DOCUMENT RESUME

ED 025 444 SE 006 265

By- Blosser, Patricia E.; Howe, Robert W.
An Analysis of Research Related to the Education of Secondary School Science Teachers.
ERIC Information Analysis Center for Science Education, Columbus, Ohio.
Pub Date Jan 69
Note- 11p.
Journal Cit- The Science Teacher; Volume 36, Number 1, pp. 87-95
EDRS Price MF-$0.25 HC-$0.65
Descriptors- *College Science, Educational Research, *Research Reviews (Publications), *Science Education, *Science Teachers, *Secondary School Teachers, Teacher Behavior, Teacher Certification, Teacher Characteristics, *Teacher Education

Research related to the education of secondary school science teachers is analyzed for the period, 1960-68. Major areas examined include (1) desired behaviors, competencies and skills for science teachers, (2) the relationship of science teacher behaviors, competencies and characteristics, teaching success, and classroom climate, (3) guidelines and recommendations for the education of science teachers, (4) state certification requirements, (5) surveys of teacher preparation, and (6) investigations of the effect of teacher education programs. Recommendations include (1) the development of an adequate descriptive base so that significant correlational, predictive, casual studies can be made, (2) closer investigation of relationships between preparatory programs and product outcomes, (3) further examination of individualized instruction techniques to more effectively accommodate student differences, (4) design of preparatory programs to give preservice teachers a more adequate conceptualization of the teaching task, (5) closer investigation of the kind of undergraduate education rather than the quantity in terms of quarter hours, and (6) further investigation of identifiable personality patterns of successful teachers to improve recruitment efficiency. Included is an extensive 95-item bibliography of the research reviewed. (GR)

VOLUME 36, NUMBER 1 • JANUARY 1969

THE TEACHER

THE SCIENCE TEACHER

Journal of the National Science Teachers Association
Volume 36 • Number 1 • January 1969

COVER

Cover quote from Hendrik D. Gideonse.
Design by William J. Kircher and Associates
Washington, D. C.

Published monthly, September through May. Editorial and executive offices, 1201 Sixteenth Street, N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C.

NSTA membership rates: Regular $10; Elementary $5; Comprehensive $20; Student (university) $4; Life $300 (payable in ten annual installments, or $270 if paid in three years or less). *TST* school or library subscriptions, $8; single copies of *TST*, $1.

An Analysis of Research

Related to the Education of Secondary School Science Teachers

PATRICIA E. BLOSSER and ROBERT W. HOWE

Information Analyst and Acting Director, Respectively
ERIC Information Analysis Center for Science Education
Columbus, Ohio

THE PURPOSE of this article is to report to the profession an analysis of recent research related to the preparation of secondary school science teachers. It is based on an analysis of selected research reports and other publications produced primarily since 1960. The analysis yielded interesting information concerning the present status of the education of science teachers. The analysis also identified several aspects of the education of science teachers that have not received adequate attention of investigators.

Research analyzed included such topics as teacher behaviors, teacher competencies, recommended guidelines for teacher education, certification requirements, preparation in science content, teacher behaviors and characteristics, the use of technology in teacher education, and the use of techniques such as simulation and microteaching.

Science educators, as well as educators in other teaching areas, have assumed that the prime concern of the preparation program should be with its end product: the teacher. They have also assumed that the objective of such a program is to produce an effective, competent teacher who can help children learn. Can a consensus be reached on the definitions of the terms "effective" and "competent" as they apply to classroom teachers? Is it possible to identify teacher behaviors that relate to effective learning by students? Do teacher education programs and certification requirements reflect the research data and/or recommended guidelines for teacher education? What are some of the changes which are occurring in the education of science teachers?

Desired Behaviors, Competencies, and Skills for Science Teachers

During the past decade there has been considerable attention to the planning of programs for the education of science teachers. Increased emphasis has been placed on behaviors, functions, and competencies desired of science teachers to provide more effective planning of teacher education programs. Several studies have involved the investigation of teacher behavior in the classroom to describe how the teacher functions in various elements of instruction.

The verbal and nonverbal behaviors of classroom teachers have been the focus of several recent studies (Balzer [6], Barnes [7], Bruce, McLeod, and Matthews [14], Evans [21], Gallagher [27], Kleinman [36], Kochendorfer [38], Matthews, C. [44], Matthews, J. G. [45], McLeod [47, 48], Parakh [63], Schirner [72], Snider [81]).

Kleinman [36] investigated the verbal behaviors of teachers as they related to questioning. Using a population of 23 junior high school science teachers, she identified two groups for detailed study on the basis of the number of questions they asked which could be characterized as eliciting critical thinking behavior on the part of the pupils. Kleinman was also interested in determining the possible relationship, if any, existing between the kinds of questions teachers ask and pupil and teacher behavior. After analyzing the data obtained, she concluded that there apparently was a positive correlation between the number of critical thinking questions asked and pupil and teacher behaviors.

Balzer [6] and Evans [21], pursuing investigations that were parallel in part and different in part, investigated the behavior of biology teachers. They were interested in describing both the verbal and nonverbal aspects of the teachers' behaviors. A category system was developed from the behaviors identified by direct observation of teachers and from videotapes of the teachers participating in their study. The investigators were concerned with developing a description of what teachers did in the classroom. Their data indicated several similarities in teaching behavior among teachers. Nonverbal behaviors appeared to be important aspects of teacher behavior.

Kochendorfer [38] developed and used the Biology Classroom Activity Checklist to determine the extent to which the teaching behaviors and practices used by the teacher in an individual classroom conformed to practices

recommended by the Biological Sciences Curriculum Study (BSCS). His data provide descriptions of several styles of teaching used by teachers with varying preparation and experience. Significant differences existed among three groups of teachers investigated. Teachers with greater experience with BSCS materials used practices recommended by BSCS to a greater extent than did teachers with less experience with BSCS materials or teachers not teaching BSCS.

Barnes [7] investigated laboratory instruction of three groups of biology teachers. He was interested in analyzing the relationship between the degree to which laboratory activities in the classroom conformed to those recommended by BSCS. Significant differences in instructional procedures related to teacher variables were identified. Teachers who agreed with the objectives of BSCS used the laboratory more in the way recommended by BSCS. Teachers with more experience teaching BSCS also taught laboratory activities to a greater extent as recommended by BSCS.

Parakh [63] has conducted several studies of teacher behavior in the classroom. Using a modification of the verbal interaction analysis technique developed by Flanders,[1] he investigated several aspects of classroom teacher behavior including laboratory activity. Both significant differences and similarities in teaching behavior can be inferred from Parakh's data. Most teachers investigated tended to use direct teaching procedures more than indirect teaching procedures.

Gallagher [27] investigated teacher behavior in teaching *Molecules to Man,* the BSCS Blue Version. Data analyzed indicated similarities and differences in teacher interaction with students. Among the significant findings of his study was that teaching style was independent of the teaching material.

Pankratz [62] investigated verbal interaction patterns of physics teachers. The Observational System for Interaction Analysis developed by Hough [2] was used to record and classify verbal behavior. Pankratz compared a sample of teachers rated as more effective in instructional activities with another sample rated as less effective in instructional activities. Significant differences in behavior were identified when the two groups were compared. Teachers who were rated as more effective teachers used more indirect teaching procedures.

Matthews, C. [44] and McLeod [47] used the system of interaction analysis developed by Flanders to analyze the verbal interaction in science classrooms. Both studies were concerned with verbal behaviors of student teachers. McLeod also analyzed the relationship of teacher behavior and teacher personality characteristics. He reported personality and interest measures related significantly to teacher behavior.

The studies cited and others reviewed tend to indicate that there are significant similarities and differences in teaching behavior. There is considerable agreement concerning patterns of teaching behavior; differences and similarities have been identified among various subgroups of teachers. Descriptions of both verbal and nonverbal teacher behavior indicate that the analyses of these behaviors should provide useful information for the design of teacher education programs. The studies reviewed provide some indication of teaching strategies used by teachers. There is not yet, however, enough information to generalize.

Several investigators have conducted surveys to determine how various types of educators perceive their roles as teachers and also to determine competencies and skills which they believe to be important. Examples of investigations of this type are those of Spore [83], Farmer [22], Van Houten [88], Fawcett [23], and Nelson [57].

Spore developed a list of 60 competencies related to six roles of a teacher. The six teacher roles that were considered were (1) director of learning, (2) counselor and guidance worker, (3) mediator of the culture, (4) link with the community, (5) member of the school staff, and (6) member of the profession. The 60 competencies were submitted to four groups of educators to be ranked from most important roles to least important roles. The four groups surveyed were administrators, science teachers, science educators, and college faculty who taught foundations of education courses (philosophy, psychology, sociology). All four groups ranked the second role, that of counselor and guidance worker, as being the most important role of the teacher. This educational role frequently receives little attention in the preservice teacher education program.

Farmer [22] investigated the image of the competent secondary school teacher as seen by teachers themselves, administrators, supervisors, industrial and research scientists, and members of several national curriculum committee groups. He found what he considered to be substantial agreement among the groups regarding the competency factors. The most important area of competency was found to be that of the effective use of laboratory work to teach methods by which scientists have solved problems and to help students learn to identify problems and solve them empirically. Skillful handling of student questions also received high priority. Skill in conducting class discussions which stimulate students to evaluate critically and understand materials more fully was ranked third in importance of the 16 competency areas investigated in Farmer's study.

Teacher competency investigations have provided the rational judgments of a number of persons concerning what they believe to be abilities science teachers should possess. While there were similarities in the competencies reported in the studies analyzed, there were indications of differences in the importance of some competencies and indeed of the functions of the teacher.

Many investigators have focused on the study of teacher personality traits, needs, and values (Blankenship [10], Blankenship and Hoy [11], Evans [21], Kleyensteuber [37], Lee [39], Levine [41], McLeod [47], Merrill, R. M. [50], Merrill and Jex [51], Morris [54], Navarra and Dugan [56], Sargent [71], Snyder [82], Walberg

[1] Amidon, E. J., and Flanders, A. *The Role of the Teacher in the Classroom.* Paul S. Amidon and Associates, Minneapolis, Minnesota. 1963.

[2] Hough, J. B. "An Observation System for the Analysis of Classroom Instruction." *Interaction Analysis: Theory, Research, and Applications.* E. J. Amidon and J. B. Hough, Eds. Addison-Wesley, Reading, Massachusetts. 1967.

[89], Walberg and Anderson [90], Walberg and Welch [91]).

If personality patterns that characterize successful science teachers could be found, such information could be used in recruitment and selection of teachers. This information could also be used to guide the development of learning experiences to influence teacher behavior.

Morris [54] analyzed and compared needs, values, and motives of selected groups of science and nonscience teachers. Using data gained from his study, Morris speculated that, when recruiting college students into science teaching, female students who exhibit greater needs than the average female students for success, for deference, and for order should be considered as prime candidates. Male students with a greater than average need for deference, change, and endurance should be encouraged to consider science teaching as a career, as should those male students who exhibit a high value of doing things for other people and of doing what is socially correct.

Lee [39] conducted a five-year study of career development in which he paid special attention to scientific careers. As a part of this study, he constructed a personality model to compare personality trends of liberal arts graduates who became scientists and those graduates who became science teachers. Lee felt that his results confirmed the hypothesis that teachers were "people-oriented" and that scientists were "non-people-oriented." He found, as a part of the career development model, that teachers and scientists followed a similar pattern up to the point in their college life when the teachers decided to move out of science *per se* and into science teaching. Lee found that three fourths of the individuals investigated followed this pattern or approximated it closely. The remaining one fourth differed only in the timing of the decision.

Such information contains implications for guidance activities at the high school and college levels. Interest in science appears to precede interest in teaching. Interest in people may not manifest itself until late in the individual's college career. The data from this study appear to indicate that there are identifiable personality traits associated with individuals entering science teaching from science backgrounds.

Relationship of Science Teacher Behaviors, Competencies and Characteristics, Teaching Success and Classroom Climate

If science teacher behaviors, competencies, and characteristics were related to desirable outcomes of instruction, then guidance in the selection of content and the organization of learning experiences for teacher education programs would be available. A number of investigations have centered on behaviors, competencies, and characteristics of science teachers and their relation to student achievement, rated teacher effectiveness, and classroom climate (Anderson, K. E. [4], Barnes [7], Blum [12], Brandwein [13], Davis [20], Fullwood [26], Howe [33], Kleinman [36], Kochendorfer [38], Loud [42], Reed, H., Jr. [64], Ryans [69], Schirner [72], Shannon [75], Sheppard [76], Taylor [85], Tubbs [86], Van Allenstein [87], Walberg and Anderson [90], Yager [94]).

An analysis of the investigations cited indicates that several relationships exist between teacher behaviors, competencies, characteristics, and various elements of successful teaching. Many different techniques were used to define and evaluate successful teaching. Hence, one must be cautious in combining studies to develop generalizations. Several common relationships did emerge from these studies, even though the definitions of teaching success were not always similar. Therefore, it is likely that these relationships could be of use to persons involved in various aspects of teacher education and recruitment.

Relationships that were identified in several of the studies are listed:

1. Several teacher personality traits were identified that related positively to teaching success and/or to classroom climate. These traits included such areas as the teacher's personal adjustment and personality traits exhibited in the classroom in the form of pupil-teacher relationships.
2. The academic preparation of teachers in science related positively to teaching success in several studies. Broad preparation in the sciences appeared to be more desirable than narrow specialization. The amount and kinds of science experiences teachers should have in college courses could not be determined from these investigations.
3. The procedures used in teaching science classes were related to teaching success as defined in several of the studies. Several teaching patterns were found to be related to teaching success, depending on the method used to analyze the teaching act and the definition of teaching success. High involvement of students in learning activities characterized the procedures of individuals identified in most studies as being successful teachers. The amount and kind of involvement appeared to be related to classroom climate.
4. The investigations tended to indicate that teaching procedures are not equally effective in attaining many different objectives of science education. The teacher's knowledge and acceptance of broad objectives of science education may be important factors in the objectives stressed and the procedures used.
5. The investigations provided data that indicate that the teacher and the procedures he uses tend to differ in their effect on different groups of students. Scholastic ability, interests, socioeconomic background, student self-concept, and student perception of the classroom were some of the student factors identified as important learning variables.

Guidelines and Recommendations for the Education of Science Teachers

Many states and professional organizations have cooperated to develop guidelines for the preparation of science teachers. Among the recent efforts are several that should be identified.

A joint committee of the National Association of State Directors of Teacher Education and Certification and of the American Association for the Advancement of Science

[55] developed a set of guidelines for the education of secondary school science and mathematics teachers. These guidelines placed emphasis on the need for depth and breadth in preparation in the sciences. Stressed also were experiences in the methods of teaching the teacher's major science area.

More recently, the Cooperative Committee on the Teaching of Science and Mathematics of the American Association for the Advancement of Science (AAAS) and the Association for the Education of Teachers in Science (AETS, a section of NSTA) issued a set of guidelines designed to emphasize the necessary components of the professional education portion of the preservice program [32]. This publication contains a discussion of three approaches to the preparation of teachers: the traditional, the functional, and the competency approaches. The guidelines indicate areas in which teachers should have knowledge and some experiences that should be provided for prospective teachers.

Other associations [16, 30] and individuals [17, 24, 28, 46, 77] have also developed recommendations or guidelines for science teacher education programs.

Ferguson [24] surveyed administrators of Midwest teacher training institutions to determine what a biology teaching curriculum should include. His survey resulted in recommendations for 30 semester hours in biology and one year each of chemistry and physics, as well as a background in mathematics through trigonometry. The recommendation was also made that eight of the 30 hours in biology should be in the form of an integrated biology course.

Gallentine and Solbert [28], in a survey published in 1967, analyzed the academic background of teachers applying for National Science Foundation programs. They concluded that the total college credit hours of preparation presented a favorable picture, but that a further analysis of the courses showed that the teachers were not prepared for "modern" biology. State requirements are too low in many states and science electives are not well chosen to form an adequate core of background information.

The increase in the number of earth science courses in the public schools has focused increased attention on the preparation of earth science teachers (Caldwell [15], Connally [17], Mayer [46], Merrill and Shrum [52], Shrum [78]). In 1963 only 27 states had regulations for the certification of earth science teachers. According to Shrum [77], the interdisciplinary nature of the earth science course necessitates unique teacher competencies involving a breadth of study and understanding of the interrelationships among the sciences.

Mayer [46] found, as the result of a survey made in 1964, that 123 institutions had formal or informal programs for the preparation of earth science teachers. The majority of these programs were designed for geology majors and had requirements in other areas, such as astronomy, meteorology, and oceanography, for those planning to teach earth science in the secondary schools.

Both Shrum [77] and Mayer [46] propose criteria for designing a program to prepare earth science teachers. A different approach is presented by Connally [17]. In a report on what is termed "multiple nested curricula," he details how earth science teachers can be prepared within the curriculum for a liberal arts geology major.

Most of these recommendations were based on the rational judgment of many persons with varied experience and responsibility related to the teaching of science and the education of science teachers. These recommendations indicate a concern for teacher functions and competencies rather than for hours of courses in the sciences or professional education. State certification requirements reported in the next section, however, have not reflected the function and competency emphasis. They have been primarily stated in terms of required semester or quarter hours of course work.

State Certification Requirements

An analysis of state certification requirements by Woellner and Wood [93] indicate that most certification requirements for science teachers are based on accumulated credit hours in college courses. Analyses of these certification requirements indicate a wide range of hours required in both science and professional education. Science requirements required for a teaching field ranged from 12 to 60 semester hours. Requirements in professional education ranged from 12 to 36. There was also a wide range in the breadth of study in science required for all science teachers. Analyses of certification requirements indicate a trend toward increasing the number of hours required in major science areas for teaching.

Surveys of Teacher Preparation

Investigators have conducted surveys of teacher education programs to determine the kinds of courses and experiences provided by colleges and universities for science teachers. They also have been concerned with another phase of the problem, the preparation which science teachers in the field have obtained.

Several studies regarding the preparation of junior high school science teachers were reported (Rentschler [67], Webber [92], Youkstetter [95]). Webber [92] investigated the preservice preparation of junior high school science teachers in the South Atlantic states. She limited her sample to those with six years or less teaching experience. She found that, for the individuals surveyed, few had had preservice preparation in science content or in professional education designed especially for the preparation of junior high school science teachers. More of these teachers had been prepared to teach in the elementary school than in the senior high school. Many had had no preservice preparation for science teaching at any level.

Rentschler [67], who limited his survey to general science teachers in Indiana, concluded that many teachers did not have an adequate preparation in areas of science basic to the teaching of general science. In this study, as in that of Webber [92], many of the individuals surveyed had majored in a subject other than science at the undergraduate level. Many were teaching science on a part-time rather than a full-time science teaching assignment and preferred to teach a subject other than general science.

A United States Office of Education report, *Science and Mathematics Teachers in Public High Schools* by Obourn and Brown [61], provided further evidence that many

junior high school teachers were part-time teachers of science in the early 1960's. It was reported that about 15 percent of the teachers investigated were teaching only one period of science.

N. D. Anderson [5] analyzed the preparation programs for secondary science teachers at 78 institutions. He found a great diversity of programs. Programs in a majority of the schools did not provide breadth and depth of science experiences for preservice teachers. The majority of the preservice teachers took less than 50 percent of their course work in science.

Newton [58] conducted a study of teacher education programs in over 700 colleges and universities, but the final report has not yet been released. It should provide the best descriptive data of recent teacher education programs for science teachers.

These surveys and others analyzed but not cited emphasize two basic problems: the need for good preservice programs and the need for strong inservice education programs. Many teachers apparently lack sufficient experiences in science to develop an adequate understanding of the concepts and processes of science. Many also appear to have had inadequate education in procedures for guiding students in learning activities.

Investigations of the Effect of Teacher Education Programs

Since 1964 there has been an increase in the amount of research on programs for educating science teachers. Such studies still, however, are few in number. Most of the investigations have focused on verbal interaction analysis, microteaching situations, simulation techniques, and general outcomes of teacher education programs.

The increased concern of educators for the behavior of the teacher and the influence of the teacher's behavior on that of the students has been evident in a considerable amount of research using verbal interaction analysis (Bruce, McLeod, and Matthews [14], Matthews, C. [44], McLeod [47, 48], Molchen [53], Sandefur [70]). These investigations reveal that student teachers can establish classroom teaching patterns and that they are able to vary the verbal interaction patterns in desired directions. Several of the investigators studied the preservice teacher during student teaching. The data indicate a strong effect of the cooperating teacher on the classroom behavior of the student teacher. Most of the student teachers investigated altered their teaching styles to become more like that of their cooperating teacher. None of the investigations analyzed reported on the longitudinal effect of the cooperating teacher on the behavior of the student teacher after the student teaching experience was completed. The influence of the cooperating teacher on the student teacher raises many questions concerning the use of cooperating teachers, their duties and obligations to the student teacher, the relationship of their teaching styles to those being developed through the teacher education program, and development of inservice education programs for cooperating teachers.

Microteaching has been used in several teacher education programs to develop a variety of teaching skills. Microteaching is a technique in which a teacher teaches for a short segment of time focusing on specific aspects of the teaching act. Teacher educators at Stanford University [2] have used microteaching extensively in the program for preparing interns. Videotaping of the teacher's behavior allows him to view himself as he appears to others and provides a record to be used as a basis for comparison of his acquisition of skills during the program. Data reported from the Stanford program indicate that there are a number of immediate outcomes, but no research reports were identified that detail the performance of those who have participated in the intern program and are now in their own classrooms.

Goldthwaite [31] conducted an investigation with preservice teachers to determine whether presenting science demonstrations on a teach-reteach basis would result in immediate improvement in the effectiveness of the teacher in presenting demonstrations. He was also interested in learning whether the students who had participated in the microteaching experiences would present demonstrations more effectively during their student teaching than would those students who had not participated in microclasses. He found that those student teachers who had participated as pupils in the microclasses received higher ratings on the effectiveness of their demonstrations than did the students who had been teachers of the microclasses or who had not participated in microclasses. His data suggest that learning results from participation in such microteaching classes.

Simulation techniques have been used in several universities in the general preparation program for teachers. Only one report specifically involving secondary school science teachers was identified. Lehman [40] used simulation techniques in an experimental program for secondary school student teachers of science. The students performed in five basic instructional roles: motivator, critic-evaluator, discussion leader, subject-matter representative, and adapter-modifier. The problem situations focused on basic conflicts in the area of interpersonal student-teacher relationships and dealt with such activities as motivating pupil interest, adapting instruction to differences, questioning, budgeting time and controlling tempo, and problems of pupil control and behavior. At the time this work was reported, in 1966, no attempt had been made to evaluate the program other than that of asking the participating students for their reactions to it. Most of the students reacted positively.

Studies assessing the contribution of other types of instructional procedures for preparing science teachers were not identified. Many articles can be found in the literature in which programs, classes, and experiences for educating science teachers are described. Few studies could be found that indicated the kind of teacher produced by a program or the kinds of behaviors, competencies, skills, or characteristics developed through planned experiences. It would appear that little is known concerning the specific effects of teacher education programs on science teachers.

A few studies were identified in which general outcomes of teacher education programs were analyzed. Several studies have been conducted to investigate the critical thinking and problem-solving abilities of science teachers (Andersen [3], Craven [19], George [29], Sieber [79]).

Data gathered in these investigations tend to indicate that critical thinking, as evaluated, is not a major learning outcome of the study of college science. It is possible, however, that the evaluation instruments used in these studies did not assess elements of critical thinking developed in science courses.

The understanding of the nature of science and of scientific methodology which science teachers possess has been investigated by several persons (Kimball [35], Meinhold [49]). Meinhold [49] reported that secondary school science teachers possess no greater degree of knowledge and understanding of the methodology of science than do teachers of other subjects. Kimball [35] found that the group of philosophy majors included in his investigation demonstrated a better understanding of the nature of science than did the population of science teachers. There is considerable evidence that an understanding of the nature of science and of scientific methodology can be taught. Data from the studies cited can be used to infer that this aspect of the preparation of science teachers deserves further study.

Summary and Recommendations

Research data have been presented regarding what the content of teacher education (behaviors, competencies, skills, characteristics) should include. Evidence concerning the relationships of the teacher's behaviors, characteristics, competencies, and skills to classroom activity and student learning has been reviewed. Guidelines and recommendations, based on some empirical data but largely on rational judgment, have been cited. Studies related to certification requirements and surveys of teacher preparation have also been cited. Finally, studies relevant to the effect of various elements of the teacher education program on preservice teachers have been reviewed. Research related to inservice education for secondary-school science teachers was not included in this article.

Corrigan [18], writing in a publication for the Association of Student Teaching, stated, ". . . Apparently, there are no studies of teaching at present that will yield the broad, predictive generalizations that are a long-range goal of inquiry into teaching. Descriptive studies of teaching, however, serve as essential prerequisites to subsequent investigations which may yield such generalizations . . ."

Science teachers and science educators have frequently assumed that the way in which a teacher usually conducts a class depends on a variety of factors, such as the ability level of the class, the particular content being taught, the teacher's objectives for teaching the particular unit, and the specific point in the sequential development of the unit. Studies of teacher behavior and classroom interaction might be used to determine whether there are identifiable teacher behaviors characteristic of such situations. Such studies would add to the description of science teaching. Hopefully, an adequate descriptive base will be accumulated so that significant correlational, predictive, causal studies can be made. At present, few such studies exist.

There is a dearth of research relevant to the instructional roles of the teacher. Little research has been done in science education to show the relationship between preparatory programs and product outcomes. Only in recent years has any research been done on the interaction between teachers and students in secondary school science classrooms.

Those studies which have been done have limited the observations to situations involving the teacher and the majority of the class. Science teachers work with individual students and with small groups as well as with an entire class. Research should be done to investigate the activity taking place during these sessions to determine how it differs, or if it does, from those sessions in which the entire group participates.

Research needs to be done relevant to the ways in which science teachers handle the problem of individualization of instruction and the ways in which they accommodate for individual differences of their students.

Jackson [34] has described "preactive" and "interactive" teaching. He considers "preactive" teaching activities to include such things as marking tests, preparing lesson plans, and thinking about the behavior of a particular student. "Interactive" teaching activities occur when a teacher is involved in working directly with students. Preactive behavior is more or less deliberative; interactive behavior is more or less spontaneous. If this is a valid categorization, research could be done to identify whether a shift takes place in the teacher's cognitive style between preactive and interactive teaching. What are the resultant changes in teacher behavior? Can preparatory programs in science education be designed to produce in preservice teachers a more adequate conceptualization of the various aspects of the teaching task?

Few research studies have been done to lead to the development of any theory of instruction relative to science teaching. Would adequate research develop a theory of teaching science that would differ from theories for teaching other subjects?

The assumption of many teacher education programs that more than 30 quarter hours of science content in the undergraduate program will lead to an increase in teaching skill and student learning is yet without empirical verification. Current certification patterns are also formulated on the basis of courses completed and not on performance. More attention should be given to the kind of undergraduate education that science teachers receive. Are there common science concepts that teachers are expected to teach? Can these be identified? What modifications need to be made in the preservice program in order to develop teachers competent to teach this common body of concepts in a particular science or in integrated science courses? Many college courses in science have been designed primarily to prepare students for graduate study in that subject. Such a design does not necessarily constitute adequate depth and breadth for teaching this subject to secondary school students. Should the scope and sequence of the subject studied by preservice science teachers differ from that studied by persons planning for scientific research?

The personality of the teacher appears to be an important variable in the instructional situation. Studies such as those by Biddle and Ellena [8] and by Ryans [69] have resulted in the analysis of patterns of teacher personality and behavior. Such identifiable personality pat-

terns deserve further research, particularly as they hold implications for selection and recruitment into the teaching profession.

Science education is faced with unresolved issues in the different areas described in this paper. Exact knowledge of these issues is essential for continued development of the education of science teachers. Basic questions need to be asked and researchable problems identified. Areas for study should include the content and experiences to be provided in the preparatory programs, the relationship of the content and experiences to teacher behavior, and the relationship of resulting teacher behavior to the behavior of students in the classroom situation.

The investigations must be designed and carried out in such a manner that the data can be tabulated, analyzed, and interpreted so that the study is replicable, the findings generalizable and capable of wide application. Obourn and Blackwood [60] emphasize that, "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."

References

1. Adalis, Dorothy. "An Appraisal of Broad Subject-Matter Areas in the Pre-service Preparation Program of Biology Teachers in West Virginia." University Microfilms, Ann Arbor, Michigan. 1965.
2. Allen, Dwight. *Micro-Teaching: A Description.* Stanford School of Education, Stanford University, Stanford, California. 1968.
3. Andersen, Hans O. "An Analysis of a Method for Improving Problem-solving Skills Possessed by College Students Preparing to Pursue Science Teaching as a Profession." University Microfilms, Ann Arbor, Michigan. 1966.
4. Anderson, Kenneth E. "The Relative Achievements of the Objectives of Secondary School Science in a Representative Sampling of Fifty-six Minnesota Schools." University Microfilms, Ann Arbor, Michigan. 1949.
5. Anderson, Norman D. "An Analysis of Programs for the Preparation of Secondary-School Science Teachers." University Microfilms, Ann Arbor, Michigan. 1965.
6. Balzer, A. L. "An Exploratory Investigation of Verbal and Non-Verbal Behaviors of BSCS and Non-BSCS Teachers." Unpublished doctoral dissertation, The Ohio State University, Columbus. 1968.
7. Barnes, L. W. "The Nature and Extent of Laboratory Instruction in Selected Modern High School Biology Classes." University Microfilms, Ann Arbor, Michigan. 1966.
8. Biddle, B. J., and Ellena, W. J., Editors. *Contemporary Research on Teacher Effectiveness.* Holt, Rinehart, and Winston, New York. 1964.
9. Black, H. T. "The Physics Training of Indiana High School Physics Teachers." *College Journal* 32: 12-14; March 1962.
10. Blankenship, J. W. "An Analysis of Certain Characteristics of Biology Teachers in Relation to Their Reactions to the BSCS Biology Program." University Microfilms, Ann Arbor, Michigan. 1964.
11. Blankenship, J. W., and Hoy, Wayne K. "An Analysis of the Relationship Between Open-mindedness and Closed-mindedness and Capacity for Independent Thought and Action." NARST paper.* February 1967.
12. Blum, Sidney. "The Value of Selected Variables in Predicting Rating Success in Teaching Science." University Microfilms, Ann Arbor, Michigan. 1966.
13. Brandwein, Paul F. *The Gifted Student as Future Scientist —The High School Student and His Commitment to Science.* Harcourt, Brace & World, Inc., New York. 1955.
14. Bruce, M. H.; McLeod, R. J.; and Matthews, Charles C. "A Study to Identify Relationships Between Behavior Patterns and Personal Traits in Science Student Teachers." NARST paper.* February 1967.
15. Caldwell, Loren T. "Subject Organization Proposed for Teaching Related Fields Concepts Required to Learn Earth Science Concepts in the Junior High School." *Science Education* 50: 26-31; February 1966.
16. Commission on College Physics, Panel on the Preparation of Physics Teachers. "Preparing High School Physics Teachers." Commission on College Physics, College Park, Maryland. 1968
17. Connally, G. Gordon. "Multiple Nested Curricula and the N-6 Major." *Journal of Geological Education* 14: 54-56; April 1966.
18. Corrigan, Dean, Editor. *A Study of Teaching.* The Association for Student Teaching, National Education Association, Washington, D.C. 1967.
19. Craven, G. F. "Critical Thinking Abilities and Understanding of Science by Science Teacher-Candidates at Oregon State University." University Microfilms, Ann Arbor, Michigan. 1966.
20. Davis, C. R. "Selected Teaching-Learning Factors Contributing to Achievement in Chemistry and Physics." University Microfilms, Ann Arbor, Michigan. 1964.
21. Evans, T. P. "An Exploratory Study of the Verbal and Nonverbal Behaviors of Biology Teachers and Their Relationship to Selected Personality Traits." Unpublished doctoral dissertation, The Ohio State University, Columbus. 1968.
22. Farmer, Walter A. "The Image of the Competent Secondary-School Science Teacher as Seen by Selected Groups." University Microfilms, Ann Arbor, Michigan. 1964.
23. Fawcett, Claude W. *The Skills of Teaching.* Students' Store, University of California, Los Angeles. May 1965.
24. Ferguson, Max B. "A Curriculum for Training High School Biology Teachers Which Administrators of Teacher Training Institutions Will Support." *The American Biology Teacher* 24: 337-339; May 1962.
25. Fleek, J. B. "General Chemistry for Prospective Teachers of Physical Sciences in High School." University Microfilms, Ann Arbor, Michigan. 1956.
26. Fullwood, W. E. "Selected Factors as Related to Achievement in College Physics." University Microfilms, Ann Arbor, Michigan. 1965.
27. Gallagher, James. "Teacher Variation in Concept Presentation in BSCS Curriculum Program." *BSCS Newsletter.* Biological Sciences Curriculum Study, Boulder, Colorado. January 1967.
28. Gallentine, J. L., and Solbert, A. N. "Factors Relating to Success in Teaching Modern High School Biology." *Science Education* 51: 305-309; April 1967.
29. George, Kenneth D. "A Comparison of the Critical-Thinking Abilities of Science and Non-Science Majors." *Science Education* 51: 11-18; February 1967.
30. Ginsberg, Benson E., *et al* "Preparing the Modern Biology Teacher." *BioScience* 15: 769-772; December 1965.
31. Goldthwaite, D. T. "A Study of Micro-Teaching in the Preservice Education of Science Teachers." Unpublished doctoral dissertation, The Ohio State University, Columbus. 1968.
32. "Guidelines for Content of Preservice Professional Education for Secondary School Science Teachers." A Statement by the Association for the Education of Teachers in Science and the Cooperative Committee on the Teaching of Science and Mathematics. *The Science Teacher* 35: 85-90; May 1968.
33. Howe, Robert W. "The Relationship of Learning Outcomes to Selected Teacher Factors and Teaching Methods in Tenth Grade Biology Classes in Oregon." University Microfilms, Ann Arbor, Michigan. 1964.

* Presented at a meeting of the National Association for Research in Science Teaching.

34. Jackson, Philip. "The Way Teaching Is." In *The Way Teaching Is.* Association for Supervision and Curriculum Development and the National Education Association, Washington, D.C. 1966.
35. Kimball, M. E. "Opinions of Scientists and Science Teachers About Science." University Microfilms, Ann Arbor, Michigan. 1965.
36. Kleinman, Gladys S. "General Science Teachers' Questions, Pupil and Teacher Behaviors, and Pupils' Understanding of Science." University Microfilms, Ann Arbor, Michigan. 1964.
37. Kleyensteuber, Carl J. "Group Classifications of Teachers with Evaluative Attitudes Favorable to Science Study." *Science Education* 45: 236-237; April 1961.
38. Kochendorfer, Leonard, H. "Rationale of High School Biology Teachers Using Different Curriculum Materials." University Microfilms, Ann Arbor, Michigan. 1966.
39. Lee, Eugene C. "Career Development of Science Teachers." *Journal of Research in Science Teaching* 1: 54-63; March 1963.
40. Lehman, David L. "Simulation in Science Teaching—A Preliminary Report." Presented at the meeting of the American Association for the Advancement of Science, Washington, D.C., December 1966.
41. Levine, Benjamin. "Characteristics of Prospective Science Teachers as Compared with Those of Prospective English Teachers." University Microfilms, Ann Arbor, Michigan. 1964.
42. Loud, Norman D. "The Administrator, The Teacher, and The Students Evaluate a Science Teacher—A Comparative Study." University Microfilms, Ann Arbor, Michigan. 1964.
43. Lozanoff, Paul. "The Effectiveness of Higher Institutions in the Preparation of Biology Teachers." *The American Biology Teacher* 27: 18-19; January 1965.
44. Matthews, Charles C. "The Classroom Verbal Behavior of Selected Secondary School Science Student Teachers and Their Cooperating Classroom Teachers." NARST paper.* February 1966.
45. Matthews, J. G. "A Study of the Teaching Process in the Classrooms of Selected Science Teachers." Unpublished doctoral dissertation, The Ohio State University, Columbus. 1968.
46. Mayer, Victor J. "Criterion Model of an Earth Science Teacher Preparation Program." *Science Education* 51: 290-292; April 1967.
47. McLeod, Richard J. "A Study to Identify Relationships Between Science Student Teachers' Behavior Patterns and Those of Their Cooperating Teachers." NARST paper.* February 1968.
48. McLeod, Richard J. "Changes in the Verbal Patterns of Student Teachers Who Have Had Training in Interaction Analysis and the Relationship of These Changes to the Patterns of their Cooperating Teachers." NARST paper.* February 1967.
49. Meinhold, Russell. "An Analysis of the Scores of Science Teachers on a Test of the Methodology of Science." University Microfilms, Ann Arbor, Michigan. 1961.
50. Merrill, Reed M. "Comparison of Education Students, Successful Science Teachers, and Educational Administrators on the Edwards PPS." *Journal of Educational Research* 54: 38-40; September 1960.
51. Merrill, Reed M., and Jex, Frank B. "Role Conflict in Successful Science Teachers." *Journal of Educational Research* 58: 72-74; October 1964.
52. Merrill, William M., and Shrum, John. "Planning for Earth Science Teacher Preparation." *Journal of Geological Education* 14: 23-25; February 1966.
53. Molchen, Kenneth J. "Verbal Behavior as Related to Local Supervisors as Models." NARST paper.* February 1968.
54. Morris, Kenneth T. "A Comparative Study of Selected Needs, Values, and Motives of Science and Non-Science Teachers." University Microfilms, Ann Arbor, Michigan. 1963.
55. National Association of State Directors of Teacher Education and Certification. "Guidelines for Preparation Programs of Teachers of Secondary School Science and Mathematics." American Association for the Advancement of Science, Washington, D.C. September 1961.
56. Navarra, J. G., and Dugan, R. B. "A Pilot Study to Determine the Relative Importance of Selected and Professional Factors in the Success of the Student Teacher in Science." *Journal of Experimental Education* 31: 413-418; 1963.
57. Nelson, T. A. "Competencies Desirable for Beginning Science Teachers as Viewed by Administrators and Science Teachers in the State of Illinois." University Microfilms, Ann Arbor, Michigan. 1953.
58. Newton, David. "Research on Science Education Study." Presented at the Association for the Education of Teachers in Science meeting, Washington, D.C. March 1968.
59. Nicholas, Charles H. "Analysis of the Course Content of the Biological Sciences Curriculum Study as a Basis for Recommendations Concerning Teacher Preparation in Biology." University Microfilms, Ann Arbor, Michigan. 1965.
60. Obourn, E. S.; Blackwood, P. E.; *et al.* "Research in the Teaching of Science, July 1957-July 1959." U.S. Office of Education, Washington, D.C. 1962.
61. Obourn, E. S., and Brown, K. E. "Science and Mathematics Teachers in Public High Schools." U.S. Office of Education, Washington, D.C. 1963.
62. Pankratz, Roger S. "Verbal Interaction Patterns in the Classrooms of Selected Science Teachers: Physics." University Microfilms, Ann Arbor. Michigan. 1966.
63. Parakh, Jal S. "A Study of Teacher-Pupil Interaction in High School Biology Classes." University Microfilms, Ann Arbor, Michigan. 1965.
64. Reed, Horace, Jr. "Teacher Variables of Warmth, Demand and Utilization of Intrinsic Motivation Related to Pupil's Science Interests: A Study Illustrating Several Potentials of Variance-Covariance." *The Journal of Experimental Education* 29: 205-229; March 1961.
65. Reed, Jack Arthur. "A Description and Evaluation of the Secondary-School Science Methods Course in Teacher Preparation Programs in the United States." University Microfilms, Ann Arbor, Michigan. 1967.
66. *Regional Science Experience Center Review.* Regional Science Experience Center, Oak Ridge, Tennessee. January 1967.
67. Rentschler, James Ewing. "A Study of the Academic Training in Science of the General Science Teachers of Indiana." University Microfilms, Ann Arbor, Michigan. 1962.
68. Richardson, John S., and Howe, Robert W. "The Role of Centers for Science Education in the Production, Demonstration, and Dissemination of Research." U.S. Office of Education, Washington, D.C. 1966.
69. Ryans, D. G. *Characteristics of Teachers: Their Description, Comparison, and Appraisal.* The American Council on Education, Washington, D.C. 1960.
70. Sandefur, J. T. *An Experimental Study of Professional Education for Secondary Teachers.* Kansas State Teachers College, Emporia, Kansas. 1967.
71. Sargent, E. A. "A Study to Determine Certain Characteristics of Earth Science Project Teachers and Students in the Permissive or Authoritarian Classrooms Which Lead to Greater Academic Achievement in These Students." Unpublished doctoral dissertation, Colorado State College, Greeley. 1966.
72. Schirner, S. "A Comparison of Student Outcomes in Various Earth Science Courses Taught by 17 Iowa Teachers." NARST paper.* February 1968.
73. Schueler, Herbert; Lesser, Gerald S.; and Dobbins, Allen L. *Teacher Education and the New Media.* The American Association of Colleges for Teacher Education, Washington, D.C. 1967.
74. Seeling, R. H. "A Study of the College Science Preparation of Idaho High School Biology Teachers for the 1964-65 School Year." Unpublished Master of Arts in Education thesis, Idaho State University, Pocatello. 1965.
75. Shannon, John R. "Elements of Excellence in Teaching."

Educational Administration and Supervision 27: 168-176; March 1941.
76. Sheppard, Moses M. "The Relation of Various Teacher and Environmental Factors to Selected Learning of Ninth-Grade Science Pupils." University Microfilms, Ann Arbor, Michigan. 1966.
77. Shrum, John W. "A Proposed Curriculum for the Preparation of Earth-Science Teachers." University Microfilms, Ann Arbor, Michigan. 1963.
78. Shrum, John W. "Recommendations for a Basic Academic Preparation for Earth Science Teachers." *Journal of Geological Education* 14: 26-28; February 1966.
79. Sieber, Joan E. "Problem Solving Behavior of Teachers as a Function of Conceptual Structure." *Journal of Research in Science Teaching* 2: 64-68; March 1964.
80. Skinner, Ray, Jr., and Davis, O. L., Jr. "Preparation of Earth Science Teachers in Ohio." *Journal of Geological Education* XIII: 85-87; June 1965.
81. Snider, Ray M. "A Project to Study the Nature of Physics Teaching Using the Flanders Method of Interaction Analysis." University Microfilms, Ann Arbor, Michigan. 1966.
82. Snyder, Norman C. "Socio-Cultural Background Differences in the Personnel of the Social, Biological, and Physical Sciences—A Chapter in the Institutionalization of the Sciences." University Microfilms, Ann Arbor, Michigan. 1965.
83. Spore, Leroy. "The Competencies of Secondary Science Teachers." *Science Education* 46: 319-334; October 1962.
84. Steidle, Walter E. "The Preparation, Certification, and Teaching Employment of Graduates of Science Education Programs in Ohio." University Microfilms, Ann Arbor, Michigan. 1964.
85. Taylor T. W. "A Study to Determine the Relationships Between Growth in Interest and Achievement of High School Science Students and Science Teacher Attitudes, Preparation, and Experience." University Microfilms, Ann Arbor, Michigan. 1957.
86. Tubbs, F. B. "Some Characteristics of Highly Effective and Less Effective Secondary-School Science Teachers." University Microfilms, Ann Arbor, Michigan. 1963.
87. Van Allenstein, Richard. "Warmth and Technical Competence of Teachers and the Concomitant Variation in Teacher Effectiveness." University Microfilms, Ann Arbor, Michigan. 1966.
88. Van Houten, William. "Laboratory and Demonstration Skills Needed to Teach Physics and Chemistry in the Secondary Schools—A Checklist and Suggested System for the Development of These Skills." University Microfilms, Ann Arbor, Michigan. 1965.
89. Walberg, H. J. "Personality, Role Conflict, and Self-Concept in Beginning Teachers." Educational Testing Service, Princeton, New Jersey. 1966.
90. Walberg, H. J., and Anderson, G. J. "Classroom Climate and Individual Learning." Mimeographed. Harvard University, Cambridge, Massachusetts. 1967.
91. Walberg, H. J., and Welch, W. W. "Personality Characteristics of Innovative Physics Teachers." *Journal of Creative Behavior* I: 163-170; Spring 1967.
92. Webber, Clemmie Embly. "A Study of the Pre-Service Education of Junior High School Science Teachers in the South Atlantic States." University Microfilms, Ann Arbor, Michigan. 1966.
93. Woellner, E. H., and Wood, M. A. *Requirements for Certification.* Third Edition. University of Chicago Press, Chicago. 1968.
94. Yager, R. E. "Teacher Effects Upon the Outcomes of Science Instruction." *Journal of Research in Science Teaching* 4: 236-242; December 1966.
95. Youkstetter, Frank O. "Proposals for the Professionalization of a General Science Course for Prospective Junior High School Science Teachers." *Science Education* 45: 348-353; October 1961.