindquist. Educational Measurement. Washington: American Council on Education, 1951. 819 p.

[6] Arvid S. Barr, Robert A. Davis, *and* Palmer O. Johnson. Educational Research and Appraisal. Chicago: J. B. Lippincott Co., 1953. 362 p.

the educational process. Nicholas A. Fattu [7] discusses the characteristics of good studies in some detail:

> A good study puts us ahead of where we are now, tackles problems not handled by peers, solves problems that others have failed to solve. A good study makes a difference in educational practice if the potential applications are taken seriously. A good study is imaginative, ingenious, and productive of new approaches, new ideas, and new data. A good study fits into a pattern of long range work. It has antecedents and consequents, and the total result is increased understanding of a field as a result of the accumulation of studies.
>
> A good study is carefully designed and planned. It identifies a definite problem. All parts of the procedure are relevant to the question being studied—data collected, analysis of data. The interpretation of findings or meanings of results is directly related to the organization of the study and the procedures used. The results are also directly related to the conceptualization used, and may suggest new data and new concepts.
>
> A good study is aimed at discovering truth, not at supporting a current or proposed practice. It deals with more general and universal aspects of questions that concern education. The goal is not to find a quick solution, but to develop tested principles. Results of a good study can be communicated to peers working in the same area.
>
> A good study is appropriate to the level of development of its field and to the questions asked. Education is an enormous public enterprise engaged in a form of mass production. It is impossible to operate on this scale without systematic quality control, for without quality control we don't know where we stand, and we cannot correct the weak spots. A program of quality control involves systematic and continuous collection of facts on pupils, including long term follow-up of graduates. Data would include tests but would also include data on motivation, socioeconomic background, level of aspiration, emotionality, etc. Operations research tells the school about its raw material and about its output. Operations research and quality control methods could be applied to operational data.

Although educational research studies run the gamut as to problems studied, good studies are characterized by the identification of definite problems to be investigated. No doubt there are a host of identifiable problems needing solution. Some of these are represented in the nine fields of investigation which should be assigned to research centers. But should not the central and underlying purpose be to improve instruction in science? If this be the primary purpose, then the real problem is to evaluate the outcomes of learning in science. Evaluation then must involve objectives and an appraisal of whether or not these objectives have been reached.

What are some important objectives or criteria of learning?

[7] See his "A Survey of Educational Research at Selected Universities." *First Annual Phi Delta Kappa Symposium on Educational Research.* Bloomington, Ind.: Phi Delta Kappa, Inc., 1960. p. 15.

These may be stated in many ways, but are not the following almost all-inclusive?

Has the learner:

1. Acquired and retained useful and pertinent information of a factual nature?
2. Acquired and retained a workable understanding of the principles or *big ideas* of an academic field?
3. Learned to use intelligent methods in adapting to the problems of his life?
4. Reached a level of understanding, application, and performance in the three points above, commensurate with his ability?

The purpose of this discussion was to point out that:

> . . . evaluation must be geared to objectives along a continuum from simple understandings and skills and limited adaptability to more complete understandings and complex skills and greater adaptability. Where we as students and teachers are on this continuum determines the evaluation procedures to be employed. As long as we operate on a rather low level of understanding near the lower end of the continuum, the ordinary evaluation procedures will suffice. A little thought and ingenuity, however, can lift us off the lower levels of evaluation and place us a bit higher on the continuum. As we and our students continue to move upward in an understanding of what we are trying to accomplish, the simpler procedures will no longer evaluate adequately the transfer of understandings and abilities of the pupils.[8]

Regardless of whether or not you subscribe to the four criteria of learning stated above in terms of a continuum or spectrum, *it is imperative that the purposes of a research study be couched in terms of sound learning objectives if the research study is to have a chance of being implemented into action.*

In a previous paper entitled *Implementing Research Into Action,*[9] the writer emphasized that school personnel must be made a real working part of the research team and acquire some psychological ownership of the research process if research is to be implemented into action.

Psychological ownership cannot be acquired in full by active participation in the research process. Before or along with participation there must be some solid exposure to: (1) formal instruction in the discipline or in the area where the educational research is to be conducted; (2) the psychology of learning, both in psychology of learning per se and in psychology of learning as

[8] Kenneth E. Anderson *and* Gordon M. A. Mork. "Evaluating Science Teaching." *Science for Today's Children* (Thirty-Second Yearbook of the Department of Elementary School Principals, National Education Association), 33:141, September 1953.

[9] Kenneth E. Anderson. "Implementing Research into Action." *Science Education,* 44:178–187, April 1960.

applied to a particular academic area; and (3) methods of educational research and the applications of statistical methods to research in education.

The first point need not be labored upon too long. It should be obvious that one cannot do much real educational research unless he knows his academic field well. The researcher must be well grounded in his discipline at the undergraduate level and in addition must have pursued real graduate work in the area. Programs in teacher education must demand real academic attainment in the major or minor teaching field.

The second point need not be treated at length in this discussion. Pertinent, however, is the following statement:

> Education is an integral part of modern life. Modern individual and social life encompasses a great complexity of phenomena. Systematic and orderly investigations of the "great buzzing confusion" of life require conceptualizations; that is, views of what to look for, how to look for them, and what kinds of structures, processes, and relationships are involved. If, when one entered a classroom, he had no prior conceptualization of teaching and learning, he would see children and an adult, he would hear several children and the adult speaking, he would note physical items in the room, movements of people, and the like. What gives it meaning for the investigator of classroom instruction is a model which he conceives, a simplified picture of the structure and process of classroom instruction. This model usually includes such elements as a teacher, pupils, objectives of instruction, learning outcomes. If he holds such a model in mind, he has a basis for focusing his observations and for arranging and analyzing his data. This development of a formal model provides a way of viewing the complex phenomena in a fashion which permits scientific study.
>
> Models serve to simplify a process which appears on the surface to be too varied or complex or haphazard to be understood. But models must not only simplify complex phenomena; they must provide a means for explaining and predicting the variations and regularities observed in the phenomena. Hence, conceptualizations change as research indicates that earlier models fail to explain or predict many of the observations noted. For example, a common model for research in instruction in the 1920's included a teacher, a group of pupils, methods of teaching, learning outcomes.
>
> This conceptualization recognized variations in the intelligence of pupils, various methods of teaching and variations in the degree of achievement by the pupils of the learning outcomes. Since that time, a number of things have been added to this model, such as variations in the skills, preparation, and personalities of teachers, variations in the initial achievement of pupils, in the kinds of pupil motivation, in the content and intensity of pupil interests; and variations among several major kinds of educational outcomes, such as knowledge, skills, attitudes, and problem solving. Effective educational research is commonly guided

by conceptualizations which provide ways of viewing the complexity of educational phenomena in orderly and meaningful patterns.[10]

The third point is particularly important, for it is in this area that the real break-through in educational research may occur. I quote:

> As is so often the case, a study of a particular problem in education is given a stamp of approval or is labeled respectable, because the study contains a number of tables which are statistical in nature. Actually, statistical analysis of data is only in order provided the researcher:
>
> 1. Selects the appropriate statistical technique for the data at hand, and in addition tests the assumptions basic to the technique. This implies an adequate background in the field of statistics and measurement. Even the coroner conducting a post-mortem examination selects appropriate tools and techniques, but even then his examination more often than not fails to produce additions to the knowledge of medicine.
> 2. Applies the Golden Rule of statistics. This in essence means that consideration is given to statistical techniques early in the study, which is often a controlled experiment, before the data have been gathered. Too many studies supposedly experimental in nature are like corpses—all that one can do is hold a post-mortem examination. An experimental study should be carefully planned in advance under conditions which will afford a secure basis for new additions to knowledge.
>
> In most investigations other than the descriptive type, the two chief problems are: (1) testing statistical hypotheses, and (2) estimating population parameters. The first involves an exact test of significance, or a test which is based on a known probability distribution. Usually this involves setting up the hypothesis as a null hypothesis, applying the appropriate statistical tool, referring the final result to the appropriate model or distribution, and last of all a rejection of the null hypothesis or its acceptance (failure to reject it).
>
> It is essential in an experiment that the principle of randomization be observed. Otherwise, a test of significance has no validity. It is important that groups of students who are to be treated differently, have the same probability of being so treated. In other words, the educational treatments should be randomized. In addition, the students should be assigned at random to the various groups receiving different educational treatments. Only when samples are obtained in this manner and only when the experiment makes it possible to secure a valid estimate of the experimental errors, is statistical inference permitted.[11]

It is important in setting forth the plans of an experiment to answer the questions that prompted the research and to list all the variables that might conceivably influence the results. In an experiment based on the assumption of controlling all factors

[10] Ralph W. Tyler. "The Contribution of the Behavioral Sciences to Educational Research." *First Annual Phi Delta Kappa Symposium on Educational Research*. Bloomington, Ind.: Phi Delta Kappa, Inc., 1960. p. 57–58.

[11] Kenneth E. Anderson. "The Statistical Approach to Problems in Science Education." *Science Education*, 38:390–93, December 1954.

except the one under investigation, it is often observed that results will change from one experiment to another of the same kind. If all the essential conditions are varied simultaneously rather than one at a time, one can observe the effects of the factors in a nearly natural setting. Factorial design is appropriate because the effects of the interactions of all combinations of factors under consideration are measured. The chief advantages of factorial experiments are: (1) greater efficiency, (2) greater comprehensiveness in that effects and interactions are estimated, and (3) that the conclusions have a wider inductive basis. I quote again:

> It is possible to partial out in a factorial design, such as the above, the effects of pre-science information and intelligence. This would call for a factorial design involving analysis of covariance.
>
> Consideration of designs of the factorial type before the investigation gets underway might make the research efforts more fruitful.
>
> . . . the research worker in science education should: (1) use adequate and reliable statistics when the research calls for description, (2) use statistical techniques properly by testing assumptions basic to the techniques, and (3) select and use statistical tools in the early stages of an investigation. In addition, the research worker in science education should be aware of new statistical tools and sampling distributions available for exact tests of significance and think of problems in science education not only in terms of tests of significance but in terms of problems of estimation.
>
> Finally, the science researcher should use the powerful tool of analysis of variance and covariance to bolster the controlled experiment in science education, and insofar as possible consider in future studies the possibilities of varying all the essential conditions simultaneously by designs of the factorial type so that our findings will reflect natural settings and thus have wider applicability in our science teaching. When this becomes an accomplished fact, science teaching via realistic research will improve immensely.[12]

When the statements quoted above were written (in 1954), some references to multivariate analysis were appearing in the literature. Today, there is not an abundance of space devoted to the topic, but nevertheless many scholars in the area believe that multivariate analysis may trigger a real break-through in educational research. To quote Johnson and Jackson:

> As a general rule—in fact, any phenomenon under observation—is, or may be, affected by the influence of numerous factors, and these factors may be related among themselves—sometimes operating in the same direction, and sometimes in opposition. One of the tasks of the researcher is to identify and describe these relationships and interrelationships.[13]

Multivariate analysis is a mode of statistical operation and may

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[12] *Ibid*, p. 397.

[13] Palmer O. Johnson *and* Robert W. B. Jackson. *Modern Statistical Methods: Descriptive and Indictive.* Chicago: Rand McNally and Company, 1959. p. 371.

involve such methods as partial and multiple regression and correlation, factorial design involving analysis of covariance, and the discriminant function. Illustrative of a very simple application of the method of multivariate analysis is a study entitled *An Evaluation of the Introductory Chemistry Course on Film by Factorial design and Covariance With Method and Sex as the Main Variables.*[14]

In this study the problem was to test which method produced superior results in measured achievement in chemistry during one year of instruction: the conventional or the film method. The design of the study was a 2 x 2 factorial type. The factors were the two sexes, male and female, and the two teaching methods, film and nonfilm. Analysis of covariance was introduced in that the pretest and the SCAT (School and College Ability Test) scores were held constant. The factorial design employed permitted stratification of the data and the testing of three null hypotheses as follows:

1. Students taught by the film method did not differ in achievement from those taught by the nonfilm method, with pretest and SCAT scores held constant.
2. Male students did not differ from female students in achievement with pretest and SCAT scores held constant.
3. The sexes did not differ in achievement when taught by the film method and when taught by the nonfilm method, with pretest and SCAT scores held constant.

The primary hypothesis was the first, and hypotheses 2 and 3 helped make the first more meaningful than it would have been, if they had not been introduced into the problem. From the standpoint of the efficiency of the factorial design, it can be said that we will have tested one hypothesis regarding interaction and two hypotheses concerning main effects. If the single-factor plan of experiment had been used, the two main hypotheses would have required separate treatments and no information would have been possible concerning the effect of interaction. The following four groups could have been compared at once in one analysis of covariance: (1) film-male, (2) film-female, (3) nonfilm-male, and (4) nonfilm-female. However, six T-tests would have been subsequently required, and again the interaction effect would not have been available.

In this study, 10 students were selected by means of random numbers from each of the following groups:

[14] By Kenneth E. Anderson, Fred S. Montgomery, and Dale P. Scannell, *Science Education*, 45:269–74, April 1961.

Film Method—Male	79
Film Method—Female	49
Nonfilm Method—Male	289
Nonfilm Method—Female	178

Three scores for each student were placed in one of the cells of a 2 x 2 table as follows:

	Male			*Female*		
Group	*X*[1]	*Y*[2]	*Z*[3]	*X*[1]	*Y*[2]	*Z*[3]
Film						
Nonfilm						

[1] Raw scores on the pretest (*Anderson Chemistry Test*, Form Am, World Book Company, Yonkers-on-Hudson, N.Y.).

[2] Raw scores on the SCAT (*School and College Ability Tests*, Cooperative Test Division, Educational Testing Service, Princeton, N.J.).

[3] Raw scores on the posttest (*Anderson Chemistry Test*, Form Am).

The sums of scores, sums of scores squared, and sums of cross products were obtained for the three measures X, Y, and Z. From these, the sums of squares of SS's ($\Sigma x^2, \Sigma y^2, \Sigma z^2, \Sigma xz, \Sigma xy, \Sigma yz$) were obtained for: (1) the total sample, (2) method, (3) sex, (4) interaction, (5) within, (6) method plus within, (7) sex plus within, and (8) interaction plus within. The following regression coefficients were used in obtaining the adjusted SS's:

$$b_1 = \frac{(\Sigma xz)(\Sigma y^2) - (\Sigma yz)(\Sigma xy)}{(\Sigma x^2)(\Sigma y^2) - (\Sigma xy)^2}$$

$$b_2 = \frac{(\Sigma x^2)(\Sigma yz) - (\Sigma xy)(\Sigma xz)}{(\Sigma x^2)(\Sigma y^2) - (\Sigma xy)^2}$$

The adjusted SS's were obtained by using the following formula:

$$SS = (\Sigma^2 - b_1\Sigma xz - b_2\Sigma yz) - (\text{Adjusted SS for within})$$

The final step in analysis of covariance appears in the following table:

Analysis of Covariance

Source of variation	*d.f.*	*Adjusted SS*	*MS*	*Probability*
Method	1	555.50	9.58	P<.01
Sex	1	127.03	2.19	P>.05
Interaction	1	10.65	0.18	P>.05
Within	34	1,970.64		
Total	37	2,623.53		

The significance of the mean squares was determined by entering the F table with 1 and 34 degrees of freedom. The mean square for method was the only significant one and indicates that a significant difference in chemistry achievement occurred with pretest and SCAT scores held constant in favor of the nonfilm group. The adjusted means were 48.49 and 41.06, respectively. Since the F value for sex was not significant, no bias was introduced by this factor. Also, since the F value for interaction was not significant, the difference in achievement of the students in the film and nonfilm methods cannot be accounted for on the basis of being a male or a female, when taught by the film method and when taught by the nonfilm method.

Factors other than sex can be introduced into additional factorial designs. In this way, it will be possible to vary all the essential conditions simultaneously rather than one at a time, thus resulting in greater efficiency and comprehensiveness. The results therefore have wider applicability than do single experiments, since the ordinary analysis gives information only in respect to a narrowly restricted set of conditions.

A similar study [14] was made, using a 2 x 2 design involving the same types of scores for each student and using method and career plans as main factors.

The problem was one of testing which method produced superior results in measured achievement during one year of instruction: the conventional method or the film method. The design of the study was a 2 x 2 factorial type. The factors were the two methods of instruction (film or nonfilm) and plans of going to college for a *science career* and *nonscience career*. Analysis of covariance was introduced in that the pretest and SCAT scores were held constant. The factorial design permitted stratification of the data and the testing of three null hypotheses as follows:

1. Students taught by the film method did not differ in achievement in high school chemistry from the students taught by the nonfilm method.
2. Students who planned to go to college for a science career did not differ in achievement in high school chemistry from students who planned to go to college for a nonscience career.
3. The science career students did not differ in achievement in high school chemistry when taught by the film method and when taught by the nonfilm method from the nonscience career students when taught in the same two ways.

The following conclusions were made on the basis of the data obtained:

1. The film and nonfilm groups achieved the same with pretest and SCAT scores held constant. This was our primary hypothesis.
2. The science career students achieved significantly more than the non-

[14] Kenneth E. Anderson, Fred S. Montgomery, *and* Dale P. Scannell. "An Evaluation of the Introductory Chemistry Course on Film by Factorial Design and Covariance with Method and Career Plans as the Main Variables." *Science Education*, 45:275–278, April 1961.

science career students with pretest and SCAT scores held constant, since the F was significant at the 5 percent level and the adjusted means were 53.35 and 45.95, respectively. Since the F values for method and interaction were not significant, the conclusion was not biased by the factor of method nor influenced by interaction between method and career. But since the F value for career was significant, control of this factor by stratification was justified.

Perhaps of most importance to the problem of implementing research into action is an all-out commitment to the worth of the research process. The following is pertinent as a conclusion to my remarks:

Research can serve education in the same way that it serves such fields as medicine and agriculture. It can test the effectiveness of new programs; it can establish principles which will suggest new procedures. Changes are being proposed and made in our educational programs because of the current concern that all citizens shall achieve their full educational potentials. We would be delinquent in our duty if, at the same time, we did not strengthen and extend the program of evaluation, whereby we might know whether the new programs are producing their intended results.

Research is needed today to resolve the heated, and often bitter, controversies regarding educational policies and methods. Many of these differences in views stem from a lack of basic knowledge regarding learning and learners. Only when we know what various educational programs produce, and when these results are attested by objective scientific evidence, can we settle upon the better programs.

It is not enough to urge classroom teachers to put more effort into teaching subjects by traditional methods. Many current methods are the product of years of traditional practice and they are not necessarily the most effective in terms of current needs and knowledge. Over a period of years research has shown repeatedly that traditional methods are often based in part upon false principles of learning and that new methods can be devised to replace them.

We need research not only on educational methods, but we need a great deal of research on the problems of motivation; we need to know far more about aptitudes and their development; we need to know more about the social forces which encourage or discourage youth from staying in school or entering a learned profession. Research has already provided insights and techniques for making better use of our human resources, but we shall remain comparatively ineffective until we know far more than we do now.

Research on educational problems and on problems significantly related to education is increasing in amount and in coverage. Funds from the Federal Government, foundations, and institutions have steadily increased. But, in relation to the need for improving education and to the importance of educational efficiency, the present investment in educational research is totally inadequate.

Organizations of professional educators and groups of specialists are independently promoting many kinds of research. The results are often fragmentary. Too little opportunity exists for the ablest research leaders

> to pool their thinking in formulating research studies in education. Creative investigators from many fields need to focus their interests and capabilities on education. The interdisciplinary approach must be encouraged if educational research is to extend its full values to the profession of teaching. This probably can be done best by means of a research center.[15]

In summary, the title of this paper, "Avenues to the Improvement of Research in Science Education," means just this: that our research *workers* in science education must be so trained that they (1) are well grounded in their academic fields, (2) know the academic areas related to and important to education, (3) know the psychology of learning, (4) are sophisticated in the application of research and statistical methods to problems in educational fields, and (5) will be given an opportunity to pool their resources in an interdisciplinary effort via a research center.

In addition to these demanding requisites, time must be taken and effort made to improve educational measurement, and multivariate analysis must be employed with increasing frequency. The two in combination may well represent a crucial approach to problems in education, and if well done may constitute the breakthrough so desperately needed in educational research.

Die Wahrheit liegt in der Bewährung—Truth is what stands the test of experience.

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15 Kenneth E. Anderson. "A Report From the American Educational Research Association President." *AERA Newsletter*. 10:1–8, October 1959.

Research Studies in Elementary School Science

Introduction

ALTHOUGH THE STUDIES in this section deal with science in the elementary school, they hold implications for science teaching at other levels. The increased emphasis during recent years on developing a coordinated program in science from kindergarten through grade 12 suggests that these studies be examined by committees and curriculum leaders for their contribution to such a program. More than ever before, science education leaders at every level of instruction need to keep abreast of science education at the elementary school level. The studies in this section should therefore be of interest not only to elementary science educators, but also to those at the secondary school and college levels.

This section contains abstracts of 26 of the 43 studies on elementary science reviewed by the committee and a complete list of all these studies.[1]

Analysis

A majority of the research studies on elementary school science dealt with (1) problems of learning involving problem solving, scientific inquiry, scientific concepts, and pupil learnings; (2) problems related to the curriculum; (3) problems related to teacher education, both preservice and inservice; (4) trends in placement and allocation of science content and time allotment; (5) learning or teaching aids.

Problems Related to Learning

A number of the studies were concerned with the different aspects of problem solving. *Carpenter* contrasted pupil learning by way of a comparison of the familiar textbook-discussion method with that of the problem-solving method. He concluded that prob-

[1] Arrangement for each is alphabetical by author, the abstracts starting on p. 28 and the list on p. 36.

lem solving with the use of classroom experimentation resulted in higher test scores; and that, as a method, it was preferred by both teachers and pupils.

Garone, Jones, and *Neal* emphasized the anecdotal record of children's behavior as a basis for determining growth, not only in problem solving, but also in the ability, through use of the problem-solving method, to inquire and to organize inquiries and discoveries into concepts and skills. *Ramsey* used a similar technique, that of sharing experiences, as recorded by the tape recorder, to discover that younger children were more likely to share their experiences than those in grades 4-6. The science experiences were then classified according to the science concepts to which they contributed.

Nelson studied the development of concepts in two areas of physical science—light and sound. *Neal* studied procedures which promoted ability in children to utilize science inquiry methods. *Jones* discovered through the development and use of the problem-solving method, resulting in the ability of first-grade children to organize their learnings into simple concepts, that the elementary science texts for this grade level were not sufficiently challenging. *Davis* studied the teaching to intermediate grade children of concepts of time and space relating to geographic time zones. He was concerned about the problem of grade placement of these concepts and concluded that rigid grade placement of understandings about time and space is impossible, if not undesirable.

Other studies in this group emphasized pupil inquiry, pupil learning, and pupil interest in science. *Bixler* attempted to correlate the classroom teacher's attitude towards science with the learnings of his pupils, while *Boyer* compared scientific achievements of elementary school pupils with criteria of achievement established by leading science educators. *Neal* was interested in the development of scientific inquiry in children of elementary grades; *Preston* compared the learnings of American and German children; and *Young* contrasted learnings of 3d- and 6th-grade children, boys as compared with girls, in the area of atomic energy. She found that television played an important role in these extracurricular learnings, particularly for boys.

The use of the outdoors as a laboratory and learning tool was the core of a study by *Hollenbeck.* She employed the school camp as her medium.

Problems Related to Curriculum

Curriculum studies varied, ranging from those analyzing existing curriculum guides to those developing new ones which emphasize grade placement of important science topics. The advisability of integrating elementary science with other subjects was also explored. *Bryant* and *Challand* examined the content of science guides or courses of study. They found little uniformity. *Ashley* emphasized integration of elementary science and found that learning was improved when subjects were integrated. *Notkin* outlined a guide to serve as an aid to teachers in New York City. *Hone* analyzed State and city curriculums in order to determine the status of conservation education.

Problems Related to Teacher Education

The preservice and inservice preparation of teachers for elementary science was an area of major emphasis for research. Examination of preservice and inservice courses across the country revealed little similarity. Studies by *Berryessa* and *Tyndall* attacked the problem by attempting to evaluate classroom science teaching in terms of the courses taken by teachers while in college. *Bryant* evaluated curriculum guides in order to assay the science understandings expected of children and recommended that the understandings thus derived be part of the preservice training for teachers.

Sostman demonstrated that inclusion of nutrition materials in the inservice education of teachers brought about an improvement in the eating habits and nutrition of the children they taught.

Various methods were propounded for inservice assistance and training of teachers. One method was to prepare teaching aids elaborating on areas in which teachers were generally deficient. Such studies undertaken by *Branley* in astronomy and by *Caruso* in oceanography could serve as a form of individual inservice assistance. Inservice training through workshops was utilized by *Nelson* and by *Sims*. In these two studies pupil gains were used as the criterion of the effectiveness of this method of teacher training.

Guides or courses of study could be considered as another form of inservice assistance to teachers. The study by *Notkin* previously mentioned was based on the development of such a guide. *Ashley* and *Kerr* conducted studies showing how to utilize the consultant as an inservice aid.

Trends Revealed by Studies of Science Guides

Trends revealed by research studies by *Blanc, Low, and others* indicated that science curriculum development now includes elementary school science, that the K–12 program is generally accepted as an ideal and that guides or courses of study assist a science program by suggesting subject matter, science experiences, objectives, and principles. However, there seems to be little agreement as to grade level of specific science experiences. The study by *Challand* indicates that the textbook still serves for many teachers as the determining factor in choice of sequence of science topics. She found that early elementary grades tend to integrate science to a greater extent than upper elementary grades, that there is usually a specific time allotment for science in the upper grades, and that this time allotment averages two hours per week.

Learning or Teaching Aids

Learning or teaching aids have been previously mentioned as one method of assisting inservice programs by *Branley, Caruso, Dunfee and Greenlee, Jones,* and *Notkin.* Teaching aids also help the inexperienced teacher by giving her information, and suggesting activities, scientific objectives, and principles to stress. This is particularly true in such areas as astronomy, geology, chemistry, and physics.

Young found that television can indirectly assist the classroom science program. Current televised science programs will doubtless be the basis for future research studies.

Other Studies

Garone reported research on the ability of children of superior intelligence to develop understandings, interpretations, and concepts. *Carpenter* found that method of presentation had less influence on the learning of students of high scholastic ability than on those of low scholastic ability.

A study by *Mallinson and Holmes* of teachers' ability to estimate reading difficulty of science materials concluded that readability formulae tend to be more consistent than estimates by either teachers or reading experts.

Interpretation

Examination of the research studies reveals existing deficiencies or areas of need for future research consideration. Some of these are the following: (1) criteria to determine adequacy of both preservice and inservice science courses; (2) identification of ways by which children can transfer to home and community the skills and attitudes developed through problem-solving experiences; (3) criteria to determine readiness of children at different grade levels for science experiences; (4) better evaluative procedures for existing elementary science programs; (5) selection and development of science interests; (6) a comparison of the adequacies of elementary science programs for girls as compared with boys; (7) a comparison of the emphasis on a few science areas and principles at each grade level with the emphasis on many science areas and principles repeatedly covered in each grade; (8) the reasons for diminishing science interests of children as they progress through school and into college; (9) means of evaluating children's growth in problem-solving skills; (10) evaluation of televised science programs.

A few of the studies deal with children's science learnings in relation to the total learning situation in the classroom. That is, observations were made of the growth of children's science skills and knowledge in situations where science learning opportunities were not limited to a brief specific science instruction period. They give attention to a wide range of factors which are important if the objectives of science teaching are to be achieved. Such research may seem unwieldy, but it points up the importance of supporting procedures and practices that will unify, rather than fragment, the science learnings of children.

With only limited resources and time, most graduate students find it difficult to study the many factors that may influence children's learnings throughout a week, a month, or a year. It is almost impossible to make continuous longitudinal studies of children's changing attitudes, skills, and knowledge. Yet such studies are badly needed.

The evidence is growing that a problem-solving, inquiry-oriented approach to science teaching enables children not only to learn the skills of investigation, but also to gain a greater understanding of science concepts. Longitudinal studies would give us a further basis for judging the soundness of this inference. Even this one conclusion, if applied generally by elementary teachers, would redirect science teaching significantly from a limited, fact-learning, reading approach to an inquiry-centered approach. This, in the view of many scientists and science educators, is the direction which science teaching should take.

Selected Abstracts

ASHLEY, TRACY HOLLIS. The Development of a Science Program in the Elementary School.

Major Adviser.—Willard J. Jacobson.

Problem.—To show steps in the development of a science program for the elementary school and to depict the role of science consultants and classroom teachers.

Procedures.—Use of records, data from consultants and teachers, evaluation studies of science programs, and anecdotal records of children's experience in science.

Findings.—It is possible through close cooperation and planning by an elementary science consultant, general supervisors, and classroom teachers to develop an elementary science program that is an integral part of the total classroom program. In such a program, the classroom teacher can successfully direct all learning experiences, assisted when necessary by a consultant serving as a resource person.

BERRYESSA, MAX J. Factors Contributing to the Competency of Elementary Teachers in Teaching Science.

Major Adviser.—Wesley Sowards.

Problem.—To identify some factors which differentiated generally competent elementary teachers who carried on particularly effective science programs from generally competent teachers whose science programs were only mediocre.

Procedures.—Twenty-five teachers who carried on effective science programs were compared with 25 teachers whose programs were mediocre. Personal interviews, the Kuder Preference Record, and the Minnesota Teacher Attitude Inventory were used to secure data about each group.

Findings.—No significant difference was found between the two groups of teachers as to 23 factors, such as the science interests of the participants' parents, number of teachers who as children had liked science, number of hobbies related to science, number who read science magazines, scores on the Minnesota Teacher Attitude Inventory, and grade-point averages of the science courses taken by teachers.

The teachers whose science programs were considered especially effective had been stimulated considerably more in science and in the teaching of science than those whose programs were mediocre. Adequate room space, facilities, and storage space seemed to be factors in the development of effective science programs. Finally, a teacher's interest in science appeared to be an important factor in the kind of science program she developed.

BIXLER, JAMES EDWARD. The Effect of Teacher Attitude on Elementary Children's Science Information and Science Attitude.

Problem.—To investigate the effect on pupil learning in science of teacher attitude toward science, teacher degree of authoritarianism, teacher attitude toward desirable teacher-pupil relations, children's intelligence, and children's sex.

Procedures.—It was hypothesized that greater positive change in pupil learning in science would be brought about by: (1) teachers who possessed more favorable attitudes toward science, (2) teachers who were relatively non-authoritarian, and (3) teachers whose attitudes were consistent with desirable teacher-pupil relationships. The effect of children's intelligence and children's sex on learning science was explored.

To obtain the data, 62 intermediate grade teachers took the Edwards and Kilpatric's Attitude Toward Science Scale, the California F-scale, and the Minnesota Teacher Attitude Inventory. Pre-test anod post-test scores on Brown's California Elementary School Science Information and Science Attitude Test were obtained for 1,481 children in the classes of the 62 teachers. The children's intelligence scores were available from their school records. Critical ratios were determined for the various factors studied.

Findings.—(1) The children's science *attitude* test scores changed significantly in relation to favorable teacher attitude toward science. The critical ratio for change in *information* only approached significance. (2) The teacher's attitude toward science was more closely related to the means of evaluation and to children's science information and attitude than were the other variables. (3) The critical ratio for the degree of the teacher's authoritarianism and his attitude toward desirable pupil relations was not significant. Children's sex did not contribute significantly to changes in science learnings.

(4) Both science information and science attitude were inversely related to children's intelligence. The differences were significant in favor of the lower intelligence of any two groups compared.

BOYER, DONALD ALLEN. A Comparative Study of the Science Achievement of Pupils in Elementary Schools.

Problem.—To survey midwestern school systems to determine science achievements of elementary students.

Procedures.—A survey of 12 midwestern school systems was conducted to determine science achievements of elementary pupils. In addition, the literature relative to science teaching was analyzed. A series of statements regarding science teaching practices was produced as a result of this analysis. The statements were then combined to produce five sets of pattern statements relative to science teaching programs, which were evaluated by leading science educators as adequate or inadequate. Twenty-four school systems then participated in an attempt to align their specific school programs in elementary science with these patterns. The 6th grade pupils in these school systems were tested as a further evaluation of the science programs included in the study.

Findings.—(1) Teachers in schools having inadequate science programs were likely to lack facility in using the best combination of science teaching procedures. (2) The teachers had a deficiency in science education. This lack along with poor science supervision produced the inferior results. (3) More than half the schools having inadequate science programs had thought their science programs adequate because of satisfactory results on a science-knowledge test given as part of the school testing program. (4) A majority of schools with good science programs did not incur excessive expenditures for science materials or for special science personnel. These schools carried on inservice programs, had a consultant, used free or inexpensive materials.

BRANLEY, FRANKLIN. Astronomy for the Elementary School Teacher.

Problem.—To develop a teaching aid to serve as a basis for an elementary teachers' course in astronomy at the Hayden Planetarium in New York City.

Procedures.—By consulting astronomers, educators, and the literature of elementary science and astronomy, the author identified the concepts in astronomy important to teach children. Thus, a series of activities was developed by which the concepts could be taught. These activities were such as could easily be used in a classroom without need for elaborate equipment.

Findings.—The major concepts identified and included in the study were the following: Change is continuous in the universe, motion is universal, the universe is extremely large, and man obtains knowledge through his senses. Built around these concepts an inservice course for elementary teachers was given at the Planetarium.

BRYANT, PAUL PAYNE. Science Understandings Considered Important for Children and the Science Required of Elementary Teachers.

Problem.—To determine the amount of attention the required science courses in 225 selected colleges for teacher education give to the science understandings considered important for children.

Procedures.—Twenty curriculum guides recommended by a committee of the Association for Supervision and Curriculum Development were analyzed to ascertain the science understandings recommended for grades 1—6. Only those understandings suggested by one-fifth or more of the guides were included. Persons of recognized ability in different fields of science were asked to synthesize them. The resulting 98 science understandings were assumed to be important to children and to the science education of elementary school teachers.

Science programs of institutions belonging to the American Association of Colleges for Teacher Education were studied. A questionnaire-rating scale containing the science understandings considered important to children was sent to instructors of science courses required of elementary education majors. The instructors were asked to state how much attention they gave in these courses to each of the understandings.

Findings.—(1) Although there was no agreement on specific grade placement of understandings, there was some agreement as to their importance for primary and for upper grade children. (2) The 225 institutions studied required a mean of 17.7 quarter hours of science for elementary education majors. (3) Biological and physical science survey courses and elementary school science methods are the courses most frequently specified. (4) Course content was usually determined by the instructor and based on students' needs, but instructional activities generally centered around the instructor. (5) Although as well prepared as college teachers in general, over three-fourths of the instructors of the science courses required for elementary education majors had had no experience in teaching children.

CARPENTER, REGAN. A Study of the Effectiveness of the Problem Solving Method and the Textbook-Discussion Method in Elementary Science Instruction.

Problem.—To compare the effectiveness in elementary science instruction of a teaching method based upon demonstration and classroom experimentation (problem method) with that of a teaching method based upon reading and discussing a basic textbook (textbook-discussion method).

Procedures.—All of the 4th-grade pupils (323) of three nonpublic elementary schools in Honolulu were divided into two groups (A and B). These groups were equated upon the basis of intelligence test scores, age, and sex. The teachers in the two groups were also equated on the basis of education, experience, and rating by administrators. Comprehensive, detailed teaching units on "magnets" and on "the adaptations of animals, excluding man," were constructed.

The group-A pupils studied "magnets," using the textbook-discussion method, while the group-B pupils studied the same subject, the same length of time, using the problem method. An identical objective test, previously constructed and validated by the experimenter, was administered to both groups, and the mean scores were compared by the *t*-technique. Later, the two groups studied "the adaptations of animals, excuding man." The same conditions prevailed for this study as for the previous one except that the two groups switched methods. Again, too, the mean scores on an objective test were compared by the *t*-technique.

Findings.—(1) For each of the two studies, the group taught by the problem method achieved a mean score significantly superior to that achieved by the group taught by the textbook-discussion method. (2) The pupils ranking highest in general scholastic ability were less influenced by the change in teaching methods than were other pupils. (3) The pupils ranking lowest in general scholastic ability were significantly influenced by the change in teaching methods. (4) A majority of the pupils interviewed preferred the problem method of teaching. (5) Five of the six participating teachers preferred the problem method to the textbook-discussion method.

CARUSO, MARY L. An Ocean Geography for Children.

Problem.—To develop a teaching resource book on oceanography suitable for children in the upper elementary grades.

Procedures.—Concepts relative to oceanography and suitable for development in the upper elementary grades were identified by consulting geographers and reading the literature. These concepts were elaborated and a list of suggested activities was prepared. The materials were checked for comprehension and vocabulary by 6th-grade pupils and their teachers.

Findings.—A list of concepts about the ocean, its inhabitants, and its uses suitable for upper-grade pupils was agreed on. The material produced for upper-grade pupils will serve also as a resource for teachers with little background in this area.

CHALLAND, HELEN J. An Appraisal of Elementary School Science Instruction in the State of Illinois.

Problem.—To appraise the status of elementary school science programs in the State of Illinois.

Procedures.—Questionnaires were sent to elementary teachers inquiring about the grade placement of science content, the methods used to determine areas, the context of elementary science in terms of the total curriculum, and the time allotment for the science program.

Findings.—The areas of zoology, physiology, and astronomy were found to be stressed the most by teachers. In general, a majority of the teachers employed a textbook which determined the sequence and selection of science topics discussed. Teachers of the early elementary grades were found to be more likely to integrate science with other subjects, while teachers of the later elementary grades allocated a specific period of time to science as such. Time allotment did not vary widely, the average being approximately two hours per week.

DAVIS, OZRO LUKE, JR. Learning About Time Zones: An Experiment in the Development of Certain Time and Space Concepts.

Major Adviser.—Harold D. Drummond.

Problem.—To determine whether children in the 4th, 5th, and 6th grades can profit from instruction in concepts of time and space relating to geographic time zones.

Procedures.—Two classes each from the 4th, 5th, and 6th grade levels were selected from six different schools. One class at each level was designated as the experimental group, the other as the control group. The experimental classes were taught a unit on geographic time zones. The experimenter taught the unit to the experimental classes to control for variations in teaching method, learning materials, and subject matter. The experimenter devised a test to measure time-zone learnings. This test was administered as a pre-test, an immediate post-test, and a test of delayed recall. The resulting data were treated by analyses of variance.

Findings.—(1) At the end of the experimental teaching period, the experimental classes had significantly profited from the instruction about geographic time zones and there were significant differences among the grade levels. (2) One month after that period, the experimental classes had maintained their superiority over the control classes and the significant differences among grade levels persisted. (3) During the experimental teaching period, the 4th-graders gained more in their understandings than did the 6thgraders. The experimental classes made a significantly greater gain in understanding than did the control classes. (4) There was no difference in the gains of understanding among grade levels during the time the pre-test was given and the administration of the test of delayed recall, although there was a difference favoring the experimental classes over the control classes. (5) One month after the teaching period, the experimental classes had a higher retention than did the control classes. There were no significant differences in retention among grade levels.

DUNFEE, MAXINE *and* JULIAN GREENLEE. Elementary School Science: Research, Theory, and Practice.

Problem.—To bring together in a concise booklet, research findings, authoritative opinions, and results of successful practice in science education in the elementary school.

Procedures.—The questions that elementary teachers in college classes asked about the teaching of elementary school science served to help organize the content of the booklet. Questions were organized under the following topics: (1) Identifying the role of science education in the elementary school. (2) Exploring the nature of the elementary science program. (3) Teaching science in the elementary school. (4) Improving the elementary science program.

One hundred seventy-six professional books, articles in educational publications, master's theses, doctoral dissertations, and research studies were examined by the authors.

The results of pertinent research, authoritative findings, and expert opinions are generously quoted to substantiate the answers to the specific questions of elementary teachers.

Findings.—The interpretations indicate that science has made an important place for itself in the elementary curriculum, but much remains to be done in building programs more effective than the present ones.

GARONE, JOHN E. Acquiring Knowledge and Attaining Understanding of Children's Scientific Concept Development.

Major Adviser.—Willard J. Jacobson.

Problem.—To present and illustrate a general approach to children's scientific concept development by study and analysis of their percepts, interpretations, and problem solving.

Procedures.—Twenty-nine 10-to-12-year-old children of superior intelligence were included in the study. Anecdotal records of their percepts, interpretations, problem solving, and concepts were prepared, tape recordings of a variety of their verbalized group activities were made, and their written materials were collected and analyzed.

Findings.—Children perceive and try to organize their perceptions to form understandable concepts. Experience, opportunity to explore ideas through trial and error methods, and proper guidance are factors influencing concept development.

HOLLENBECK, E. IRENE. A Report of an Oregon Camp With Program Emphasis on Outdoor Science Experiences.

Major Adviser.—Harold Anderson.

Problem.—To ascertain the amount and kinds of outdoor science experiences now provided for Oregon children by schools and other agencies and to investigate the feasibility and value of presenting outdoor science experiences at a school camp.

Procedures.—Information on the outdoor science experiences of 601 high school seniors in a stratified random sample of Oregon high schools was obtained by questionnaire. The findings were compared with those of a similar survey of 495 college freshmen made two years earlier. Plans were made for the organization and administration of a one-week pilot science camp for 22 5th- and 6th-grade children. The effectiveness of the camp was measured by precamp and postcamp sociometric tests, interest inventories, artistic presentations, opinion questionnaires to parents and participants, and interviews with classroom teachers and camp resource people.

Findings.—(1) Too few children in Oregon have had an opportunity to participate in outdoor science experiences. (2) Too little use has been made of skilled resource personnel as leaders of outdoor science experiences. (3) The school camp participants showed evidence of growth in an appreciation of the interrelationships of living things and of the beauties of nature, developed knowledge and skills related to outdoor science and outdoor living, exhibited desirable attitudes toward work and conservation practices, found areas in which their individual abilities could be recognized, and acquired new science interests. (4) The school camp was of value to the teacher in helping him identify new areas in which individual children could succeed and in which certain ones needed help to meet the problems of living. (5) School camping was feasible in southern Oregon because it was possible to lease a campsite from an organization which maintained an established summer camp, the cost was nominal, and resource personnel were willing to assist.

HONE, ELIZABETH. An Analysis of Conservation Education in Curriculums for Grades K–12.

Major Adviser.—Raymond C. Perry.

Problem.—To investigate some of the causes of discrepancy between American thought and practice with regard to conservation education.

Procedures.—Printed curriculums of the public schools and the texts and tests used in conservation education from kindergarten through high school were analyzed. Data were tabulated according to categories of concepts of conservation education. The findings were substantiated by a jury of experts, who corroborated the findings of the curriculum study in 7 of the 12 areas covered by a questionnaire sent them.

Findings.—More conservation material came from State than from city school sources and the States furnished more general than specific curriculum suggestions. In general, there was consistency between the aims, content, and method of school and nonschool conservation education. Conservation was taught most frequently in grades 6 through 9. Conservation was seldom recommended as a separate subject; it was most frequently associated with science at the elementary level and with social studies at the secondary level. Conservation education was regarded mainly as a problem of renewable resource. Emphasis on conservation education in texts was found to be mainly on renewable resources also.

Concepts of conservation should be redefined in terms of the needs of modern society. The present emphasis on renewable resources only has little relationship to the resource problems of a modern industrialized society.

JONES, MARY ELLIOT. A Study of the Possible Learning Resulting from Science Experimentation by a Class of First-Grade Children.

Problem.—To investigate and determine the learnings acquired by first-grade children from a program based on experimentation.

Procedures.—Anecdotal records of the children's questions, responses, and resulting decisions regarding solutions of problems were maintained for a year. Responses made by the class as a whole were also recorded and analyzed. An attempt was made to determine to what degree any one of the possible learnings resulted from experimentation.

Findings.—Children at the first-grade level can learn from experimentation in the classroom. Concepts, skills, and attitudes were listed as outcomes. The children gained the following concepts: (1) Experimentation is a way of finding out. (2) An experiment consists of certain elements. (3) Some experiments need controls.

In addition, the children gained skills in:

(1) Suggesting, planning, and participating in experiments, (2) predicting outcomes of experiments, (3) interpreting the results of experiments, (4) seeing the relationship between an experiment and a practical situation, (5) applying the results of the experiment to the situation, (6) exercising the right to demand experimental proof before believing a statement, and (7) resolving differences of opinion through experimentation.

The children also gained certain attitudes. Most significantly it was found that when children, even at the primary level, are exposed to experimentation, development occurs in areas other than science.

KERR, ELIZABETH FEENEY. The Role of the Consultant in Elementary Science.

Major Adviser.—Gerald Craig.

Problem.—To define the qualifications, functions, and responsibilities of the consultant in elementary science.

Procedures.—An anlysis of opinions of elementary science consultants and other educational leaders over a 5-year period was made to determine the qualifications, functions and responsibilities of elementary science consultants.

Findings.—Among the characteristics and responsibilities of the successful elementary science consultant are the following: (1) Likes children and enjoys their companionship. (2) Gets along well with adults. (3) Has a good background in science. (4) Sees children's science experiences as contributing to worthwhile values and behaviors. (5) Is willing to spend time necessary to develop good relationships as well as a good science program. (6) Possesses qualities of leadership. (7) Sees science in its relation to the total curriculum. (8) Contributes to building good school-community relationships. (9) Helps build rapport among workers within a school and among schools within a system. (10) Carries on an inservice program for teachers.

In addition, the study gives suggestions for evaluating a science program and for selecting science materials for an elementary school.

MALLINSON, GEORGE GREISEN *and* ROMA H. HOLMES. A Study of the Ability of Teachers to Estimate the Reading Difficulty of Materials for Elementary Science.

Problem.—To determine whether the measurements of the reading difficulty of certain passages from textbooks for elementary science are more consistent than estimates by reading experts and elementary teachers.

Procedures.—In order to support or negate the assumption that any elementary teacher could estimate the reading difficulty of a passage from a textbook, 199 sample reading passages from textbooks of science for grades 4 through 8 were measured for level of reading difficulty, using the Flesch, Lorge, and Dale-Chall formulae. Packets of 20 of these samples were made by random selection of samples from the 199 passages.

Packets were then sent to 26 teachers classified as reading experts or specialists in a number of large midwestern cities. These specialists and two elementary teachers in each city were asked to estimate the level of reading difficulty for each passage.

Findings.—The measurements made by means of reading formulae for level of reading difficulty in elementary science textbooks tend to be more consistent than the estimates made by reading experts or elementary school teachers. If reading formulae are inaccurate, their inaccuracies tend to be consistent. The median difference for measurements by reading formulae is 1.0 years; for reading experts, 3.0 years; and for elementary teachers, 4.0 years. Hence, it seems that the use of reading formulae is justified for estimating the reading difficulty of elementary science textbooks.

NEAL, LOUISE A. Techniques for Developing Methods of Scientific Inquiry in Children in Grades 1–6.

Problem.—To attempt to determine adequate methods of science inquiry in children in grades 1-6, using the laboratory schools at Colorado State College.

Procedures.—Sixty-one teaching techniques were selected and tested to promote the growth of 4th-grade children in developing the ability to use methods of scientific inquiry, i.e., to recognize and state problems, select pertinent and adequate data, formulate and evaluate hypotheses, form a conclusion or a concept, and apply concepts or see relationships. The techniques required the children to make overviews of problems, demonstrate concepts, take exploratory excursions, select readings, do experiments, observe objects and processes, organize ideas, and determine criteria for evaluation of their activities.

The techniques and procedures were evaluated through a study of the children's written responses and creative expression; and through objective testing and observation of overt behaviors which could justifiably be associated with the ability to use the methods of scientific inquiry.

Findings.—Children can be aided through direct teaching procedures to identify and state problems, formulate plans to collect and evaluate data from a number of sources, formulate hypotheses and concepts, and apply concepts and methods to new situations. Abilities basic to the development of intellectual maturity that may be expected at each grade level were revealed.

Testing data indicated a consistent pattern of growth for each method of scientific inquiry from grades 4 through 6. The differences between test administrations were significant at the 5-percent level of confidence.

NELSON, PEARL ASTRID. The Acquisition of Concepts of Light and Sound in the Intermediate Grades.

Major Adviser.—John O. Read.

Problem.—To investigate the learning of scientific concepts and principles in the areas of light and sound by intermediate grade children.

Procedures.—An inservice workshop for the teachers was planned. Individual interviews were conducted to ascertain the children's preconceived ideas of light and sound. Tests were given before and after completion of the units, and the gains in understanding recorded. The two schools participating in the study varied widely as to the pupils' socioeconomic background.

Findings.—Gains in principle-understanding and in concept-gain were significant in the schools having workshops for the teachers. These teachers transferred their learning and interest back to the classroom. The pupils' socioeconomic background was of no significance as far as gains were concerned.

NOTKIN, JEROME. Experiences to Implement the Course of Study in Science for the Elementary Schools in New York City, Kindergarten through Grade Six.

Major Adviser.—Willard J. Jacobson.

Problem.—To develop a teaching resource that would implement the New York City course of study in science. Its purpose was to provide a series of 193 classroom experiences for kindergarten through grade 6, covering 7 science areas: earth and its resources, weather, transportation, communication, earth in space, magnetism and electricity, and plants.

Procedures.—Experiences and activities were worked out for each of the selected science areas. Some were adapted from science resource books for teachers, while others were new-type activities developed by the author. Each activity was tested with children in classroom situations.

Findings.—This teaching aid will assist elementary teachers with meager backgrounds in science to do better classroom teaching.

PRESTON, RALPH C. A Comparison of Knowledge of Direction in German and in American Children.

Problem.—To determine whether or not 6th-grade German and American children were different in regard to their knowledge of interrelationships between bodily position (right and left), the four cardinal directions, and the position of the rising and setting sun.

Procedures.—Four questions, selected because of their culture-free character, were answered by a random sample of 400 6th-grade pupils in Hamburg, Germany, and a similar group of 332 6th-graders in Philadelphia and Baltimore. Half of the children of both nationalities included in the study were in the highest 27 percent and half were in the lowest 27 percent with regard to intelligence (based on national norms in each country for 6th-grade children).

Findings.—Results showed consistently higher scores by the American children. Their absolute knowledge, however, was not impressively higher. This belies the often accepted statement that American children are educationally inferior to those of European countries.

Many bright American and German children in grade 6 evidently do not have a grasp of directional relationships. This fundamental is probably neglected in both countries, with the result that children are thrust into the use of direction symbolism with inadequate preparation.

RAMSEY, IRVIN LEE. Children's Contributions in Sharing Experiences and Their Potentialities for the Elementary Science Program.

Problem.—To record and analyze the sharing experiences of children in grades 2, 4, and 6 in order to find their potential for the elementary science program.

Procedures.—A sampling of the oral reports and conversations of 832 children in grades 2, 4, and 6 were tape-recorded during their experience-sharing time. The recordings were analyzed to discover the frequency with which experiences reported were related to science topics and principles.

Findings.—A wide variety of out-of-school experiences were described by the children. For example, they mentioned trips, communication activities, recreation, and experiences with animals. Though the children mentioned experiences with animals most frequently of all single topics, they tended to talk less about biological-science topics in general than they did about physical-science topics. The children did not mention any science principles as such. The investigator, however, identified 194 science concepts and 376 science clues related to 17 science concepts.

SIMS, WARD L. The Development and Evaluation of an Inservice Education Program in Elementary Science.

Problem.—To develop and evaluate an inservice science program for elementary teachers.

Procedures.—A series of meetings was conducted to provide information and assistance to the teachers. Their participation was voluntary. At each meeting one or more broad topics pertaining to science in the elementary school was discussed, and demonstrations were given. Pupils of the participating teachers, as well as pupils of nonparticipating teachers, were tested at intervals, as were the teachers. Controls, participating classes, and teachers were matched. Both pretests and post-tests were given.

Findings.—Pupils in the experimental classes achieved significantly more on the post-tests.

SOSTMAN, EDNA RUTH. An Evaluation of the Methods, Techniques, and Findings Used During a Six-Year Nutrition Education Program in a City School.

Major Adviser.—Clara Mae Taylor.

Problem.—To bring about improvement in children's food habits, to improve their health (appearance, growth, and general alertness), and to bring about curriculum changes as a result of an inservice teacher-education program.

Procedures.—Schools in the Puerto Rican section of New York City participated. About 80 percent of the parents spoke only Spanish. A nutrition-education program was inaugurated in the classroom as a part of the regular curriculum. Inservice workshops for the teachers gave them the necessary background in nutrition. Meetings were held with parents to give them information regarding food and food selection.

Findings.—A definite increase occurred in the number of children eating breakfast. The breakfast pattern improved and participation in the school lunch program increased from 25 percent to 42 percent. Significant differences appeared in the growth patterns of the participating children as compared with those of nonparticipating children in other schools of similar setting.

TYNDALL, JESSE PARKER. The Teaching of Science in Elementary Schools by Recent Graduates of Atlantic Christian College as Related to Their Science Preparation.

Major Adviser.—Aleyne Haines.

Problem.—To investigate and evaluate the science teaching of recent elementary graduates of Atlantic Christian College and to examine the science program provided at the college for prospective elementary teachers.

Procedures.—An observation checklist, an interview checklist, and a questionnaire were developed and validated as a means for (1) evaluating science teaching practices of 40 elementary teachers recently graduated from Atlantic Christian College, and (2) determining the achievement of these teachers in high school and college science courses. Five basic questions were explored: What part of college helped you in carrying out a science program? What experiences in college would have helped you? What inservice experiences have been helpful? What other experiments have been helpful? How important do you think science is in the elementary school?

The chi-square was used to determine the relationship of teaching to strengths and weaknesses in the college science preparation of the elementary teachers.

Findings.—The elementary teachers were judged satisfactory in relation to nine criteria of good teaching. For example: They utilize storage space in an orderly manner. They respect, give personal attention to, and enjoy working with children. They encourage investigation in solving problems, aid children in arriving at tentative conclusions. The teachers were judged unsatisfactory in relation to six criteria of good teaching. For example: They lack an understanding of the importance of a laboratory-like classroom for teaching science. They do not encourage children to see the relationship between the physical and biological sciences, nor do they help children understand inclusive scientific principles.

There was a high degree of relationship between grades made on science courses and performance as elementary teachers of science. There was no significant relationship between courses taken and the quality of science teaching, nor any between teachers with or without inservice experiences and the quality of their science teaching.

YOUNG, DORIS. Atomic Energy Concepts of Children in Third and Sixth Grades.

Problem.—To analyze the atomic energy concepts of 3d- and 6th-grade children through interviews and questionnaires.

Procedures.—Seventy-five 3d-grade children were interviewed about the subject of atomic energy. A guide sheet, pictures, and diagrams were used. The same information was solicited from 68 6th-grade children by means of a questionnaire containing pictures and diagrams. The children were questioned regarding the sources of their information. Responses for both grades were scored by identifying three levels of response for each question.

Findings.—The investigation indicated that many 3d- and 6th-grade children have developed concepts of atomic structure and the use of atomic energy, and at least a fourth of both groups were ready to pursue further study. The girls showed less understanding of atomic energy than did the boys. Television was the main source of information. There was a wide range of individual differences in readiness for science and in misconceptions.

A List of the Studies

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Research Studies in Secondary School Science

Introduction

THIS SECTION contains abstracts from 40 of the 67 studies on secondary school science reviewed by the committee and a complete list of all these studies.[1]

Analysis

The studies reported here were classified in four broad groups: (1) programs, (2) the teaching process, (3) learning, interests, and attitudes, and (4) the teacher. No brief is offered for the categories. It was difficult to avoid an element of arbitrariness in the selection of the categories and the distribution of the studies among them, since several studies had more than a single problem and it was thought desirable to reduce the number of categories to a minimum. The present state of research in science education makes it difficult to apply research criteria vigorously to the selection of studies to be included in a summary review. Inevitably, a greater degree of uncertainty enters into the selection process than is desirable.

Programs

About 40 percent of the studies included in this review were related in one way or another to the science program and its development in the secondary school. Several were concerned with content and its organization for teaching purposes. *Stone* and *Pierce*, with the help of a group of interested and competent teachers, worked out elaborate courses of study in biology and chemistry respectively, which stressed the inclusion of new findings from scientific investigations and the conceptual unit of each of the two fields.

Seeking to find out what should be taught about nuclear energy

[1] Arrangement for each is alphabetical by author, the abstracts starting on p. 52 and the complete list on p. 64.

in the high school, *Atkinson* developed a list of principles of nuclear energy (ranked in order of importance) and a validated test for evaluating the teaching of these principles. *Tyrell,* using a large group of biology teachers, ascertained their opinions as to the most important areas in high school biology and the achievement of their students in these same areas. He reported that the average score of the students taking the test was less than 50 percent. In an attempt to assess the effectiveness of the science and mathematics work in vocational instruction programs, *Shoemaker* sent out a list of science and mathematics principles to on-the-job supervisors, who were asked to judge whether or not the high school graduates under their supervision understood these principles and were able to apply them to their jobs. Finding that the high school instruction apparently had not been adequate, he recommended revision of plans for vocational instruction.

A checklist of physiology topics was submitted by *Henderson* to relatively large groups of students, teachers, and parents and to a small group of physicians for their evaluation as to potential interest and importance. He discovered that teachers and parents were better judges of students' interests than were physicians, that parents felt sex education should be part of the school program, and that students were more interested in practical than theoretical information. Seeking to improve the selection of supplementary reading materials for the gifted high school student, *Barnes and others* developed a list of 23 criteria which were submitted to a group of respondents for their evaluation. These respondents recommended that the list of 12 criteria should be used by teachers, parents, and others to upgrade the reading level of gifted high school students.

A comparison of current objectives and content in high school biology with those prevailing 40 and 80 years ago was reported by *Howard.* He found that purely factual information objectives were largely replaced during the period studied by functional information objectives, and that mental discipline and religious objectives had disappeared from current texts and courses of study in high school biology. In an investigation of the advantages and disadvantages of offering biology at the 9th grade and physical science at the 10th grade in two schools, *Heidgerd* reported that achievement in biology for 9th-grade groups was somewhat inferior to that in schools where biology was taught in the 10th grade; but when adjustment was made for mental age, achievement was about as good as would be predicted. Achievement in physical science was found to be high in the experimental groups.

Schenberg analyzed the records of 27,756 seniors in 55 academic high schools in New York City. He concluded: (1) Guidance and testing programs were needed to identify interests and aptitudes of gifted pupils. (2) Homogeneous grouping of specially interested and gifted science and mathematics students should be established. (3) Increased attention should be given to the possibilities in science careers for girls. (4) Three years each of science and mathematics should be required of college preparatory students. (5) A well-trained core of teachers was needed for these students.

Roper reported on the nature and scope of the utilization of industry-sponsored teaching materials in Colorado high school chemistry courses.

The activities of science supervisors and State agencies, and surveys of curricular and teaching practices, attracted several investigators during the period under review. Using survey, jury, and statistical techniques, *Lee* investigated the relationship between the rank order of importance of supervisory activities as judged by a jury of experts, and the actual practices reported by a selected group of State and local science supervisors. The coefficients of correlation between the jury rankings and frequency of practice were moderate for both State and local supervisors. Interestingly, the category with the lowest ranking in practice was research.

In a study of critical areas in the science programs of Negro schools in Louisiana, *Rand and Brazzill* recommended that learning opportunities in the physical sciences should be increased, that science facilities should be expanded, and that a systematic and continuous attempt should be made to encourage students to take science courses and to choose careers in science and technology.

A study of the status of science teaching in the United States was undertaken by the *Research Division of the National Education Association*. The data in this study were provided by 1,876 questionnaires completed by principals and science and mathematics teachers. An analysis of the data obtained showed: (1) In general, mathematics and science teachers of large secondary schools are better prepared and more likely to be teaching their subjects full time than are their counterparts in small schools. More than three out of four of the mathematics teachers are teaching their particular subject full time. About 82 percent of the mathematics teachers and 93 percent of the science teachers in large high schools have had at least 20 hours of college study in their respective fields. (2) Nearly a quarter of the sample in all three categories of schools had between three and four years of both mathematics and science. Large high schools have added new science courses at a rapid rate. The rate of adoption of new courses has increased somewhat in medium and small high schools, it has increased less rapidly there than in large high schools. Again, large high schools showed their superiority in science teaching, and the adequacy of facilities and equipment in these schools seemed to be in proportion to the enrollment. (3) In the opinion of the administrators, teachers need to obtain up-to-date knowledge of the field they are teaching. Here again, principals of large secondary schools stress this need more than do principals of small and medium-size ones.

The Teaching Process

The teaching process is a major concern and responsibility of the science teacher and an object of frequent criticism by many people both inside and outside the formal school. The improvement of science teaching has always been a major goal of science educators, although the relatively few studies available for inclusion in this review seem to indicate a lessening of interest in studies focused on the teaching-learning process than was the case in former years.

In a comparison of the inductive and deductive methods of teaching high school chemistry involving a relatively large group of students and teachers, *Sister Ernestine Marie* found that inductively taught classes showed significant superiority over deductively taught classes in achievement for the year's work as a whole and also for a special unit on the balancing of chemical equations. The use of reflective thinking in high school chemistry was comprehensively explored by *Fonsworth* and further studied by *Newman,* who compared the effectiveness of three teaching approaches in biology.

During the last 10 years there has been an accelerated emphasis in science education on the use of teaching aids, particularly the motion picture and television. A few studies were reported for the period under review. *Garside,* working with 60 physics classes in Wisconsin, made a comprehensive study of the influence of the "White Physics Films" on learning in mechanics and heat. He found that the level of achievement of students of high and low intelligence respectively in the experimental (film) group was not significantly different from that of comparable students in the control (nonfilm) group, but there was significant difference in the level of retention, favoring the control group.

In a study of the effect of a special motion picture on the learning of biological principles related to the control of poliomyelitis and on attitudes toward the National Foundation and the March of Dimes, *Bichler* found that the use of the film produced no significant difference in changed understandings and attitudes from those achieved in comparable groups where the film was not used.

Schulman investigated the relative effects of positive and negative introductory sequences inserted in a selected instructional film on the immediate and delayed recall of factual information learned from the film by two similar groups of pupils in 9th-grade general science. By means of appropriate testing techniques, he discovered that the group viewing the film with positive introductory sequence did better on immediate recall tests than those groups viewing the film with the negative introductory sequence. On delayed recall tests, the relative achievement of the groups was reversed. Students with average intelligence (the middle group) profited most from the film, irrespective of the type of introduction.

In a study of the effect of television instruction on achievement in high school physics, *Engelhart* found that students with I.Q.'s above 120 and below 100 profited relatively more from the usual methods of instruction without television. He concluded that both the fast and slow groups need the stimulation and guidance of the teachers and that it may be possible to develop adequate television instruction for the average students who are more interested in the cultural than the technical value of physics.

Champa, studying the potential of television in developing science understandings and interests in 300 9th-grade pupils, found that gains were significantly greater (at the .01 level) for all three groups, with the conventional group gaining the most. A year later more students from the television and motion picture groups than from the conventional group were continuing to take science. In a study by *Hubbard,* involving the effect of television on teaching science, one group of physics students was taught by television alone, another by television supplemented by direct teaching, and the third by the same teachers using conventional classroom techniques. He found that there was no statistically significant superiority in any of the teaching methods and that no one teaching method was better for any one scholastic ability level.

Learning, Interests, and Attitudes

A substantial portion of the studies reviewed were related in one way or another to learning, interests, achievement, aptitudes, or attitudes. This fact is significant, since such studies are of great importance in giving direction to the creation of effective science education programs. *Rosenberg* investigated the ability of 8th-grade pupils to indicate understandings of three simple machines by means of a test devised to observe the responses of selected pupils on the relationships of the lever, wheel and axle, and pulley. The results were correlated with sex, I.Q., and certain aptitude scores. He observed that, according to the tests, boys and girls were equally capable on the test and that the greatest difficulty was encountered in expressing relationships involving the pulley. The pupils seemed to discover relationships concerning these machines through a wide variety of approaches as they progressed in the test.

Frankel investigated causes for the differences in scholastic performance of achieving and underachieving boys of equivalent intellectual ability at the Bronx High School of Science. He showed that the achievers demonstrated greater aptitude in the verbal and mathematical areas and greater interest in mathematics and science than was true for the underachievers. As a group, the boys with poor achievement records expressed more negative feelings toward school in terms of less participation in extracurricular activities, poorer attendance, and more disciplinary offenses than was found for the comparable group who were doing well in their school studies.

Using analysis of variance and the chi-square test of normality, *Porter and Anderson* studied the achievement in chemistry of a selected group of students in order to determine the relationship of specified abilities in chemistry to each other and to intelligence. They discovered that although there was a consistent decrease in overall achievement as measured by a standardized test from the top intellectual group to the lowest, this did not always hold true when the same groups were compared on the basis of their achievement on specific abilities identified in the test.

Using specially constructed tests in mathematics and science, *McCutcheon* compared the achievement of 8th-grade students in mathematics and science with the organization of the school, grade enrollments, and certain pupil and teacher factors in Minnesota public schools. He concluded that an important factor in predicting success in advanced standing high school physics would be a high score on the Cooperative Algebra Test. *McCutcheon* also concluded that the broad spectrum of capabilities of the gifted needed careful study before assignment to college-type physics courses in high school.

Sheldon identified and studied certain factors characteristic of science instruction in New York State and related them to results on Regents Examinations in biology, chemistry, and physics. *Norton* attempted to find out by means of a multiple regression analysis whether or not achievement in 9th-grade general science was related more closely to study habits than to intelligence, reading ability, and aptitude. He concluded that aptitudes were better predictors of success in general science than the other variables studied and that teacher ratings were the least valuable of all.

Seeking to discover how closely interests of pupils in second-semester biology classes compare with the emphasis given certain topics in 10 current high school texts in the field, *Blanc* found little correlation between emphasis given topics in textbooks and expressed interest of pupils; but the higher the first-semester grade, the greater the number of expressed interests in textbook topics. As the result of a comprehensive study of the relationship between science teacher attitudes, preparation, and experience, and growth in interest and achievement of high school science students, *Taylor* concluded that there was a significant difference in growth in interest as between students under full-time science teachers and those under part-time science teachers. A difference in achievement of these two groups, however, was not highly significant. A composite of other teacher factors falling above the median produced significant changes in science achievement, but not in interest.

In a comprehensive study of the attitudes of high school seniors toward science and scientific careers, *Allen* showed that, for the group studied, the overall picture of attitudes was favorable and constructive toward science when judged by the response ratings determined by a competent jury. On the other hand, an item analysis of all responses revealed the existence of misunderstanding on the part of many students concerning questions related to the scientist and his work, and to the nature of science. Intelligence was found to be related to the character of the responses: the greater the intelligence of the given senior, the greater the chances he would have favorable attitudes toward science. The aptitudes and attitudes of high school youth toward science and scientists were studied by *Stoker*. He found, in general, that students expressed favorable attitudes toward science as a social institution and that their attitudes toward scientists as people were significantly related to their aptitudes, but that their attitude toward science as a vocation was not significantly related to their aptitudes for science. Pupils' attitudes toward science as an institution and as a vocation and toward the scientists were closely related to their grades in science and to their socioeconomic status. Their attitudes toward the other criteria varied with personal factors.

Attempting to identify potential scientists, *Cooley* developed a multiple discriminant analysis of the data on 19 variables secured for 251 pupils who had been in the scientific curriculum at Forest Hills School, New York City. He found that career development, even among students of high ability, was not a random process and that aptitude of students for science careers was probably a function of general intelligence and previous scholastic experiences.

The Teacher

The classroom teacher has always enjoyed preferential status as an object of concern and often as a subject for research. This is understandable in the light of the key position of the teacher in formal education programs. His training, his general competence, his aptitude for teaching, his attitudes toward society, and even his attitudes toward science and science teaching have been investigated by the researcher from time to time.

Investigating the competencies needed by secondary school teachers, *Spore* devised a rating scale composed of 60 competencies derived from the literature in science education and submitted the rating scale to four groups of judges who were asked to rate each competency as to its importance on a five-point scale and to indicate at what point in the training program of teachers the various competencies should be emphasized. Differences among the four groups of judges were found: the science teachers and school administrators were in closest agreement, and the foundation educators and science educators were farthest apart in their judgments on the relative importance of the various competencies. The four groups of judges were found in general agreement that the competencies listed should receive equal emphasis in the education of science teachers.

The problems and training needs of science teachers are of considerable importance. By means of a questionnaire administered to two groups of randomly selected beginning science teachers in Massachusetts, one with, and the other without adequate training in science, *Victor* investigated the help and assistance that beginning science teachers think they need. Both groups indicated need for help on all the 21 practices commonly associated with science teaching which were described on the questionnaire. *Shrader* investigated the problems encountered by beginning science teachers in the high schools of the Pacific Northwest.

A questionnaire study of summer institutes for teachers of science and mathematics involving 9 sponsoring agencies, 30 cooperating institutions, and 934 high school teachers was conducted by *Schlesinger*. He found that 44 percent of the participants held bachelor's degrees and 53 percent master's degrees; and that 85 percent had majored in science and/or mathematics. The teaching experience of the group ranged from 1 to 39 years, with a median of 9. Fifty-eight percent taught science or mathematics exclusively, and the majority were better trained than science or mathematics teachers for the country as a whole.

In their nation-wide study of certification requirements for teachers of science and mathematics, *Sarner and Frymier* found that 42 States required a 4-year college degree and one State required five years of college preparation. Only two States which required four or more years of preparation required additional preparation in the teaching field for advanced degrees and higher certificates. The number of required semester hours in mathematics ranged from zero to 24 with a mode of 18 and a mean of 15.1. Minimum science requirements ranged from zero to 48 semester hours, with a mode of 15 and a mean of 17.9. Minimum professional education requirements ranged from 12 to 24, with a mode of 18 and a mean of 18.4. Twenty States required course work in particular areas of science, but only eight of these specified a minimum number of hours to be completed. There was lack of agreement on what constitutes minimal preparation in subject matter. Agreement was fairly good on professional education. Little was found concerning the quality of preparation. There seemed to be a need for some sort of uniform minimal requirements throughout the United States.

Interpretation

The secondary school studies provided for this report cover a wide range in topic, research design, and procedures. Generally speaking, however, only a few of them could be characterized as unique or profound. In fact, they contribute few new findings and shed little new light on the many well-known problems of science education. Most of these secondary school science research studies, like those provided for the reports of previous years, are findings of facts, surveys of status, descriptive inquiries, and assemblings and reassemblings of teaching material.

Studies of this type are, of course, important, useful, and necessary. They must be regarded, however, only as routine-type activities to be carried out from time to time as the need for status information arises. In general, they are useful only in a limited sense, such as indicating places where a more basic type of research needs to be carried out. In and of themselves they are not adequate for answering fundamental questions about basic concerns in science education.

It seems unfortunate that studies based largely on techniques such as the survey and the jury opinion, have come to occupy a major place in the research effort in science education. The total research endeavor in this discipline should be re-examined in order to bring into sharper focus the great need for what Fletcher G. Watson and William W. Cooley have called "dynamical descriptions as to how and why the status or achievements or opinions changed."[2]

This interpretation would be remiss if it failed to point out that it would be almost impossible for a second person to repeat certain of the secondary school science studies. This difficulty is partly inherent in the design and partly in the manner of reporting. One of the things that make science unique as a discipline is the fact that the findings of one investigator are constantly under test and check by other investigators. It is essential that the techniques and processes, the assumptions and the hypotheses, employed by the original investigator be reported with such detail and clarity that they may be used by others who may wish to repeat the research. If we are ever to develop a science of science education, research workers must report their studies in such a way that these studies can be duplicated exactly.

In only a few of the studies in secondary school science could one identify the hypotheses being tested; and among these, the ones in which the hypotheses had been derived from educational theory were still fewer in number. Research in science education must seek to test hypotheses that have been suggested by an established theory in the discipline if that research is ever to attain respectable stature.

Science education is beset with basic unresolved issues in each of such areas as public policy, teaching-learning, methodology, philosophy and purposes, administration and supervision, teacher education, and evaluation of learning. Exact knowledge of these fundamental issues is essential to the growth and development of the field.

And yet, as one examines the studies reported in this section it becomes apparent that many who are engaged in directing, and

[2] *Rethinking Science Education.* Yearbook LIX, Part 1, 1960. Chicago: University of Chicago Press, 1960. p. 298.

many who are charged with carrying out, the studies are somehow not aware of the basic questions that need to be asked if answers to crucial concerns are to be forthcoming. If issues are to be resolved, fundamental questions must be asked, and hypotheses rooted in educational theory must be tested.

It must be said over and over again that once a research problem has been identified, it is essential to select promising hypotheses for testing, and to design the study in such a way that the data will be tabulated, analyzed, and interpreted in a manner to make the study replicable, the findings generalizable and capable of wide application. Only when such procedures are assiduously followed will "the studies generally promote the development of reliable predictive systems [which are] based upon laws and principles that are applicable to the . . . problem of maximizing [science] learning in the schools."[3]

The cultivation of basic research is just as important to the well-being and advancement of science education as it is to the advancement of science and technology. To deny this, as many do, is to consign science education to the uncertain pitfalls of unexamined theory, mere opinion, and every man's foregone conclusion.

Studies Related to Curriculum

Investigations of course content continue to seek to develop courses adequate for general education purposes as well as for specialization. Attempts are being made to place the history of science in its true perspective. In fact, there is considerable groping for an integrating theme around which general education and specialized introductory science courses may be organized. Many investigators are questioning how course content can be streamlined or otherwise modified so as to permit higher level instruction at each grade level.

Studies Related to Learning

Psychological studies reemphasize such points of view as: "The student must be put in an environment in which he will not only be exposed to the objects of knowledge, but in addition will actually desire and want to learn these objects" . . . "Lack of problem-solving skills is the cause or reason for many cognitive errors." . . . "Students faced with problem-solving situations become less effective after failure in such situations." A whole-part approach

[3] *Ibid.*, p. 299.

seems to be consistent for most individuals when they face problem-solving situations, but individuals differ in the flexibility-rigidity factor when they are confronted with situations of different structures.

While engaged in concept learning, learners forced to search for the correct response after feed-back of their incorrect answers are more successful than those who are dependent upon a teacher for the correct answer. Intention to learn does not significantly facilitate retention of learned material, although it does enhance original learning. Study habits, primarily reading, predict improvement better than any single variable, whereas verbal intelligence is likely to be inversely related to improvement.

Studies Related to Philosophy and Objectives

Writers from the field of philosophy emphasize the need to broaden the scope of training for specialists, to point the way to greater social wisdom, to keep scientific concepts and methods intelligible in our culture, to make traditionalists aware of change and progress and at the same time make devotees of progress sensitive to traditions. Thus, it appears that science continues to arouse study not only from the viewpoint of integrating, but also of clarifying, its unique function.

Studies Related to Public Policy

Studies in the area of public policy were concerned with evaluating the effectiveness of academic-year and summer institutes—a matter of concern to the general public for tax and national security reasons. Since the number of institutes continues to increase, studies such as these will doubtless be more numerous and more definitive in the future.

One study dealt with scientists' and educators' opinions on the issues related to science teaching. Such a study is particularly valuable since it touches a segment of the population not always consulted when science programs are planned.

Additional studies have been directed toward the relationship between creative responses and working time and instructions, approaches to the learning process, transfer of learning, and many of the other questions traditionally involved in educational psychology.

Studies dealing with the characteristics of students are aimed at trying to identify those characteristics most likely to be related to success in the sciences. Many of these investigations reflect the science-student recruitment problem as well as the need for reducing the casualty rate among students already enrolled. Competency in mathematics continues to share a major responsibility for success of beginning students in science.

Studies Related to Methods

Studies in methodology continue to emphasize the motivational benefits which seem to derive from experimentation in methodology. Few studies, however, reveal significant differences when one type of procedure is compared with another. Several promising studies suggest that audiovisual aids, particularly television and motion pictures, are gaining in value as their producers develop new and better ways of incorporating problem-solving and other higher level intellectual processes.

Studies Related to Facilities and Equipment

Facilities and equipment for teaching science have not been a significant area of study at this level. Such investigations will doubtless become more numerous as national curriculum studies at this level mature.

Studies Related to Administration and Supervision

Studies in the area of administration dealt with means of effective use of staff time, the characteristics of honors section students, and problems associated with large class size.

Studies Related to Teacher Education

In the area of elementary and secondary schools science teacher education, the dearth of definitive studies continues. Some of the studies reveal that college courses for teachers are beginning to acquaint their students with the resources available for enriching science teaching. In general, studies are lacking on what relationship may exist between the success of college science students in their classes and their later success in teaching science.

Selected Abstracts

ALLEN, HUGH. Attitudes of Certain High School Seniors Toward Science and Scientific Careers.

Major Adviser.—Hubert M. Evans.

Problem.—To investigate the following: (1) Do high school seniors have positive, constructive attitudes toward the scientific endeavor? (2) Do those seniors choosing scientific careers have more positive and constructive attitudes toward science than those choosing other careers? (3) Is the intelligence of the high school senior related to his attitudes regarding science? (4) Is there a difference in attitudes toward science and scientific careers between high-ability high school seniors who (a) plan careers in science or engineering, and (b) those who plan other careers?

Procedures.—The sample consisted of all the 3,057 seniors in 20 representative New Jersey high schools. The questionnaire submitted to them contained a section on personal data, a short vocabulary test to estimate intelligence, and an attitude scale, and the resulting data were coded and punched on I.B.M. cards. To ascertain positiveness or negativeness of the expressed attitudes, the jury technique was employed.

Findings.—The high school seniors in this study showed constructive attitudes toward science. The item analysis revealed that a substantial number held nonconstructive views, especially on those items bearing on the scientist and his work and on the nature of science.

No significant differences were found when the responses of the *science group* (those specifying a science or science related career) and the *non-science group* (those specifying other careers) were compared with each other and separately with the scale score of the judges.

In general, as far as this study indicated, the higher the intelligence of a given student, the greater the chances that he would have favorable attitudes toward science. No significant differences were found when the responses of the high-ability group (top one-eighth in intelligence) who had indicated interest in a scientific or science-related career and the responses of a similar group who had indicated interest in other careers were compared with each other and the scale score of the judges.

ATKINSON, GENE. The Identification of Facts and Principles of Nuclear Energy Suitable for Inclusion in the Secondary School Curriculum.

Major Adviser.—Esther M. Nelson.

Problem.—To determine facts and principles of nuclear energy of importance to U. S. citizens and to construct a test to measure understanding of them.

Procedures.—A list was made of facts and principles pertaining to nuclear processes or applications. This list, together with a rating scale, was submitted to a jury of twelve. A test was constructed with internal reliability (0.88 by split-half method stepped up by the Spearman-Brown formula) and validity (most items discriminated satisfactorily between upper and lower halves of the sample), and was given to 172 students.

Findings.—The jury ranked a list of 86 relevant facts and principles. The following were the first five: (1) Human life has always been exposed to radiation. (2) The rate of nuclear reaction can be controlled. (3) Nuclear radiation cannot be detected by the ordinary senses. (4) The heat from a reactor must be transferred to an engine to produce power. (5) Nuclear reactors produce radioactive isotopes.

The correlation of the test scores with I.Q. scores was 0.30. Students who had taken courses in physics or chemistry scored higher on the test than those who had not.

BARNES, CYRUS D. *and others.* Criteria for Selecting Supplementary Reading Science Books for Intellectually Gifted High School Students.

Problem.—To develop a list of criteria for selecting supplementary reading books in the sciences for gifted high school students and to determine the relative importance of these criteria.

Procedures.—A questionnaire containing 23 criteria was developed. In addition respondents were asked to suggest other criteria. Among those suggested, some were duplicates of the ones originally proposed.

The criteria were divided into (1) those pertaining to the effect of the book on the reader and (2) those pertaining to the intrinsic quality of the book.

Findings.—A list of 12 criteria for selecting supplementary science reading books for gifted high school students was set up.

The reading level of academically gifted high school students should be upgraded and can be if teachers, administrators, and parents (using the criteria worked out in this study) select supplementary science books.

BECK CHARLES F., JR. The Development and Present Status of School Science Fairs.

Problem.—To ascertain the development and present status of school science fairs.

Procedures.—Questionnaires were sent to 166 school science fair directors. Adequate information was received from 88 of them and was analyzed.

Findings.—In 1956 the typical science fair was held in either a gymnasium or science building on a college campus; its director was a member of the college staff; the fair was in the third year of its operation; the exhibits were on display for two days; no admission charge was made; the fair was sponsored by a newspaper, professional society, or an industry.

BICHLER, DAVID L. The Effect on Selected Science Education Objectives of a Sound Motion Picture, With Accompanying Classroom Teaching Unit Concerning Poliomyelitis Presented to High School Students.

Major Adviser.—J. Darrell Barnard.

Problem.—To study the gain in information on medical research against poliomyelitis; to measure the change in the understanding of the biological principles in a teaching unit on poliomyelitis; to measure the changes in attitude of the students towards the National Foundation; and to measure the change in attitude of the students toward the March of Dimes.

Procedures.—The data were obtained through the cooperation of three schools in different areas of New Jersey. The 292 students who participated in this study were either high school biology students or junior high school general science students in the 9th and 10th grades.

Tests for understanding of biological principles and achievement in biology were devised and constructed by the investigator. Pilot studies conducted by the investigator indicated that the reliability of the test items was sufficient for use in this study. Remmers Generalized Attitude scales were used as pre- and post-tests. Groups were equated on the basis of their I.Q., reading ability, and chronological age. These variables were statistically treated and their relationship to pretest results was interpreted.

Findings.—(1) There is no statistically significant relationship between chronological age of these students and their performance on the achievement and principles tests. (2) Intelligence of an adolescent gives no indication of his attitudes towards the National Foundation and the March of Dimes. (3) Reading ability of an adolescent gives no indication of his attitudes towards the National Foundation. (4) The older the child, the less favorably inclined he is toward the National Foundation. (5) The film *Interim Report* alone had little or negligible effect on the gains achieved on the biology achievement test.

BLANC, SAM S. Biology Interests of Tenth- and Eleventh-Grade Pupils.

Problem.—How closely do interests of pupils in second-semester biology classes compare with emphasis given to these topics by 10 current high school texts in the field?

Procedures.—A questionnaire was checked by 60 boys and 60 girls from 10 biology classes. Half of each were in the 10th grade and the samples were equally divided as to the biology grade (A, B, C, or D) received in the first semester. Each of the 92 topics was to be marked as "yes", "no", or "undecided" for interest and ranked for interest-value under each of the headings: "Boys, girls, 10th grade," and "A, B, C, and D grades."

Findings.—(1) There was little correlation between emphasis given topics in textbooks and expressed interest of pupils. (2) There was high agreement between groups in likes and dislikes of specific topics. (3) "A-group pupils" were most inclined, and "B-group" pupils least inclined, to agree with emphasis in textbooks. (4) The higher the first-semester grade, the greater the number of expressed interests in topics.

CHAMPA, V. ANTHONY. Television: Its Effectiveness in Ninth-Grade Science Classroom Teaching.

Problem.—To explore the potential of television in helping 9th-grade pupils learn more science as well as predisposing them to further study in science.

Procedures.—Three hundred 9th grade science students from Lancaster, Pa. were selected for this experiment. The conventional (*C*) group was taught science as it had been taught previously. The *TV* group was taught the same course of study, with two quarter-hour television programs per week during the year. The Motion Picture (*MP*) group was taught the same course of study, with a half-hour per week for viewing the same two films as the *TV* group. Neither the *C* group nor the *MP* group had the advantage of the science resource people used on television.

Findings.—The gains were significant between the pre- and post-test (at the 0.01 level of confidence) for all three groups, with the rank of improvement as follows: *MP* group, *TV* group, *C* group. A year later slightly more students from *TV* and *MP* groups were continuing to take science courses than from the *C* group. The classroom teachers in this sample welcomed help in achieving objectives and recognized the value of the telecasts and motion pictures almost unanimously.

If used in the earlier grades, perhaps this technique could stimulate learning and create a favorable disposition toward science as a career.

COOLEY, WILLIAM W. Identifying Potential Scientists: A Multivariate Approach.

Problem.—From data collected during high school, to distinguish among the various post-high school career directions.

Procedures.—A total of 250 students in the pre-scientific curriculum over a period of years at Forest Hills High School (N.Y.) were included in the present study. Data on 19 variables were made available by school authorities. The technique of multiple discriminant analysis was used for treatment of the data.

Findings.—Even among a group of high I.Q. students, career development cannot be considered as a random process. Since statistical significance does not imply practical significance, selection or exclusion of students from the special science program on the basis of these results would be unreasonable. The results lend support to the view that science aptitude is a function of general intelligence and previous scholastic achievement. Factors in combination produced the group differences on each function. Study results lend encouragement for further similar studies.

ENGLEHART, M. D. *and others.* Instruction in Physics by Television in the Chicago Public Schools.

Problem.—To evaluate and study new techniques in the use of television on the basis of data and the comparative achievements of students at different levels of ability.

Procedures.—Testing students taught physics by television after completion of course. The I.Q. of each group was known along with other data for comparative study.

Findings.—Students with I.Q. scores above 120 and below 100 apparently profited relatively more from usual methods of instruction than from TV instruction. Such groups as these two apparently need to be guided and stimulated by a teacher. Probably a different kind of TV instruction is needed and will be developed for the average student for whom physics has more cultural than vocational or professional value.

FONSWORTH, EMILE CHARLES. The Use of the Reflective-Thinking Approach in the Teaching of High School Chemistry.

Problem.—To devise and test the effectiveness with high school pupils of procedures that use the reflective-thinking approach, as opposed to approaches that emphasize acquiring knowledge of facts and principles.

Procedures.—Procedures were developed to improve students' abilities in thinking by solving chemistry problems. Students and teacher cooperated in selecting problems and methods of solving them and in acquiring the necessary skills and techniques. Results of these procedures were measured by I.Q. and critical-thinking tests and standardized achievement examinations in chemistry. These results were compared with similar results from the more usual factual information approach to the subject matter. Equivalent groups and the same group were used in the analysis.

Specifically, the following group-gain comparisons were made: (1) reflective-thinking approach versus factual information approach in two different groups, (2) reflective-thinking approach versus factual information in the same groups, and (3) reflective-thinking group versus factual-information group, with extra class periods added for both.

Findings.—The gains by students under the reflective-thinking approach were highly significant as to (1) growth in mental ability, (2) the application of abilities required in critical thinking, and (3) the use of the scientific method in solving chemistry problems. Gains in the acquisition of facts and principles were significant in those groups submitted to a factual-information approach, although the former students obtained satisfactory scores in this area. Various other observations of positive changes in behavior not directly measured by the tests were noted. Since these changes in total are usually considered worthy objectives of democratic education, it is recommended that teaching methods be modified in order to emphasize reflective thinking.

FRANKEL, EDWARD. A Comparative Study of Achieving and Underachieving in High School Boys of High Intellectual Ability.

Problem.—To investigate possible causes for the differences in scholastic performance of achieving and underachieving high school boys of presumably equivalent high intellectual ability.

Procedures.—The experimental group consisted of 50 pairs of boys selected from the June 1957 senior class of the Bronx High School of Science in New York City. Each pair consisted of an achiever and an underachiever matched on the basis of equivalent intellectual quotient, score on entrance examination required by the school, and age.

Areas explored for possible significant differences were (1) aptitudes, (2) interest, (3) personal problems, (4) health, (5) home and family background, (6) socioeconomic status, (7) reaction to school subjects, (8) reaction to school, (9) out-of-school activities, (10) vocational and college planning, and (11) academic performance in junior high school.

Instruments used for collecting the data related to these areas were (1) Differential Aptitude Tests, (2) Kuder Vocational Preference Record, (3) Mooney Problem Checklist, (4) school records, (5) a questionnaire developed by the investigator, and (6) the Hamburger Socioeconomic Scale.

Findings.—The achievers showed greater aptitude than the underachievers in verbal and the mathematical areas, and were more interested in mathematical and scientific areas than the underachievers, who favored the mechanical and the artistic. Achievers selected mathematics as the easiest, and mathematics and science as the best liked subjects. They chose English as the most difficult and least liked subject. The underachievers chose science as the easiest and best liked subject; foreign language as the most difficult and least liked. The underachievers expressed more negative feelings toward school in terms of (a) less interest and participation in extracurricular activities, (b) poorer attendance, and (c) more disciplinary offenses.

Achievers were more interested in pure science and mathematics and planned their college courses accordingly, while underachievers planning to enter science tended to select college programs in applied fields. A significant number of underachievers did not plan to enter science. The pattern of academic performance in the junior high school revealed that at least one-half the underachievers were already underachieving; their scholastic records became progressively worse in high school.

GARSIDE, LEONARD J. A Comparison of the Effectiveness of Two Methods of Instruction in High School Physics as Measured by Levels of Achievement of Students of High and Low Intelligence.

Major Adviser.—Milton O. Pella.

Problem.—To determine whether there is a significant difference in level of achievement and retention in high school physics between students of high and low levels of intellectual ability, who studied physics by traditional procedures, when compared with students of high and low levels of intellectual ability who studied physics by means of the Harvey White physics films.

Procedures.—Sixty Wisconsin classes in physics were selected at random and divided into 30 experimental (film-using) and 30 control groups, each containing 485 students. The top and bottom 27 percent in intelligence of each of the physics classes was selected on the basis of the Henman-Nelson Intelligence Test and labeled as "high" and "low" intelligence groups. The experimental groups viewed a Harvey White film each day in addition to having classroom instruction, but the total time for instruction was the same in the control and experimental groups. Nine achievement tests, standardized and project-produced, were administered to the groups. The results were analyzed statistically.

Findings.—The level of achievement and retention in physics of students of high and low intelligence, respectively, in the experimental group is not significantly different from that of comparable students in the control group. The higher intelligence sections in both experimental and control groups achieved significantly higher than the lower intelligence sections, but the level of retention was not significantly different. There is no significant difference in the level of achievement and retention in physics between experimental and control students studying physics under the guidance of teachers in three level-of-preparation categories. There was no significant difference in level of achievement in physics between the experimental and control students, but the control groups were significantly higher in retention of physics information.

HEIDGERD, LLOYD H. Effects of Changing the Typical Sequence of High School Science Courses to 9th-Grade Biology and 10th-Grade Physical Science.

Major Adviser.—R. Will Burnett.

Problem.—To investigate the educational advantages or disadvantages of substituting biology for general science at the 9th-grade level, and physical science for biology at the 10th-grade level in two high schools.

Procedures.—Two approaches were used. In one, the standardizing samples of the science tests of the World Book Company's *Evaluation and Adjustment Series* were reorganized to represent distributions of average school achievement, which had been adjusted to one I.Q. level on the basis of the within-school regressions of achievement upon I.Q. The average achievements of the two schools were then compared in terms of rank with the schools in the reorganized standardizing samples. In the other method, the regression of school achievement means upon school I. Q. means within the standardizing sample was used to predict the achievement means of the two schools, given their mean I.Q.'s. The achievement means were then compared with predicted means in terms of standard errors of estimate.

Findings.—Biology achievement at the 9th-grade level in the two schools studied was somewhat inferior to that in most schools in the standardizing sample where biology was taught in the 10th-grade. However, if the method of the regression of school achievement means versus school I.Q. means had been used and an adjustment made for mental age, the students did just about as well as predicted.

General science achievement after 9th-grade biology was low when compared with the national standard. After the 10th-grade physical science course, general science achievement was above average but not significantly so. When the scores were adjusted for mental age, the results were close to average. Physics achievement was high in the two experimental schools.

HENDERSON, ALEXANDER, JR. An Investigation of the Interest of Secondary School Pupils, Parents, and Teachers in Physiology.

Problem.—What aspects of physiology do high school pupils, their parents, and teachers feel should be included in the high school curriculum?

Procedures.—A checklist of physiology topics was constructed and submitted to 999 high school students, 181 teachers, 97 parents, and 14 physicians. Items were evaluated on a scale of +4 to 0.

Findings.—Homogeneity in regard to sex seems advisable if like interests are to be considered. Parents and teachers are rather good judges of interests of pupils; physicians are not. Parents feel that sex education is part of the school's function. Students are more interested in practical than in theoretical information.

HOWARD, CUBIE W. A Comparative Analysis of the Objectives and Content of Biology Instruction in the High Schools of Today With Those of Approximately 40 and 80 Years Ago, Respectively.

Major Adviser.—I. Owen Foster.

Problem.—To compare the objectives and content of biology instruction in the high schools of today with those in the high schools of approximately 40 and 80 years ago, respectively, insofar as these were revealed in representative textbooks chosen from the three selected periods.

Procdures.—Textbooks used extensively during each of the three selected periods were collected and analyzed for emphasis on (1) objectives of instruction, (2) subject-matter content, (3) reading level difficulty of subject matter, and (4) the extent to which illustrations were used in textbooks of the three periods.

Findings.—Under the major phases of this study the following conclusions were drawn: Factual information objectives from the earliest to the latest period showed a gradual decrease in emphasis, whereas functional information objectives when similarly compared showed an increase in emphasis. Mental discipline and religious implication objectives (which received some mention in the first period) were not present in either the second or the third period. The content of biology instruction as reflected in commonly used textbooks of the first to the last period, changed in emphasis from the practice of requiring students to memorize a number of more or less unrelated facts, to the practice of having them consider familiar living things and their interrelationships. A greater effort to foster practical applications of knowledge and to stimulate critical thinking through the relation of textual content and illustrative materials was made by more writers of textbooks of the last period than of the first and second.

HUBBARD, GEORGE WENDELL. The Effect of Three Teaching Methods on Achievement in a Senior High School Physics Course.

Problem.—To determine the effect of three types of presentation of subject matter on the comprehension of high school physics.

Procedures.—One group was taught by television only, one by television supplemented by the physics teacher, and the third by the same teacher using conventional classroom techniques—a total of 63 students. Groups were matched on scores from the American Council on Education Psychological Examination, High School Edition. The criterion measured by the study was the difference between pretest and posttest scores on two forms of the Cooperative Physics Test for College Students. The statistical method used was the analysis of variants.

Findings.—There is no statistically significant superiority in any of the teaching methods. No teaching method worked better than any other for any one scholastic ability level.

LEE, VERLIN W. The Evaluation of Supervision of Secondary School Science Instruction.

Major Adviser.—John S. Richardson.

Problem.—To ascertain the status of supervision of secondary school science instruction at the State and local levels, and to evaluate the performance of supervisory activities in the light of values procured through the judgments of a jury.

Procedures.—State departments of education were asked to give the status of science supervision and the location of science supervisors in their States. Questionnaires concerning the importance of 106 supervisory activities were sent to 30 science educators. Forty-four local and 10 State science supervisors were sent similar questionnaires to ascertain to what extent they took part in such activities. Statistical treatment included the use of the coefficient of correlation, rank correlation, and the Null Hypothesis.

Findings.—The 106 supervisory activities were placed in 8 categories. Data obtained from the jury showed that the rank order of the categories was: (1) methods, (2) curriculum study, (3) research, (4) inservice growth of teachers, (5) self-growth, (6) public relations, (7) administration, and (8) materials and equipment.

Only six State Departments of Education employed full- or part-time science supervisors. The primary functions of the general supervisors were regulatory in nature. Activities to upgrade science teaching took the form of workshops and institutes.

The category of activities performed most extensively by the State supervisors was administration. The category performed least extensively was research.

McCUTCHEON, GEORGE J. An Analytical Study of Achievement in 8th-Grade General Science and 8th-Grade General Mathematics in Minnesota Public Schools.

Major Adviser.—Palmer O. Johnson.

Problem.—What is the relative achievement of 8th-grade students in methematics and science in relation to organization of the school, 8th-grade enrollment, and certain pupil and teacher factors?

Procedures.—A 50-item test in mathematics and a 75-item test in science were built from a large pool of items after an item analysis. Pretests in science and mathematics were administered to a stratified random sample of all Minnesota schools. A posttest to measure achievement was given six months later to 6,471 pupils.

Findings.—Boys made significantly greater achievement in science than girls, but no such difference appeared in mathematics. Girls had slightly higher mean scores in pre- and post-tests in mathematics. The top and middle groups had significantly larger posttest scores in mathematics and science. The middle group appeared somewhat superior in final achievement to the top 5 percent.

NATIONAL EDUCATION ASSOCIATION RESEARCH DIVISION. Mathematics and Science Enrollments.

Problem.—To survey 1957 enrollments in mathematics and science courses.

Procedures.—The data in this study was provided by 1,876 usable questionnaires completed by principals and science and mathematics teachers. The data thus collected were organized under three headings: (1) teachers of mathematics and science (numbers, time devoted to teaching in mathematics or science field, and the level of teaching in each field); (2) the program and facilities for mathematics and science teaching (enrollments, curriculum revision programs, and science equipment and facilities); and (3) principals' opinions about present serious limitations in programs of mathematics and science instruction.

Findings.—The study indicated the following: In general, mathematics and science teachers of large secondary schools are better prepared and more likely to be teaching their subjects full time. More than 3 out of 4 of the mathematics teachers and well over 8 out of 10 of the science teachers were teaching their particular subject full time. Nearly a quarter of the graduates in all three categories of the schools studied had taken between 3 and 4 years of both mathematics and science. Large high schools have been adding new science courses at an extremely rapid rate. In the opinions of the administrators, there is a need for more up-to-date knowledge of the field being taught.

NEWMAN, EARL NELSON. A Comparison of the Effectiveness of Three Teaching Methods in High School Biology.

Major Adviser.—Arthur W. Heilman.

Problem.—To compare the effectiveness of three methods of instruction: lecture-discussion with outside reading assignments, lecture-discussion with textbook reading in class, and lecture-discussion with no textbook or reading assignments in or out of class.

Procedures.—The groups had 53, 56, and 52 pupils, respectively. Alternate forms of the Nelson Biology Test were given as pre- and post-tests.

Findings.—For the groups as a whole, each method of teaching resulted in gains in biological information, but none was found to be statistically superior to any other. For those fractions of all three groups scoring high on intelligence and reading comprehension, no method was found to be superior. For those parts of the groups scoring low in intelligence and reading comprehension, only the group with assigned reading in class showed significant improvement over the other two groups.

NORTON, DANIEL P. Relationship of Study Habits and Other Measures of Achievement in 9th-Grade General Science.

Problem.—Does achievement in 9th-grade general science relate more closely to study habits than intelligence, reading ability, and aptitudes?

Procedures.—Forty-one boys and 53 girls were used as a sample from a population of 5 general science classes. The following tests were the variables incorporated in the study: Iowa Silent Reading, Iowa Algebra Aptitude, Otis Quick Scoring, Student Rating, Instructor Rating, Differential Aptitudes, Space Relations, and Mechanical Reasoning.

Findings.—Aptitudes, as measured by the Differential Aptitude Tests, were the most significant predictor for both sexes when considered together. Instructor rating appeared less valuable for predictive purposes than any other independent variable.

PIERCE, EDWARD F. Modern High School Chemistry.

Major Adviser.—Frederick L. Fitzpatrick.

Problem.—To develop a modern course of study for high school chemistry that will include modern chemical theory and unifying concepts.

Procedures.—Current chemistry courses of study and textbooks were reviewed and evaluated. The study of existing materials revealed an extensive treatment of descriptive chemistry and chemical technology and a lack of emphasis on modern chemical theory.

Proposals for a new course were submitted to, and approved by, a group of chemists. A new chemistry course was then outlined and the present monograph was developed from the outline.

Findings.—The concepts of energy, atomic structure, and equilibrium are logically developed and serve as the major unifying themes for this thoroughly modern chemistry course.

Recommendations are made as to the nature and amount of laboratory work and the use of the problem-solving approach.

PORTER, MARJORIE RUTH *and* KENNETH E. ANDERSON. A Study of the Relationship of Specified Abilities in Chemistry to Each Other and to Intelligence.

Problem.—(1) To compare the achievement in chemistry of three groups of students classified on the basis of intelligence quotients into an upper 25 percent, middle 50 percent, and lower 25 percent of the class, and (2) to determine the degree of relationship between performance on different parts of the chemistry test and between intelligence and performance on different parts of the chemistry test.

Procedures.—The sample consisted of 152 students selected from 4 States. Statistical analysis of variance and the chi-square technique were used as a test of normality.

Findings.—Significant differences appeared among the means of the three groups as to achievement on parts A, B, C, D, and the total chemistry test. The top intellectual group was not always superior to the lower groups, and the middle group was not always superior to the lower group in achievement in chemistry.

The ability to understand and apply the elements of the scientific method, together with its associated attitudes in chemical situations, is perhaps more closely related to intelligence per se than any of the other parts of the chemistry test.

The intercorrelations of parts of the test with each other were all significant but not extremely high, the coefficient ranging from 0.38 to 0.65. It was also apparent that the understanding of functional facts and concepts accompanied the other three abilities and was accompanied by the understanding and application of functional principles of chemistry. The ability to understand and apply the elements of scientific method, together with its associated attitudes, accompanied the other abilities to a lesser degree.

The correlations of intelligence with parts of the chemistry test ranged from 0.39 to 0.44. The highest correlation was between intelligence and the ability to understand and apply the elements of the scientific method, together with its associated attitudes in chemical situations. Intellectually superior students achieved more in terms of the total chemistry test than did the average or lower groups, and the average group achieved more than the lower group.

RAND, E. W. *and* WILLIAM F. BRAZZIEL. Priorities in Reappraisal for Science Education in Louisiana Schools.

Problem.—To identify critical areas for reappraisal in the science programs in the Louisiana Negro secondary schools.

Procedures.—Six basic assumptions were accepted as criteria for determining the adequacy of provisions for learning in science. The questionnaire study covered 25 schools and 10 additional ones were visited.

Findings.—Sequential priorities in reappraisal were established as follows: (1) Reorient the curriculum to provide more learning opportunities in the physical sciences. (2) Study ways and means to create a greater supply of teachers in the physical sciences. (3) Study how best to encourage and help more students to take more sciences, to learn more about scientific careers, to set career goals in science, and to become established in the next-step activities necessary to reach these goals. (4) Expand the science facilities in the schools to include laboratories and equipment for the special disciplines. (5) Study to ascertain how best to lend more purpose to the science activities of the school.

ROPER, KEITH IRL. The Utilization of Industry-Sponsored Instructional Materials by Colorado High School Chemistry Teachers.

Major Adviser.—Stanley B. Brown.

Problem.—To analyze the factors involved in the selection and use of industry-sponsored materials by chemistry teachers in Colorado high schools.

Procedures.—A collection of these instructional materials for high school chemistry was made. The materials were classified and criteria for evaluating them determined. The instrument for collecting the data was constructed and used to secure information from a random sample of Colorado high school chemistry teachers. The information was summarized and conclusions were drawn from it.

Findings.—All these teachers were aware of industry as a source of instructional materials and 96 percent used such materials. The teachers used them primarily because they felt that this information stimulated class interest, filled a need in a limited budget for instructional materials, provided more visual presentation, and allowed for variety in presentation. These instructional aids were used primarily to supplement textbooks, make a display on bulletin boards, introduce units, and serve as exhibits. The most preferred materials in order of frequency of selection were motion pictures, exhibits, tours, booklets, charts, speakers, film strips, leaflets, samples, posters, models, mock-ups, comic books, and teachers' manuals. Further study of industry-sponsored materials is indicated to improve the criteria by which they are prepared, and thus to use them more widely and effectively.

ROSENBERG, MILTON. The Ability of 8th-Grade Pupils to Indicate Understandings of Three Simple Machines.

Problem.—This investigation dealt with the ability of selected 8th-grade pupils to (1) locate relationships within the lever, wheel and axle, and/or pulley; (2) state these relationships numerically and verbally; and (3) relate graphically and verbally a lever to a wheel and axle, and a wheel and axle to a pulley.

Procedures.—The test design involved three series of flap-covered diagrams of the machines. The pupil wrote his response on a removable flap. After removing it, he was given the correct answer. This process was continued so that he could examine a series of correct responses in order to check his method or to use them as aids in solving subsequent problems. He stated his method numerically and his understanding verbally. He was asked also to relate graphically and verbally a lever to a wheel and axle, and a wheel and axle to a pulley. This resulted in a total of 13 separate abilities and a total score. Pretests revealed that the children tested were not familiar with the relationships within and between the machines.

Relationships of the 18 abilities and the total score to sex, I. Q., and scores on the Differential Aptitude Tests of Verbal Reasoning, Numerical Ability, Abstract Reasoning, Space Relations, and Mechanical Reasoning were determined by appropriate statistical means.

Findings.—(1) The children did discover relationships. Sufficient variations appeared in their methods of discovering relationships to question whether there is a "best" way. The children's apparent willingness to try to find the "answer", and their obvious satisfaction when they did, may warrant the use of similar techniques in teaching science principles by pupil-discovery methods. (2) Success in stating numerical relationships was greater than in verbalizing relationships. For example, few pupils were able to express verbal relationships involving the pulley. (3) The children saw relationships between the lever and the wheel and axle better than they did between the wheel and axle and the pulley. (4) The highest relationships observed were between the abilities and the I. Q. and the Differential Aptitude Test-Abstract Reasoning; the lowest, between the abilities and the Differential Aptitude Test-Space Relations.

SARNER, DAVID S. *and* JACK R. FRYMIER. Certification Requirements in Mathematics and Science.

Problem.—To determine the certification requirements in mathematics and science throughout the United States.

Procedures.—Information on requirements for certification in mathematics and science was secured from 40 States direct; concerning 8 other States from a current bulletin. The data were analyzed to determine the minimum requirements in science, mathematics, and professional education courses.

Findings.—Forty-two States required a 4-year college degree and one State required 5 years of college preparation. Only two States requiring 4 or more years of preparation required additional preparation in the teaching field for advanced degrees and higher certificates. The minimum required semester hours in mathematics had a range of zero to 24, with a mode of 18 and a mean of 15.1. Minimum science requirements ranged from zero to 48 semester hours, with a mode of 15 and a mean of 17.9. Minimum professional education requirements ranged from 12 to 24; with a mode of 18 and a mean of 18.4. Twenty States required course work in particular areas of science, but only eight of these specified minimum hours to be completed. There was lack of agreement on what constitutes minimal preparation in subject matter. Agreement was fairly good on professional education. Little was found concerning the quality of preparation. There seemed to be a need for some sort of uniform minimal requirements throughout the United States.

SCHENBERG, SAMUEL. A Study of the Science and Mathematics Courses Elected by the 1956 Senior Class and the Number of Seniors Who Planned to Specialize in Scientific Fields in the Academic High Schools in New York City.

Problem.—To determine what proportion of secondary school students are studying science and mathematics. To determine how many high school seniors planning to attend college, desired to specialize in science and engineering. To determine if homogeneous grouping of able students interested in science stimulates them to specialize in these areas.

Procedures.—IBM data cards were filled out for 27,756 students in the senior class of New York City's 55 academic high schools, listing the courses taken in science and mathematics and their choice of college work and future careers. The data were processed and summaries were obtained of the numbers and percentages of pupils in regard to the categories reported.

Findings.—(1) A larger percentage of all academic high school students select science in New York City than in the nation as a whole. (2) New York City seniors are going to college in large numbers and 42 percent indicated a desire to elect a career in the areas of science and engineering

(3) More seniors select science than mathematics in their programs. However, the election of three to four years of science stimulates the election of mathematics and interests students in scientific careers. (4) The three specialized science high schools in New York City are helping to increase the number of pupils who select careers in science.

SCHLESINGER FREDERICK RICHARD. A Study of Evaluation of Sponsored Programs for High School Science and Mathematics Teachers During the Summer of 1956.

Problem.—To determine the general pattern of programs, organization, content, status of participants, and evaluation of the programs of summer science institutes.

Procedures.—Questionnaires were sent to nine sponsoring agencies, 30 cooperating institutions, and 934 high school teachers; and the results were analyzed.

Findings.—An analysis of the status of the participants showed that 44 percent held a bachelor's degree and 53 percent a master's; and that 85 percent had majored in science and/or mathematics. Their experience ranged from one to 39 years, with a median of nine years. Fifty-eight percent taught science or mathematics exclusively, while eight percent also taught in other fields. The majority appeared better trained than was true for the country as a whole. Requirements placed on the programs by cooperating institutions were at a minimum; in general, a permissive atmosphere of experimentation was evident. It seemed that the major objective, improvement of the subject matter competence of the participants, was accomplished. Apparently a need exists for graduate courses in content combined with a more concentrated attention to methods.

SCHULMAN, MILTON. The Effect on Learning of Two Types of Film Introductions in Ninth-Grade General Science.

Major Adviser.—Elwood J. Winters.

Problem.—To investigate the relative effects of (1) positive and (2) negative introductory sequences inserted in a selected instructional film on the immediate and delayed recall of factual information learned from the film by two similar groups of 9th-grade general science pupils.

Procedures.—Two types of introductory sequences, negative and positive, were prepared by the investigator and a competent jury. These sequences were incorporated in two copies of the same classroom film.

Two experimental groups (I and II), 145 pupils each, were selected randomly from a 9th-grade general science class. Group I was shown the film with the positive introductory sequences; group II was shown the film with the negative introductory sequences. The effect of the two versions on learning was appraised by means of a series of subject-matter tests administered immediately after the film-viewing and two weeks later. (A pretest and an I.Q. test had been administered to the groups before the viewing.)

The data were analyzed by the analysis-of-variance technique. Significant values of F were further examined by means of t-tests.

Findings.—Positive introductory sequences incorporated within a science film result in greater factual learning from the film, as measured by an immediate recall test, while negative introductory sequences result in greater retention of factual information from the film two weeks later. Two weeks after viewing, pupils with an average I. Q. retain significantly less of what they knew immediately after film viewing, as compared with students of superior and inferior I. Q. Irrespective of type of introduction, and in terms of immediate recall, viewers with an average I.Q. profit most from a science film, followed by those with inferior and superior I. Q.'s. Learning takes place whether or not the instructional science film contains positive or negative introductory sequences.

SHELDON, THOMAS DONALD. A Study of Some Factors Involved in New York State's Secondary School Science Instruction in Connection with Results Obtained by Students on State Regents Examination in Biology, Chemistry, and Physics.

Problem.—To determine the significant differences in teacher factors, classroom procedures, or general education background, of classes which were relatively successful in Regents Examinations in biology, chemistry, and physics as compared to classes which achieved less success.

Procedures.—The percentage of each teacher's students passing the 1951, 1952, and 1953 Regents Examinations in biology, chemistry, and physics was calculated and the results were used to set up three categories, "most success," "average success," and "least success."

Twenty teachers in each category for each subject for each year were selected at random and sent a questionnaire. Of the total of 540 teachers, 398 returned their questionnaires and 300 of these, of the 540 solicited, were used in the study. Chi-square and t-ratio techniques were employed to ascertain the significance of differences in response to each item on the basis of the three categories of success.

Findings.—The most successful Regents classes were taught by teachers who (1) were graduates of New York State high schools, (2) earned an average or above-average salary, (3) had a better background in education courses, (4) were relatively experienced as science teachers, and (5) taught classes with higher rather than lower pupil enrollment. Teachers and administrators in the schools studied, favored the Regents Examinations for their value to the State science education program. A considerable number of schools selected pupils who were to try the Regents Examinations, thereby raising their school pass-fail record. Most of the science teachers participating in the study would choose the same profession again.

SHOEMAKER, BYRL RAYMOND. Adequacy of Related Technical Instruction in Vocational Trade and Industrial Education for Teaching Principles of Mathematics and Physical Science.

Problem.—To evaluate the effectiveness of a vocational program in developing understandings of principles of mathematics and physical science.

Procedures.—Graduates from the machine-trade programs who had been out of school for five and six years were selected to participate in the study. Literature in the machine trade was reviewed in order to establish a list of applicable principles. This list was then submitted to a jury of teachers in that trade. The list of principles selected by the jury was submitted to the graduates who were asked (1) to indicate their need for and use of the principles and (2) to evaluate the effectiveness of the trade and industrial education program in teaching the principles.

The list sent to graduates was then arranged according to related technical topics and sent to the industrial supervisor of each graduate participating in the program to check the accuracy of the graduates' responses. The supervisors were asked to evaluate (1) the graduate's need for instruction on the topics and (2) his ability to apply the principles in his work.

Findings.—(1) The present vocational program is not effective in developing understandings of principles of mathematics and physical science. (2) An understanding of the principles of mathematics and physical science would be of value in the industries employing graduates of this program.

SHRADER, JOHN S. An Investigation of Instructional Problems Encountered by Beginning Secondary School Science Teachers in the Pacific Northwest.

Problem.—To discover the significant problems that must be met by beginning teachers and to suggest solutions for these problems.

Procedures.—Interviews were used to prepare a questionnaire which was then sent to teachers with four or fewer years of teaching experience. A total of 130 questionnaires were returned and analyzed.

Findings.—The primary problems of the beginning teachers seemed to center around their inadequate training, variety and quantity of their daily preparations, lack of time and place for preparation, large classes, lack of audiovisual materials, necessity for moving from room to room, and inadequate equipment. Among the proposals for ameliorating these conditions were increased administrative interest and reorganization of faculty assignments.

SISTER ERNESTINE MARIE. The Comparison of Inductive and Deductive Methods of Teaching High School Chemistry.

Major Adviser.—John G. Read.

Problem.—To test two hypotheses: (1) Inductive laboratory learning produces no higher achievement on the Anderson and Cooperative Chemistry Tests than does deductive-descriptive learning; (2) No statistically significant differences in the learning of chemical equation-balancing are found when comparing students taught by methods that include inductive laboratory learning with students taught by traditional deductive methods.

Procedures.—To test the first hypothesis, six experiments and six control groups totaling 420 pupils were taught by three teachers who followed syllabi and laboratory manuals designed by the investigator. Intelligence test scores were obtained and analyzed. No significant difference in ability between the inductive and deductive classes was revealed. The Anderson and Cooperative Chemistry Tests were given at the end of the spring term and the results analyzed by applying t-tests to the mean-standard deviations in the scores of the inductive and deductive groups.

To test the second hypothesis, 32 selected schools with 56 classes and 40 teachers were used. One-half the classes were taught inductively and the other half deductively, following unit outlines prepared by the investigator. Symbolic unit tests, constructed by the investigator, were administered before and after teaching the unit on chemical-equation balancing. Analysis of the pretest scores for all groups and intelligence scores showed similar ability and chemical knowledge among the groups in the study.

Findings.—The two null hypothesis directing the study were rejected. Inductively taught classes showed significant superiority over deductively taught classes in regard to the full year's work (hypothesis I) and to the unit on chemical-equation balancing.

SPORE, LEROY. The Competencies of Secondary School Science Teachers.

Major Advisor.—Paul DeH. Hurd.

Problem.—To identify the professional competencies of secondary school science teachers, to determine where emphasis should be placed in their training program and what criteria should be used in their selection, and to ascertain whether the four groups of judges were in agreement in their conception of the science teacher's role.

Procedures.—Representing the opinions of writers in the literature of science education, the 60 competencies selected as those needed by science teachers were organized under the 6 roles assigned by a rating form C, "The California Definition of Teacher Competence". The groups of judges were composed of foundation educators, science educators, science teachers, and school administrators. For rating the competencies a five-point scale was devised that provided a place for the judges to indicate what emphasis the training program should place on the 60 competencies.

Findings.—The foundation educators, by the standard deviation of the distribution of ratings from the mean, were the most inconsistent and the administrators the most consistent. The t-test showed a high level of significance in the cases where there was a considerable difference in opinion. In general, the four groups of judges perceived the role of the science teacher in much the same way, with some significant differences concerning specific items. The judges, with some exceptions, believed that for most of the competencies equal emphasis should be given in preservice and inservice training.

The list of competencies needed by the science teacher should help establish criteria for selecting and evaluating science teachers.

STOKER, HOWARD. Aptitudes and Attitudes of High School Youth in Regard to Science as Related to Several Variables.

Problem.—The aptitudes and attitudes of high school youth toward science and scientists and the relationships of these factors to each other and to personal traits of the youth were surveyed.

Procedures.—The Purdue Physical Science Test to measure aptitude and the Purdue Opinion Panel to measure attitudes were administered to a nationally representative sample of 2,500 pupils in grades 10, 11, and 12. Attitudes and aptitudes were related to each other as well as to other personal data such as grade, sex, residence (rural or urban), mother's education, and socioeconomic status. Correlational and analysis-of-variance techniques were employed.

Findings.—In general, the pupils expressed favorable attitudes toward science as a social institution. Attitude toward scientists and aptitude in science were significantly related, but attitude toward science as a vocation and aptitude in science were not. Attitude to science as an institution, to science as a vocation, and to scientists were closely related to the pupils' grades in science and to their socioeconomic status. Attitudes in regard to the other criteria varied with certain personal factors.

STONE, DOROTHY F. Modern High School Biology: A Recommended Course of Study.

Major Adviser.—Frederick L. Fitzpatrick.

Problem.—To develop a modern course of study for high school biology that will include recent findings in biology and unifying concepts.

Procedures.—Current textbooks and courses of study in high school biology were reviewed and evaluated. Proposals for a new course were submitted to a group of experts, and a course outline and related materials were developed.

Findings.—The materials revealed little content on recent findings in biology and only minor attention to theories and unifying concepts. The theme of the proposed course is, "The behavior of living things is ordered by the constantly changing influence of their biological, chemical, physical, and social environments."

TAYLOR, THOMAS WAYNE. A Study to Determine the Relationships Between Growth in Interest and Achievement of High School Science Students and Science Teacher Attitudes, Preparation, and Experience.

Problem.—To determine the relationships between growth in interest and achievement of high school science students and science teacher attitudes, preparation, and experience.

Procedures.—The study covered 88 teachers with one class each. Teacher attitude was measured by the Minnesota Teacher Attitude Inventory, and other teacher factors were determined from administrators' records. Student gains (or losses) in science interest and achievement were measured by changes in scores on the California Occupational Interest Inventory and the Science Section of the Essential High School Content Battery from the World Book Company. These instruments provided 1,586 and 1,632 usable sets of paired (pre- and post-test) scores, respectively.

Findings.—The four teacher-related factors of attitude, semester hours of professional education, semester hours of science, and years of teaching experience, when considered singly, do not have a positive correlation with student interest or achievement.

The difference in growth in interest of students of full-time science teachers and those of part-time science teachers is highly significant, but a difference in achievement of these two groups is not. A composite of other teacher factors falling above the median produces significant changes in science achievement, but not in interest.

TYRELL, JOHN A. A National Survey of the Opinion as to the Most Important

Areas in High School Biology and an Achievement Test in These Areas.

Problem.—To determine teachers' opinions as to most important areas in high school biology and to construct an achievement test in these areas.

Procedures.—Two thousand members of the National Association of Biology Teachers were asked to name the one *most* important area and the one least important area in biology. A list of 24 most frequently named areas was made and sent to the same group with the request that they select the three most important and the three least important areas. An achievement test based on the areas thus determined to be the most important was then constructed.

Seventy-five biology teachers were asked to criticize the test; and in order to ascertain the degree of discriminating and of difficulty, it was administered to 50 other biology teachers.

Findings.—The four most important areas appeared to be biological principles, conservation, essential life processes, and human physiology. The average score in these areas was slightly less than 50 percent.

It would appear that there is a wide variety of opinions as to the important areas in biology, and that the performances on this test do not represent high achievement.

VICTOR, EDWARD. What Kind and What Amount of Help Do Our Beginning High School Science Teachers Need?

Problem.—To ascertain in what areas the beginning high school science teachers, with and without adequate college backgrounds in science, feel that they need help.

Procedures.—Fifty-two beginning high school science teachers without adequate college backgrounds in science and 54 qualified beginning teachers in Massachusetts were selected at random. Twenty-one practices commonly associated with science teaching were presented to these teachers in a questionnaire. They were asked to indicate for each item whether it required "much help," "some help," "little help," or "no help." Numerical values of 3, 2, 1, and zero were made for these evaluations. Assignments and items were ranked in order of amount of help needed.

A scalogram was constructed, using the H-techniques modification of the standard Guttman scaling technique. The 21 "need-help" items were classified into 7 broad areas. Numerical responses were totaled, average, and ranked for each area.

Findings.—Both ranking and scaling techniques revealed that the teachers in each group felt that they needed much help in all 21 areas. The ranking of the seven broad areas indicated that qualified science teachers were most concerned about locating and selecting science materials, supervising science projects, and using appropriate teaching techniques in that order. The unqualified science teachers were concerned about identifying, using, and ordering science equipment, supervising projects, and locating and selecting science materials.

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* One in a series of studies at Teachers College under the auspices of the Science Manpower Project.

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Research Studies in College Science

Introduction

A NUMBER of the 1957–59 studies were devoted to the college training of future elementary and secondary science teachers. Most of the studies of this nature are included in the present section on college-level science education; but several, judged more appropriate for inclusion under the level for which the future teachers were being trained, appear in the elementary and secondary sections of this publication. The reader interested in the training of science teachers for elementary or secondary school will therefore want to examine the abstracts and lists in the sections pertaining to all three levels.

The complete list of research studies in science education at the college level contains 68 titles. From this number, 13 abstracts were selected and edited for the present publication.[1]

Analysis

The increased number of research studies in college-level science education during the 1957–59 period under review indicates that more researchers than ever before were interested enough in the issues related to science education at that level to bring these issues into public view. The variety of the studies reflects both the diversity of factors affecting science teaching and learning, and the operational usefulness of the nine categories of investigation suggested by the U.S. Office of Education and the National Association for Research in Science Teaching: philosophy and objectives, public policy, curriculum, learning, methods, facilities and equipment, administration and supervision, teacher education, and evaluation.

Studies Related to Philosophy and Objectives

The only abstract of a study related to the philosophy and objectives of science education at the college level that was selected

[1] Arrangements for both list and abstracts is alphabetical by author, the abstracts starting on p. 74 and the complete list on p. 79.

for the present publication is the abstract of a study by *Pings* dealing with the epistemological aspects of modern physics. Other studies, however, dealt with measurement of growth toward various objectives of science instruction at the college level.

Studies Related to Public Policy

No studies were wholly within the field of public policy, although the one by *Lehmann* and *Nelson* relates to identifying, encouraging, and developing science talent. Employing a questionnaire of 50 specially prepared statements, *Behnke* studied the opinions of a randomly selected group of 621 science teachers regarding certain issues and problems in science and science teaching and compared their responses with the responses of a selected group of 70 prominent working scientists. Item analysis revealed marked differences between the teachers and scientists on many responses, especially those related to the nature of science and science teaching. On the other hand, little or no differences in responses were found between subgroups of teachers separated out on the basis of such factors as amount of course work in science and in education, type of college or university attended, and length of teaching experience.

Studies Related to the Curriculum

Studies by *Fribourgh* and by *Vivian* in biology and conservation, respectively, provided bases for selecting course content. *Helms* designed and built equipment for 11 new experiments relating to alternating current in college physics courses.

Studies Related to Learning

Probably the most regrettable deficiency in the overall research picture of the 1957–59 period under review was the limited progress, if any, toward a better understanding of how learning in science takes place. Not a single study abstracted was found to be wholly within the learning field of investigation, although a few were indirectly related—notably *Welch's* study on motivation.

Studies Related to Methods

Alterman, dealing with the application of physics principles, and *Novak,* employing a traditional and a problem-centered approach to botany, compared methods of instruction, using as major criteria published tests, tests prepared by the investigator, or both.

Studies Related to Facilities and Equipment

None of the studies dealt exclusively with facilities and equipment. Some, however, especially those related to methods and to curriculum (if their conclusions were further validated), would indicate need for certain instructional facilities and equipment.

Studies Related to Administration and Supervision

A study by *Lehmann,* and one by *Lehmann* and *Nelson,* on the characteristics of honor students have implications concerning administration and supervision, though neither lies wholly within this field.

Studies Related to Teacher Education

Chamberlain and *Esget* completed studies relating to teacher education. The former study analyzed pre- and inservice programs in teacher training institutions, and the latter compared effectiveness of science methods courses and courses combining science content and methods of teaching.

Studies Related to Evaluation

Two studies were primarily in the field of evaluation. One, by *Esget,* developed an instrument to measure student growth in courses for elementary school science courses. The other, by *Stucky* and *Anderson,* dealt with factors affecting student's length of stay in college.

Several other studies by *Alterman, Brasted, Lehmann, Lehmann* and *Nelson,* and *Novak* were partially in the field of evaluation. Published tests, and tests and questionnaires prepared by the investigators were used to evaluate academic achievement, measure aspects of problem solving in science, and obtain information about the respondents and, in some cases, about the schools they attended, the communities in which they lived, and their families. None of the new means of evaluation stands out as having more validity or reliability or as being a truer criterion of learning than the old means. A few of the studies made skillful use of modern statistical methods for analyzing test results. The need still remains, however, for tests (or other means) to measure more accurately than now is the case how well students can use facts and principles as well as recall them.

Interpretation

A number of suggestions for future research in science education emerge from a study of the present research. These suggestions are based on the following assumptions:

1. Scientific processes can be applied successfully to the problems of teaching-learning in the science classrooms and the laboratories.
2. Student achievement in each of the commonly held objectives of science instruction can be measured (provided that valid measuring devices are available or sufficient time and talent are given to developing valid instrmuents.)

If these assumptions are valid, the following suggestions should also be valid:

1. To develop a theory of learning in science and from this theory to formulate and test the factors that affect learning. (Personal, social, and physical-environmental factors might be involved.)
2. To develop checklists, scales, questionnaires, and other means for measuring those factors, and to develop tests (or other instruments) for evaluating student achievement in each objective of science teaching. (To realize the full potential of the new methods for statistical treatment of data, those data must be both accurate and pertinent.)
3. To develop effective avenues of communication among researchers in science education in order to transmit such precise information concerning the problems, procedures, and results of a study that a competent reader with adequate resources could replicate it.

Many of the science teaching studies carried out in the nine fields of investigation recommended by the National Association for Research in Science Teaching would be difficult to replicate solely from the reports usually available in professional publications. Without adequate communication, a program for research to improve science teaching would have small prospects of achieving worthwhile results.

Research in science teaching at the college level continued to emphasize conventional-traditional factors. There is need for emphasis on the dynamics of personality in determining not only *what* people learn but *how* they learn, for emphasis on the learner and not the teacher techniques, on process rather than things, on emotional adjustment and personality structurization, on how the learner feels about himself and learning, on group research, on cooperation in planning and evaluation, on outcome and process, on unity of effort rather than diffusion. However, the psychologist, statistician, and science educator must learn to work together, since it now appears that they are working in an uncoordinated fashion.

Most of the studies were designed to meet doctoral requirements. Unfortunately, the search for dissertation problems that are unique and unexplored seems to produce independent and unchecked studies, seldom continued post-doctorally and seldom pursued in sufficient depth to identify a theory of learning in science or to sharpen criteria for testing such a theory.

Selected Abstracts

ALTERMAN, GEORGE. A Comparison of the Effectiveness of Two Teaching Techniques on the Ability of College Students to Apply Principles of Physics to New Technical Problems.

Major Adviser.—J. Darrell Barnard.

Problem.—To compare the effectiveness of two methods of presenting physics principles on the ability of college students to apply principles of physics to new situations.

Procedures.—The experimental group was taught physics by an essentially inductive method, while the control group was taught the same principles by a method essentially deductive. At the end of one semester, three tests constructed by the investigator were given to measure recall of facts, ability to solve mathematical or formula-type problems, and ability to apply principles to new situations respectively. The investigator calculated coefficients of correlation between standardized tests given at the beginning of the semester and final tests as well as between each of the final tests. A t-test of significance of the difference between the means of the control and experimental groups was determined for each final test.

Findings.—In the area of application of principles, the experimental method produced significantly better results only with those students who had rated low on the preliminary background test. The ability to recall facts and principles is highly correlated with ability to apply principles and ability to solve problems. Ability to solve problems is significantly, but not highly correlated, with ability to apply principles. Critical thinking ability, as measured by the Watson-Glaser Critical Thinking Appraisal, does not significantly affect ability to solve mathematical or formula-type problems.

BEHNKE, FRANCES L. Opinions of a Selected Group of High School Science Teachers and Scientists on Some Issues Related to Science and Science Teaching.

Major Adviser.—Hubert M. Evans.

Problem.—To determine and to compare the opinions of a selected group of high school science teachers and a selected group of scientists on certain aspects of science teaching and the scientific enterprise.

Procedures.—A questionnaire containing 50 tested statements covering the nature of science, science and society, scientists and the teaching of science was administered to a randomly selected group of 1,000 high school science teachers on the rolls of the National Science Teachers Association and to a group of 100 scientists. Usable replies were obtained from 621 teachers and 70 scientists. The percentage responses of the scientists and the total teaching group were compared, item by item. Similar comparisons were made for five subgroups of teachers separated out on the basis of subject taught, region and location, course credits in science and education, type of undergraduate institution attended and length of teaching experience. Percentage differences in responses among the groups were checked for significance at the 0.01 and 0.05 levels of confidence.

Findings.—Of all the statements, those pertaining to the nature of science had the most discriminating power between the groups and subgroups compared. The most striking differences were between the scientists and the total teaching group. The factors used to separate out the teaching subgroup seemed to have only minor influence on the percentage responses of the teachers.

BRASTED, ROBERT C. Achievement in First-Year College Chemistry Related to High School Preparation.

Problem.—To determine the relationship between achievement in first-year college chemistry and high school preparation in chemistry, physics, and mathematics.

Procedures.—A questionnaire survey was made of 1,400 college students in the State of Minnesota and later of 1,100 at the University of Minnesota. Information was obtained about their high school backgrounds in chemistry, physics, and mathematics, and their college grades in first-year chemistry.

Findings.—Students who had taken high school chemistry received higher grades in college chemistry. Those who had taken no high school mathematics beyond plane geometry had high probability of failure in college chemistry and minimal prospects of receiving an "A" or "B" grade. Those who had completed high school physics were more likely to succeed in college chemistry than those who had not completed physics, although grades in high school chemistry or mathematics were better bases for predicting success in college chemistry than grades in physics. Grading practices in the colleges were found to be fairly consistent.

CHAMBERLAIN, WILLIAM D. Development and Status of Teacher Education in the Field of Science for the Elementary School.

Problem.—To analyze preservice and inservice programs of teacher training institutions and science instructional problems of elementary school teachers.

Procedures.—College catalogs were examined for courses in elementary school science. Three questionnaires were sent out: (1) to colleges for information on preservice and inservice science programs for elementary school teachers; (2) to members of the National Association for Research in Science Teaching for opinions on practices and trends in elementary school science education; (3) to elementary school teachers with extensive science training to determine what college science courses they had taken and to identify teaching difficulties associated with their training or lack of training in the field of science.

Findings.—Methods courses are often brief or nonexistent. Science-content courses are limited in depth and inadequate in scope. In general, crowded elementary school curricula and limited science facilities affect science instruction unfavorably.

ESGET, MILES H. Developing and Using an Objective Instrument to Measure Student Growth in College Elementary School Science Courses.

Major Adviser.—James R. Wailes.

Problem.—To develop a test of the knowledges and understandings achieved in college science courses for prospective elementary school teachers, and to reinforce or refute the hypothesis that there were no significant differences between two types of elementary science education courses.

Procedures.—A multiple choice test was developed and validated. It was given on a pretest and retest basis in order to compare students in elementary school science methods courses with students in a methods course and a combined methods and content course. The subjects were 102 students from four Colorado colleges and a control group of 28 elementary school teachers.

Findings.—Prospective elementary school teachers who attended the combined method and content course showed significantly higher gains in science knowledges and understandings than did those who attended the methods course.

FRIBOURGH, JAMES H. Recommended Principles and Generalizations for an Introductory Biology Course in the Junior College.

Major Adviser.—L. A. Van Dyke.

Problem.—To determine what principles and generalizations that a junior college biology course should present in order to be basic for further biology study, essential for general education, and appropriate for the junior college level of maturity.

Procedures.—A list of 61 principles and generalizations of biology was developed from college textbooks. A jury of biologists judged each principle or generalization as to whether it was essential for further study in biology or for general education, and a jury of junior college biology teachers judged each listed item as to whether it was appropriate for the junior college level. A biology course was organized around the principles and generalizations thus selected.

Findings.—The recommended principles and generalizations dealt with cytology and histology, physiology, motion and locomotion, coordination, relationships of organisms to their environments, plant and animal diseases and methods of protection, reproduction and heredity, growth differentiation and regeneration, taxonomy and evolution, and conservation of natural resources.

HELMS, RUFUS MARSHALL. The Design and Construction of Apparatus for Laboratory Instruction in Alternating Current in the College Physics Course.

Major Adviser.—J. Darrell Barnard.

Problem.—To develop meaningful laboratory experiences in alternating current electricity for the general college physics course.

Procedures.—Fifty-two principles in alternating current were gathered and rated by a jury of physics teachers. Information about instructional methods and laboratory experience in alternating current was obtained by a questionnaire sent to general physics instructors. The activities thus obtained were assigned to appropriate principles to form a second questionnaire. The second questionnaire asked the jury to identify principles for which there were no adequate laboratory activities. Nineteen were designated. These 19 were considered and an appropriate experience for developing an understanding of each principle was visualized. Equipment for the new activities was designed and constructed. The procedures were tested in college physics classes until considered satisfactory.

Findings.—It was shown that alternating current is of major importance in the lives of Americans, but that very little instruction in it is given; and that the amount of resource material on the topic needs to be increased. The seven concrete results were: (1) an original presentation on resonance, (2) a set of 52 principles in alternating current, (3) a procedure for developing new experiences, (4) identification of 5 types of problems encountered in construction of new apparatus, (5) development of 11 new experiments for teaching alternating current, (6) 12 new pieces of apparatus for teaching alternating current, and (7) a style of experiments new to college physics.

LEHMANN, IRVIN J. Some Characteristics of Honors-Section Students in Natural Science at a State University: A Followup.

Problem.—To follow up the original group of students enrolled in special sections of Natural Science at Michigan State University in order to obtain their reactions to this novel experience and compare their achievement with that shown by students in a regular section.

Procedures.—The sample consisted of 114 students in 4 honor sections and 236 in 8 regular sections. Reactions to their experience were obtained by means of questionnaires and personal interviews with a random subsample. The grades of students who moved from one section to another were obtained and comparisons were made.

Findings.—(1) The majority of students in the honors sections were pleased with their experience. (2) Honors-section students considered frequent quizzes, assigned readings, motion pictures, slides, and filmstrips more effective methods of learning than lectures. (3) Honors-section students are not adverse to undertaking additional work *provided* quality is not forsaken for quantity. (4) The laboratory work is better received and more highly valued than lectures as means of learning natural science. (5) Honors-section instructors tend to be more severe than instructors of other sections in their grading practices.

LEHMANN, IRVIN J. *and* CLARENCE H. NELSON. Some Characteristics of Honors-Section Students in Natural Science at a State University.

Problem.—To learn more about the type of student enrolled in an honors section, to ascertain what they would like to gain in such a section, and to study differences between honors and regular section students in ACE scores and a pre- and post-test scores on a test in natural sciences.

Procedures.—The sample consisted of 114 in 4 honors sections and of 236 students in 8 regular sections. Biographical data and reactions to the honors program were obtained by means of a questionnaire. A random sample of 26 men and 26 women were selected from both the honors group and the regular group. Differences in posttest scores between the groups were tested for significance by analysis of covariance using (1) ACE score as a covariant, (2) pretest scores as a covariant, and (3) both ACE and pretest scores as covariants.

Findings.—(1) Students in the sample came from a variety of backgrounds and were enrolled in nearly all the colleges of the university, with a large number in engineering and the physical sciences. (2) The majority of the students were from the upper- and middle-class homes. (3) More honors-section students, in contrast with the others, hoped and expected to attend graduate or professional school; and a majority of them had been in the upper third of their high school graduating class, had attended a public high school, and had fathers in the professional or white-collar class. (4) Honors-section students had significantly higher mean pre- and post-test and ACE scores even after adjustments were made for initial ability and intelligence. (5) The proportion of honor students receiving "A" or "B" as the final grade was significantly larger than the proportion of regular section students receiving these grades. (6) Honors-section students do not wish to move so rapidly through the course that thorough mastery is jeopardized. (7) Contrary to the common belief that grouping gifted students in special sections will result in their higher intellectual stimulation, the data suggest that the majority in the special sections of the experiment were only moderately or slightly stimulated by their fellow students.

NOVAK, JOSEPH D. Experimental Comparison Between a Conventional and a Project-Centered Method of Teaching a College General Botany Course.

Major Adviser.—Palmer O. Johnson.

Problem.—To compare student achievement under two methods of instruction in college general botany: conventional lecture-laboratory instruction and instruction similar to it except for classwork orientation to prepare the students for 6 weeks of independent project work.

Procedures.—Differences in knowledge of botanical facts and principles, ability to solve problems, and scientific attitude were measured. The study involved 522 students in college general botany. The classes met twice weekly for 1-hour lectures and twice weekly for 2-hour laboratory during a 6-month period. The project-centered group had lecture and laboratory work designed to prepare them for independent project work. (That work took the place of regular lectures and laboratory work during the last 6 weeks.) Special tests designed to measure problem-solving ability and scientific attitude were prepared by the investigator.

Findings.—No significant differences in means were found between the project-centered group and the conventional group. The former, however, was found to be significantly more variable on tests of knowledge of botanical facts and principles than the latter. This suggested that the project-centered method might provide better for individual differences. No significant change was found in scientific attitude during the 2 months between pre- and post-tests.

PINGO, VERN M. An Attitude of Science for Education: A Study of Epistemological Aspects of Modern Physics.

Major Adviser.—Merle Borrowman.

Problem.—To examine some of the epistemological aspects of the scientific revolution and determine whether they have implications for educational theory and research.

Procedures.—This study is a philosophical analysis of classical and modern attitudes toward scientific inquiry. The investigator outlined the classical scientific attitudes to develop a context for viewing modern physics. He then reviewed experiments and descriptions of modern physics.

Findings.—The investigator concluded that in classical science: (1) No "effect" is produced without an antecedent "cause"; it is within the competence of man "to know" the cause of events. (2) The universe can be analyzed into distinct systems. (3) The "state" of these systems can be described by dynamic variables which are specifiable to any desired degree of accuracy. (4) If the behavior of several systems is known, some mathematical formulation exists which can demonstrate the interaction of these systems. (5) Scientific knowledge must be independent of any specific observer. Nature thus consists of one objective reality which is "knowable" by all men in the same way. This elevates the methodology of science to a position where it is free from the desires, weaknesses, and actions of man.

The investigator found that the operations of experimentation of modern physics follow three steps: (1) A system or object of study and instruments by which to measure and describe it are selected. (2) The object of study is made to interact with another system. (3) Measurements are taken to determine the extent to which the second system changed the object of study.

When scientists work with large distances and velocities, or in the atomic realm, the classical attitude becomes suspect. Einstein's theories demonstrate that space and time must be relativized to make observations from coordinate systems coincide. This space-time continuum is not observed directly, but constructed by mathematical formalism from observable events. For example, the size of atomic particles is so small and their energy content so high that the process of observing disrupts the system under study. If the belief is to be maintained that science can produce sure knowledge, a new attitude toward inquiry is required.

Although an "actuality" is assumed, we have no means at present to make simultaneous measurements of all its aspects; we can obtain only complementary views of it. These views are not ambiguous, if the frame of reference and decisions of scientists are included in their descriptions. Two implications seem apparent for education: (1) If scientific knowledge requires a description of the decisions and frame of reference of the scientist, it cannot be considered devoid of human values. (2) If scientific inquiry is to be encouraged to deal with the uncertainties of our technological environment, the education process cannot be committed to a single method or a single orientation.

STUCKY, MILO O. *and* KENNETH E. ANDERSON. A Study of the Relationship Between Entrance Test Scores and Grade-Point Averages and Length of Stay in College.

Major Adviser.—Kenneth E. Anderson.

Problem.—The study followed a freshman class through five semesters of attendance at the University of Kansas and investigated the existence of significant differences among the means of placement-test scores and grade-point averages of the various groups of students, depending upon the number of semesters they remained in attendance.

Procedures.—Leslie's modification of the chi-square test was used to indicate nonhomogeneity in frequency distributions. The standard error method, enforced by Duncan's method, was used in finding significant differences in means.

Findings.—Generally, results showed that students with higher academic aptitudes stayed longer. Grade-point averages were more valid for predicting persistence than were placement tests. Men showed more variability in both grade points and tests.

VIVIAN, V. EUGENE. What Science Principles are Basic to the Conservation of Soils, Forests, and Grasslands?

Major Adviser.—J. Darrell Barnard.

Problem.—(1) To identify the problems of conservation of soils, forests, and grasslands and recommend measures for their solution; (2) to determine the science principles involved in these problems and solutions; (3) to determine the relative importance of these principles.

Procedures.—United States Department of Agriculture yearbooks since 1936 dealing with conservation were analyzed to locate problems, related principles of science, and corrective measures for management of soil, forests, and grasslands. The analyses were validated through judgments of conservationists.

Findings.—In soil conservation, 181 problems were found; in forest conservation, 81; and in grassland conservation, 16. Soil conservation is basic to other aspects of conservation. Practices advocated to alleviate the problems of conservation numbered 182 for soils, 80 for forests, and 48 for grasslands. The conservation practices were derived from, or were applications of, principles of science. There were 175 science principles dealing with soil, 74 dealing with forests, and 20 dealing with grasslands.

WELCH, ELLSWORTH W. Motivational Factor in Choice of Profession by American Scientists.

Major Adviser.—Paul DeH. Hurd.

Problem.—To investigate factors in the lives of American scientists related to the development of interest in science and to the choice of scientific work as a career.

Procedures.—A questionnaire was used to identify factors influencing the development of scientists' interest in science. A total of 512 scientists in the south San Francisco Bay area completed the questionnaire, making a 79-percent response. From this sample, 101 scientists were interviewed to amplify, clarify, and verify questionnaire data.

Findings.—The mean age of first interest in science was 12.4 years. Younger scientists tended to have become interested in science earlier than their older colleagues. The mean age of decision to become a scientist was 16.7 years, with younger scientists having made this decision at an earlier age than older scientists. There was no significant difference between male and female scientists as to age of decision.

The order of importance of persons who *first* interested scientists in science was teacher, self-interest, father, relative, young friend, mother, and adult friend. Chi-square analysis showed no significant differences when categories of persons who first interested scientists in science were compared individually with the following groups: (a) male and female scientists, (b) types of scientists, (c) younger and older scientists. Similar analysis showed no significant differences when the question of persons who most interested scientists in science was considered. Persons who had *most* interested scientists in science were, in order of importance: (a) teacher, (b) self-interest, (c) father, (d) adult friend, (e) relative, (f) young friend, (g) mother.

Character traits were reported of the teachers who had influenced the scientists in their choice of a science career. The extent of teacher-influenced choice of career was about equally divided among "much," "moderately," and "little or none." The teaching level of influential teachers, in order of importance, was high school, college, post-graduate, junior high school, elementary school. Effective school activities, in order of occurrence, were general classwork in science or a specific science course, laboratory work, clubs independent work and research, and field trips.

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Guidelines and Recommendations for Improving Research in Science Education

IN EVERY PART of the country, in remote and populated areas, small school and large, an awareness has developed of the need for scientific literacy and competence. Today a much more favorable climate exists than ever before. The forces arousing this concern prompt Federal, State, and local governments, as well as private agencies and foundations, to make available many hundreds of millions of dollars to promote immediate and long-range improvement in the teaching of science. This money has been spent for new facilities and equipment, added supervisory personnel at State and local levels, new aids to learning, the upgrading of teacher qualifications, and the production of new and unique curriculum materials. Each of these is a worthy contribution, and improvements, already evident in some parts of the country, will no doubt continue.

In all of these extraordinary endeavors, one factor seems to have escaped the vision of those responsible for planning and implementing the program. Scarcely any of the vast sums spent by Federal or State governments in this undertaking have been used for basic research. This is difficult to understand in a Nation whose worth and well-being are due to a large extent to science-related endeavors. More thought must now be given to the many aspects of the vital teaching-learning process.

The future vigor and impact of science on the young people who study it in school will depend in large measure on the soundness of research design. Unless the procedures, processes, and principles which make up the total of science education are based upon knowledge tested and proved through careful research, the investment of these large sums of money may not realize the intent of those who made them available.

If the discipline of science education is to improve, move forward, and flourish to the extent demanded by these crucial times, then it must build on a solid foundation of research findings in such areas as philosophy and objectives, public policy, teaching-learning, curriculum, methodology, teacher education, administration and supervision, and evaluation. In each of these areas lie many unresolved issues emanating from clusters of researchable problems. The answers to these problems will be basic and fundamental. Any science education research that tries to find the answers should first give heed to improving its own quality. And seeking improvement in science education research, like seeking improvement in anything else, is facilitated by the use of guidelines.

The following guidelines for improving science education research are offered as suggestions:

1. *To improve science education research, it is necessary to:*
   - ☆ identify the broad areas of science education in which current and previous research has tended to be concentrated
   - ☆ ascertain those issues within the broad areas of concern that require resolution
   - ☆ analyze the issues into significant, researchable problems.

2. *To direct science educational research, it is necessary to:*
   - ☆ build a body of educational theory in the field of science teaching
   - ☆ establish hypotheses related to the solutions of researchable problems
   - ☆ test hypotheses in a generalizable manner.

3. *To implement science education research, it is necessary to:*
   - ☆ develop and use research designs uniquely suited to testing hypotheses proposals that will facilitate replications of the studies
   - ☆ develop and use statistical and other techniques uniquely suited to facilitate collecting, organizing, and tabulating data
   - ☆ use presently available techniques and also design new and unique ones that would analyze and interpret data more adequately than previous techniques did.

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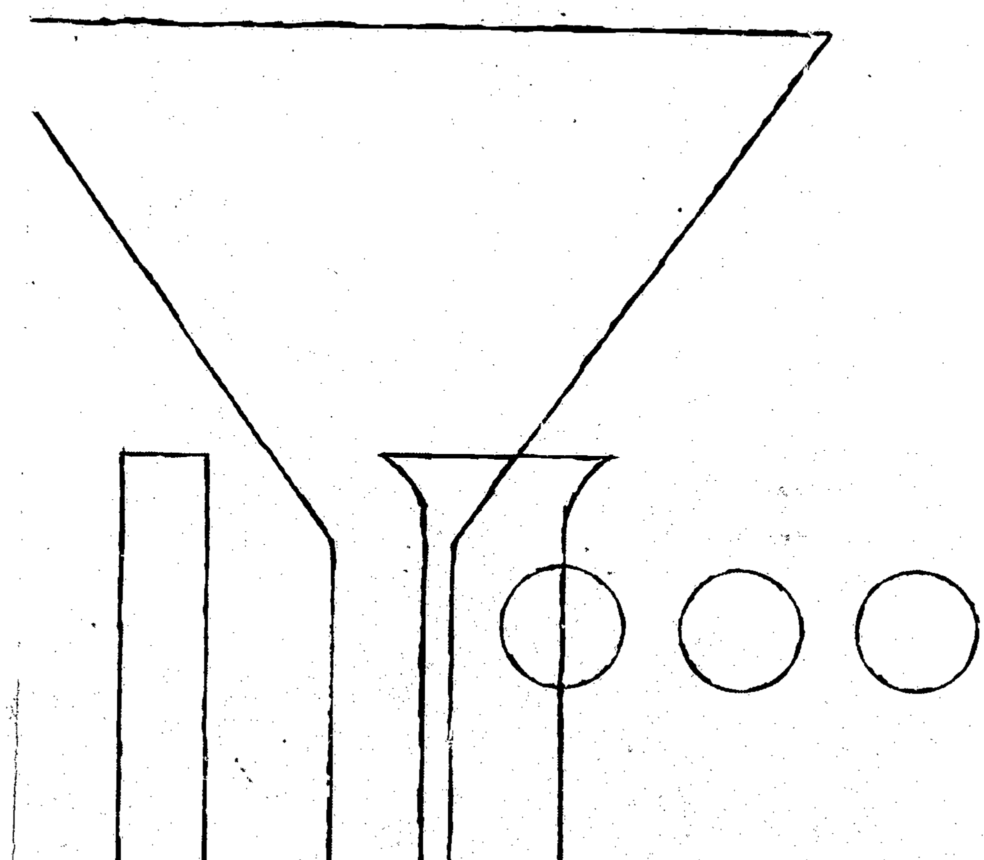

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Research in the Teaching of Science

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