PROBLEM-SOLVING: A COMPARISON OF THE EXPRESSED
ATTITUDES WITH THE CLASSROOM METHODOLOGY OF
SCIENCE TEACHERS IN SELECTED HIGH SCHOOLS

DISSERTATION

Presented in Partial Fulfillment of the Requirements
for the Degree Doctor of Philosophy in the
Graduate School of The Ohio State
University

By

THOMAS GIBBONS AYLESWORTH, A. B., M. S.

The Ohio State University

1959

Approved by

Adviser
Department of Education

ACKNOWLEDGMENTS

The writer wishes to express his deep appreciation to the administrators and teachers who participated in this study, thereby demonstrating their professional attitude toward research; to Dr. Ellsworth S. Obourn of the United States Office of Education for his interest and help in the project; to Dr. George Mallinson of Western Michigan University for his help in distributing the questionnaires; and to Dr. John S. Richardson of The Ohio State University, whose ability to guide students in research activities is a model of the direct teaching of the problem-solving process.

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CHAPTER I

THE PROBLEM

Most anthropologists today would probably agree with Linton that,

from the physical point of view, man is merely another large terrestrial primate. . . . He is set off from the other members of his order, and indeed from other mammals in general, by his tremendous ability to learn, to think, and to communicate to others what he has learned and thought.¹

Inasmuch as learning and communicating are based upon thinking, perhaps it is this last named ability that truly sets man apart from other animals. Granting that many persons hold that other animals can think in a primitive way, abstract reasoning is a capability with which only man is endowed.

Most educators today would probably agree with The Educational Policies Commission of The National Education Association and The American Association of School Administrators that the American school can "become a most effective means of leading all American youth from the immaturity of childhood to the finest manhood and womanhood that their native endowment and previous training make possible."² It should be pointed out that the previous training as described here must also in-

¹Linton, The Tree of Culture (New York: Alfred A. Knopf, 1955), Educational

²Educational Policies Commission of The National Education Association and the American Association of School Administrators, Education for All American Youth: A Further Look (Washington: National Education Association, 1952), p. 2.

volve thought processes.

Upon consideration of the above two paragraphs, it is evident that the school is the agency that must help man to take his place in society; it must transmit the culture to the next generation. In order to do this, it must assist him to think, since this is the native endowment that sets him off from other living things.

I. The Types of Thinking

Smith states that thinking is manifested in observable behavior.³ Since man cannot see actual thought processes in action, he must judge the content, quality, and essence of these thought processes by means of the effect that they have on the individual. If it is to be believed that the most effective way to evaluate learning is through observation of the action patterns of the learner, it must follow that, since learning is based upon thought processes, thinking must also be evaluated through observation of behavior. The question then arises as to what patterns of behavior can be associated with thought processes. Stating it more simply, "What types of thinking does man do?"

Cohen and Nagel have isolated four types of thinking in terms of behavior: (1) The Method of Tenacity, (2) The Method of Authority, (3) The Method of Intuition, and (4) The Method of Science.⁴

³B. Othanel Smith, "The Improvement of Critical Thinking," Progressive Education, 30:129-134, March, 1953.

⁴Morris R. Cohen and Ernest Nagel, An Introduction to Logic and Scientific Method (New York: Harcourt, Brace and Company, 1934), p. 467f.

The Method of Tenacity

This method of thinking might best be characterized by citing the voter who votes a straight ticket because he has always voted that way, since his father and grandfather always voted that way. Upon occasion, most people, wittingly or unwittingly, solve problems through this type of behavior. They resist change simply on the grounds that a given action has always been the way that they reacted to a given dilemma.

The Method of Authority

An example of this type of thinking would be the person who solves a problem in a certain manner because an educator or some other status person has said that this was the way to behave. Most people use this type of thinking from time to time.

The Method of Intuition

This much-maligned method of solving problems might well be described by referring to the person who believes in astrology, but actually, it was placed third on the hierarchy of methods of thinking because there is often a spark of reasoning behind some decisions that at first glance seem to be inspirational. Perhaps in some spontaneous actions that appear to be intuitional there is a certain element of insight, based upon intelligence.

The Method of Science

In this type of thinking, the thinker weighs the pro and con of every possible answer to his question, then selects the one answer which

seems to be most logical to him, and acts upon this information. This, then, would be the method of thought that would be used by the research scientist in solving a problem of significance to him in the area of his specialization.

Cohen and Nagel add that it is the method of science, or reflective thinking, that is the only one of these methods that admits that it might lead to error, and is, therefore, the most progressive.⁵ In using it, man is never too sure about the infallibility of his results. Thus, in this world where only the pervasiveness of change is unchanging, the method of science is the most sensible method of thought.

Of the four types of thinking, the first two are external, and might not even be considered thought at all, since the first is rather like a conditioned response and the second bases itself on a completely external solution to the problem. Considering thought in its broadest sense, however, as a means of solving a problem, it must be conceded that these are thought processes. The last two methods on the list are internal ones, and therefore permit the use of the characteristic that sets man apart from the lower animals: intelligence. It is perhaps because the fourth method permits the utilization of this characteristic to its utmost that the method of science is often called the method of intelligence.

⁵Ibid.

II. Problem-solving

Good lists no significant difference between the definitions for the method of science and problem-solving. He defines the scientific method:

A plan or procedure in which a difficulty or situation is recognized, a survey made of available information relative to the problem, a hypothesis set up concerning possible solutions to the difficulty, the hypothesis tested experimentally under controlled conditions, the results collected, evaluated, and verified, their implications reviewed, and the hypothesis either accepted or rejected.⁶

However, Stollberg points out that the scientific method is not "the private property of science," so perhaps the term "scientific method" is not the best of the names that might be used to describe this process.⁷ Other terms that mean virtually the same thing, and, judging by their use in the literature, seem to be interchangeable, are scientific reasoning, reflective thinking, relational thinking, rational thinking, creative thinking, the method of intelligence, and logical thinking. Since it appears to be the most descriptive of these terms, however, "problem-solving" will be the operational title for this process in the remainder of this study.

Science and Problem-solving

What is science? Lawson defines it as "a body of knowledge that

⁶Carter V. Good (ed.), Dictionary of Education (New York: McGraw-Hill Book Company, Incorporated, 1945).

⁷Robert Stollberg, "Problem-solving--The Precious Gem in Science Teaching," The Science Teacher, 23:225-228, 257, September, 1956.

is obtained by means of the scientific method concerning any part of the universe."⁸ Punke states that science is a pattern of explanation.⁹ Nelson seems to sum up many varied definitions by saying: "Science means both systematized knowledge and the process by which the body of new knowledge has been brought into existence."¹⁰

The last quotation seems to be a mandate for science teachers to involve their classes actively in problem-solving.

One of the contributions of science to liberal education is mentioned by Powers:

A rich experience with the scientific method is one which makes positive demands upon the use of the method for the solution of real problems. . . . Attention is focused upon the scientific method as it is used in study.¹¹

Clearly some writers consider the science class as the primary place where the problem-solving method may best be utilized. Upon investigation of the meaning of the term, "problem-solving," however, it becomes apparent that the science class is not the only place in the curriculum where this method should be found.

⁸Chester A. Lawson, "Basic Biological Science at Michigan State College," The Journal of General Education, 2:75-82, October, 1947.

⁹Harold H. Punke, "Scientific Attitude and the 3 R's," Science Education, 25:20-24, January, 1941.

¹⁰George E. Nelson, "The Introductory Biological Sciences in the Traditional Liberal Arts College," Science Education, 15:226-232, May, 1931.

¹¹S. Ralph Powers, "What Are Some of the Contributions of Science to Liberal Education?" A Program for Teaching Science, Thirty-first Yearbook of the National Society for the Study of Education, Part I (Bloomington, Illinois: Public School Publishing Company, 1932), p. 38.

Definition of Problem-solving

According to Powers,

critical thinking may be thought of as that form of mental activity that tests the adequacy of associations that have been tentatively formed as hypotheses or erroneously formed in an effort to state a truth.¹²

This statement reiterates the idea that in problem-solving there is always an element of doubt that the conclusions selected are the only true conclusions. The withholding of judgment, an integral part of problem-solving, is also one of the elements of the scientific attitude. As Ebel points out, this mutuality is present because problem-solving, being an organized series of acts, is an evidence of the scientific attitude, since the attitude gives rise to the method.¹³

Most of the more specific definitions of the problem-solving procedure describe it as a series of steps, as did the definition of Good.¹⁴ The number of steps may range from three to ten. Lampkin lists three: (1) define the problem, (2) propose the solution, and (3) test the solution.¹⁵ Shorrock lists four: (1) select the problem, (2) work on the problem, (3) draw conclusions, and (4) act upon these

¹²Ibid., p. 67.

¹³Robert L. Ebel, "What Is the Scientific Attitude?" Science Education, 22:1-5, January, 1938.

¹⁴Good, Loc. cit.

¹⁵R. H. Lampkin, "Scientific Inquiry for Science Teachers," Science Education, 35:17-39, February, 1951.

solutions.¹⁶

Dewey, in 1909 and again in 1933, mentioned five steps in a process that he called reflective thinking,¹⁷ and essentially these are repeated by Meder: (1) identify the problem, (2) establish facts, (3) formulate hypotheses, (4) test hypotheses, and (5) evaluate results.¹⁸ As an aside, she also pointed out that in order to exhibit problem-solving behavior, scientific attitudes are necessary.

One of the most comprehensive lists of problem-solving procedural steps was outlined by Kessler. They are (1) sensing a problem, (2) defining a problem, (3) studying the situation, (4) making hypotheses, (5) selecting the most likely hypothesis, (6) planning experiments, (7) carrying out experiments, (8) running checks on experiments, (9) drawing conclusions, and (10) making inferences based on conclusions.¹⁹

Basically, however, as stated by Burack,²⁰ not all of these

¹⁶William J. Shorrock, "Teaching with the Problem-solving Approach," Ohio Schools, 30:67, 84, February, 1952.

¹⁷John Dewey, How We Think (revised edition; Boston: D. C. Heath and Company, 1933), p. 292.

¹⁸Elsa Marie Meder (ed.), "Problem-solving As an Objective of Science Teaching: A Report of the Committee on Research in Secondary School Science of the National Association for Research in Science Teaching," Science Education, 33:192-195, April, 1949.

¹⁹Oreon Kessler, "A Survey of Research Dealing with the Elements of Scientific Method As Objectives of Instruction in Science," Science Education, 29:212-216, October, 1945.

²⁰Benjamin Burack, "Methodological Aspects of Problem-solving," Progressive Education, 30:134-138, March, 1953.

steps are necessary. They may all be included in the six listed by Obourn, which will be the operational facets of the problem-solving approach for the purposes of this study. They are (1) sensing and defining problems, (2) collecting evidence on problems, (3) organizing evidence on problems, (4) interpreting evidence on problems, (5) selecting and testing hypotheses, and (6) formulating conclusions.²¹

Inductive and Deductive Reasoning

Although Keeslar mentions that there is a high degree of agreement among research scientists regarding the steps and the method of problem-solving,²² and Stotler says, "The problem-solving approach is essentially the procedure of the laboratory scientist and the active citizen in a democracy,"²³ Lampkin seems to disagree.²⁴ He implies that when the scientific attitudes as listed by philosophers and those attitudes mentioned by professional science educators who were also general science textbook authors are compared, some disagreement is found. Inasmuch as scientific attitudes and the ability to solve problems, as stated earlier, are intertwined, there seems to be some

²¹Ellsworth S. Obourn, An Analysis and Check List on the Problem-solving Objective, A Science Teaching Service Circular, 481 (Washington: United States Department of Health, Education, and Welfare, 1956).

²²Oreon Keeslar, "The Elements of Scientific Method," Science Education, 29:273-278, December, 1945.

²³Donald W. Stotler, "What Should High School Science Do?" The Science Teacher, 21:68-70, 100-101, March, 1954.

²⁴Richard H. Lampkin, "Scientific Attitudes," Science Education, 22:353-357, December, 1938.

inconsistency in these statements.

The resolution of this dilemma might well be in the difference between inductive and deductive reasoning. Inductive reasoning is that type of problem-solving which leads from the particular to the general, from the individual to the universal, from premise to conclusion--in short, from facts to principle. Deductive reasoning, on the other hand, leads from the general to the particular, from the universal to the individual, from conclusion to premise, or from principle to facts. It would appear that professional scientists engaged in research would employ the former, since they are the ones who formulate principles from the facts that they discover, while the latter method is the one that would most commonly be used by the average citizen, since he knows principles and can fit facts that he comes across into the framework of these principles. Indeed, Downing reasons that the inductive method "is the method used commonly by the producer of science," and the deductive method is "the method of the consumer of science."²⁵ He adds that "it is eminently desirable that skill in the deductive method be developed in public schools including colleges."²⁶

The above quotation is also a plea for science as general education in the public schools, rather than as vocational education.

There is an implication in the foregoing discussion that the

²⁵Elliot R. Downing, "Teaching the Scientific Method," School Science and Mathematics, 34:400-405, April, 1934.

²⁶Ibid.

inductive and the deductive method of problem-solving are discrete entities. This would be an incorrect assumption, inasmuch as pure inductive reasoning is impossible, man being a creature of experience. He must always solve problems by relating them to past experience. Also, pure deductive reasoning is impossible, since man's experience is never complete enough to permit this method of problem-solving. In short, most problem-solving activities of man are combinations of deductive and inductive reasoning.

In conclusion, Dressel describes problem-solving as the goal of all education in all curricular areas, since problem-solving is the one integrating influence between the curricular areas.²⁷ Problem-solving, then, is an essential part of public school education at any level in any curricular area. It is not the sole property of the science class.

The Status of Problem-solving

The thread that weaves throughout the preceding discussion is that of the importance of problem-solving to the average citizen as well as to the scientist. On the elementary level, Meder points out that the teacher should strive for problem-solving on the part of the child; creativity leads to curiosity, observational skill, imagination,

²⁷Paul L. Dressel, "Critical Thinking--The Goal of Education," Journal of the National Education Association, 44:418-420, October, 1955.

and discovery.²⁸ Baker lists skill in problem-solving as one of his six objectives of the secondary school curriculum.²⁹ Gruenberg sums up this feeling by writing:

The most promising way of integrating the physical and organic sciences is through emphasis upon what is common to all the sciences--namely, the methods, the mode of thinking, scientific attitudes, and the social implications of science.³⁰

Although Davis cites the shifting of science objectives from facts and memorization to using the problem-solving method;³¹ although Bayles urges the forgetting of memory work in favor of problem-solving;³² although Croxton lists as one of the aims of science teaching, "to cultivate scientific attitudes and habits of procedure,"³³ is problem-solving really an integral part of the curriculum in public schools today?

Dewey seems to state the consensus when he says:

The scientific attitude, the will to use scientific method and the equipment necessary to put the will into effect, is still,

²⁸Elsa Marie Meyer, "Problem-solving for Today's Children," Science Education, 36:131-134, April, 1952.

²⁹Woolford B. Baker, "Science Teaching and the World of Tomorrow," Science Education, 34:7-15, February, 1950.

³⁰Benjamin C. Gruenberg, "Light and Smoke from the Torch of Science," Science Education, 20:60-65, April, 1936.

³¹Ira C. Davis, "Trends in Science Teaching," School Science and Mathematics, 42:450-454, May, 1942.

³²Ernest E. Bayles, "Is Science Teaching Scientific?" The Science Teacher, 23:11-12, 63-65, February, 1956.

³³W. C. Croxton, "Major Aims in Science Teaching," Science Education, 19:149-152, December, 1935.

speaking for the mass of people, inchoate and unformed.³⁴

Although this statement was written in 1934, it has been echoed down through the succeeding years. In 1937 Crowell stated that even public school textbooks do not attempt to teach the method of problem-solving.³⁵ In 1947 Wingo urged teachers to give the child a chance to attack problem-solving concerning things important to him, to think about these problems, and to act on the basis of this thinking. He then added that we have never given this method a fair trial.³⁶ In more recent times, Keeslar indicated that there is little problem-solving activity in the public schools.³⁷

For fifty years, teachers have been urged to utilize problem-solving in the classroom as a way to equip children to cope with the world, and yet author after author decries the fact that problem-solving methodology is not found even in the science classroom. Science teachers have been urged by Dewey³⁸ and the Commission on

³⁴John Dewey, "The Supreme Intellectual Obligation," Science Education, 18:1-4, February, 1934.

³⁵Victor F. Crowell, "The Scientific Method," School Science and Mathematics, 37:525-531, May, 1937.

³⁶G. Max Wingo, "Attack on the Scientific Method," Educational Digest, 12:5-7, January, 1947.

³⁷Oreon Keeslar, "The Science Teacher and Problem-solving," The Science Teacher, 23:13-14, 67, February, 1956.

³⁸Dewey, loc. cit.

Reorganization of Secondary Education³⁹ and by the American Association for the Advancement of Science⁴⁰ to include problem-solving activities in their classroom work, but the suggestion seems to be resisted by these teachers. A question might be asked at this point. What are the attitudes of classroom teachers of science toward the importance of the scientific method of problem-solving?

Direct Teaching of Problem-solving

In order to enable children to exhibit a scientific attitude to such a degree that they will utilize problem-solving methods, not only in the classroom, but also in their daily lives, it is not enough merely to discuss the problem-solving method. The students must have practice in using this procedure, and this can only come about through the teacher's purposeful planning. The teacher must provide opportunities for the students to utilize the method. Many opportunities arise daily for this direct teaching of problem-solving. One of the best lists of these opportunities was prepared by Obourn and distributed by the United States Office of Education.⁴¹ This will be discussed later.

The idea is not new that problem-solving should be directly

³⁹Commission on Reorganization of Secondary Education, Reorganization of Science in Secondary Schools, United States Bureau of Education, Bulletin 26 (Washington: Government Printing Office, 1920), p. 62.

⁴⁰"On the Place of Science in Education: A Report of the Special Committee on the Place of Science in Education of the American Association for the Advancement of Science," School Science and Mathematics, 28:640-664, June, 1928.

⁴¹Obourn, op. cit.

taught by providing practice rather than mere discussion. Noll, in 1936, stated that in order to influence behavior and bring about desired problem-solving attitudes, we must (1) teach these attitudes directly, (2) give opportunities to practice these attitudes, (3) give opportunities to generalize these attitudes, and (4) make attitudes a desirable objective of our teaching.⁴² In 1939 he reiterated this more specifically: "Unless systematic and definite provision is made for teaching scientific habits of thinking in the classroom, very little such teaching will take place, except as chance provides."⁴³

In 1941 Unzicker urged science teachers to let the students follow through the problem-solving steps, and make them feel that problem-solving is not only important, but also vital.⁴⁴ These were not the only writers urging the direct teaching of problem-solving. Mills⁴⁵ and Powers⁴⁶ also recommended it, as did Bernal, who said: "It is most important that all, and particularly those who are not continuing in

⁴²Victor H. Noll, "Teaching Science for the Purpose of Influencing Behavior," Science Education, 20:17-20, February, 1936.

⁴³Victor H. Noll, The Teaching of Science in Elementary and Secondary Schools (East Lansing, Michigan: Michigan State College Press, 1939), p. 31.

⁴⁴Samuel P. Unzicker, "What Kind of Activities in Science?" Science Education, 25:42-48, January, 1941.

⁴⁵Arthur L. Mills, "A High School Chemistry Course Based on the Principles of Reflective Thinking," School Science and Mathematics, 41:144-158, February, 1941.

⁴⁶Samuel Ralph Powers, "The Goal of Education in Science," Science Education, 28:136-141, April-May, 1944.

scientific careers, should learn the scientific method by practicing it."⁴⁷ He added that practice is necessary because it is impossible to discuss this method logically and expect it to become a habit or a scientific attitude. Heil and others restate this idea by writing: "Important objectives must be 'taught for' directly--they are not by-products of instruction."⁴⁸

Goldstein and others directed teachers to teach problem-solving directly by providing opportunities for practice, helping the child to think, and assisting the child to clarify values and reach conclusions.⁴⁹ In a report of the Twenty-fifth Conference on the Education of Teachers in Science, four steps were listed by Baker to help the teachers teach problem-solving directly: (1) deal with problems of significance, (2) use community resources, (3) improve the techniques of observation, experimentation, manipulation, interpretation, discussion, and planning, and (4) utilize the personal experiences of the children.⁵⁰ By way of summary, Stollberg urges teachers to teach this

⁴⁷J. D. Bernal, "Science Teaching in General Education," Science Education, 29:233-240, December, 1945.

⁴⁸Louis M. Heil et. al., "The Measurement of Understanding in Science," The Measurement of Understanding, Forty-fifth Yearbook of The National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1946), p. 136.

⁴⁹Joseph J. Goldstein et. al., "Thinking Can Be Learned," Educational Leadership, 6:235-239, January, 1949.

⁵⁰T. Baker, "What Can We Do to Make Our Children Capable of Thinking for Themselves?" Science Education, 34:153-155, April, 1950.

method directly, since it is not the private property of science, it is not a series of fixed steps, and it is not cold, dispassionate, and detached.⁵¹

If it is believed that little attention is being given to problem-solving in the public schools, it follows that even less attention is being given to the direct teaching of problem-solving. Two other questions thereupon arise. What are the attitudes of classroom teachers of science toward the importance of the direct teaching of the scientific method of problem-solving? What amount of the direct teaching of problem-solving is now taking place in high school science classes? Science classes and science teachers are singled out because if problem-solving attitudes are to be found anywhere in the schools of the secondary level, they should be found in science classrooms.

III. Hypotheses of the Study

Since, according to Obourn, there is "very little reliable evidence. . .available to indicate the extent to which the problem-solving objective is provided for in day-to-day classroom activities,"⁵² three hypotheses upon which this study will be based may now be verbalized:

1. Science teachers generally feel that the teaching of the problem-solving process is a worthy objective of the high school course in science.

⁵¹Stollberg, op. cit.

⁵²Obourn, op. cit.

2. Science teachers generally feel that they are making an attempt to teach problem-solving skills.
3. Science teachers generally fail to provide for direct teaching of problem-solving skills.

This study will be devoted to the testing of these hypotheses.

IV. The Importance of the Study

If ability to solve problems in a scientific manner based upon proper scientific attitudes is a desirable objective of education, to what extent is it being done in the public high school science classrooms? Three hypotheses have been stated, one of them rather ominous, about which there is little, if any, data. Three questions have been asked concerning the attitudes of classroom teachers toward the problem-solving method, toward direct teaching of this method, and the amount of direct teaching present in the classroom. There are no answers to these questions, yet, if the progress since 1909 in educating thinking citizens is to be assessed, these answers must be found.

V. Statement of the Problem

After the reasons for the importance of the study are considered and combined with the operational hypotheses, there arise three questions which should serve as a statement of the problem under consideration:

1. What attitude is expressed by science teachers toward the teaching of problem-solving as a desirable objective of the science course?
2. What methods do science teachers indicate that they use in teaching problem-solving skills?

3. What methods do science teachers actually use in teaching problem-solving skills?

The answers to these will be the ultimate tests for the hypotheses that were stated above.

VI. Limitations of the Study

It will not be the purpose of this study to answer the questions or solve the problems with respect to the entire country, but rather with respect to the state of Michigan.

Not all of the science teachers in Michigan will be contacted, but a sampling will be taken involving one hundred ninety-two teachers. As a check on the validity of the answers to the questionnaire, twenty teachers will be observed in their teaching situations. This, too, will involve sampling techniques, and will be discussed later.

Direct teaching of the problem-solving process tends to be orally verbal, and there will be almost no opportunity to observe behavioral changes on the part of the students, except as they demonstrate verbally their skill in the process. If the steps mentioned in the instrument are valid, behavioral changes will indeed take place.

CHAPTER II

REVIEW OF RELATED RESEARCH

Although much has been written of a descriptive nature concerning the problem-solving procedure, there is not a wealth of material about this method to be gleaned from experimental studies. One of the explanations for this lack is that the method of problem-solving has been considered for many years as a philosophical matter, since it is on such an abstract level, and thus little attempt was made to carry on studies of a concrete nature until the early 1930's.

One of the early studies that indicated a need for more intensive experimentation in the area of problem-solving was an investigation made by Moore. Upon analyzing data concerning the results of standardized tests of judgment, intelligence, and knowledge of facts, she was able to make some valid correlations relative to the abilities of those who had taken the three tests. She found that (1) there is a high correlation between valid explanations of phenomena and factual knowledge, but (2) there is a low correlation between further application of knowledge and factual knowledge.¹

In order to find the elements of the method of problem-solving that were practiced by students, Strauss, in 1931, administered a test,

¹Evelyn B. Moore, "A Study of Scientific Attitudes as Related to Factual Knowledge," School Review, 38:379-386, May, 1930.

formulated by Downing, entitled "Some Elements of Scientific Thinking," to 1,343 high school students in Akron, Ohio. These students ranged in grade level from eighth to twelfth. It was found that the students' ability to recognize problems was good, as was their power of observation. Their ability to analyze, reason, and see relationships, however, was judged to be poor. The conclusions that were drawn were that (1) there is a very small relationship between intelligence as measured by achievement tests and reasoning ability, and (2) there is little increase in the ability to reason as the grade level, hence chronological age, increases.²

Twenty-seven teachers were asked by Beauchamp to tell how they taught problem-solving. He found by means of this survey that five answers appeared with some consistency: (1) There is an automatic transfer from the study of science. (2) It is not possible to teach problem-solving. (3) One lesson is devoted to teaching problem-solving each year. (4) It is included in the introduction to the course. (5) Students learn to solve problems by example, from watching the teacher. There were no instances of the direct teaching of problem-solving, or the giving of opportunities in class to solve problems.³

In 1933 Weller tested elementary school children on their super-

²Sam Strauss, "Some Results for the Test of Scientific Thinking," Science Education, 16:89-93, December, 1931.

³Wilbur L. Beauchamp, Instruction in Science, A National Survey of Secondary Education, Monograph Number 22, United States Office of Education, Bulletin 17 (Washington: Government Printing Office, 1932).

stitious beliefs through the use of a true-false test on superstitions. Because of the lack of ability of the children to resist superstitious beliefs, and the implied lack of ability to think rationally by means of problem-solving, she entered a plea that teachers teach children to think. She concluded:

The teaching of elementary science with proper guidance provides an opportunity to grow in other ways than in the accumulating of factual material. . .it provides the means of developing desirable attitudes and skills in problem-solving, if focused on this aim.⁴

Downing, in 1933, analyzed high school textbooks in science and concluded that there is "no apparent provision in high school texts organized for directly imparting skill in scientific thinking."⁵ He then administered his test, "Some Elements of Scientific Thinking," that had previously been used by Strauss.⁶ The results on this test confirmed the results of Strauss' application of the test. These were, that high school students do not improve in their ability to solve problems as they advance from grade to grade, and, moreover, even at the twelfth grade level, their ability is not of the quality that would be wanted in thinking citizens. The conclusion drawn by Downing from these two parts of his investigation was that since there was no provision for direct teaching of problem-solving found in the textbooks,

⁴Florence Weller, "Attitudes and Skills in Elementary Science," Science Education, 17:90-97, April, 1933.

⁵Elliott R. Downing, "Does Science Teach Scientific Thinking?" Science Education, 17:87-89, April, 1933.

⁶Strauss, op. cit.

"there is no evidence. . .that high school pupils acquire skill in scientific thinking as a necessary by-product of the study of scientific subjects as at present taught."⁷

Two parallel studies were carried out utilizing a questionnaire developed by Davis. In this questionnaire, science teachers were asked to delineate the implications of the philosophy of education of the state of Wisconsin for teaching science. The questionnaire was prepared in such a manner that these implications would take the form of desirable attitudes in science that would conform to this statement of philosophy, which, incidentally, was formulated by the Teacher Training Council in Wisconsin.⁸ In 1933 Skewes administered this questionnaire to two hundred and fifty selected science teachers,⁹ and in 1935 Davis queried the science teachers of Wisconsin with the same questionnaire.¹⁰ The results of these two investigations were essentially the same. The attitudes of science that were suggested by the teachers were (1) a willingness to change opinions based upon the discovery of new truths, (2) a willingness to search for truth without prejudice, (3) a knowledge of cause and effect relationships, (4) a willingness to base judgment on facts, and (5) an ability to distinguish between fact and theory.

⁷Downing, op. cit.

⁸Ira C. Davis, "The Measurement of Scientific Attitudes," Science Education, 19:117-122, October, 1935.

⁹George J. Skewes, "What Is the Scientific Attitude?" School Science and Mathematics, 33:964-968, December, 1933.

¹⁰Davis, op. cit.

All of the attitudes are essential to problem-solving.

In 1936 Barnard and Robertson carried out a study with two groups of general science students. Both groups were taught in the same manner after a study guide had been prepared. The difference in methodology used between the two groups was that in the experimental group, this study guide was prepared by the students themselves, whereas in the control group, the study guide was prepared by the teacher. The result of this experiment was that the experimental group gained more in scientific attitudes, problem-solving abilities, and the ability to apply generalizations. At the end of the study, it was found that the control group, with their teacher-developed study guide, spent more time in solving problems than did the experimental group, with their pupil-developed study guide. In addition to this, the problem-solving of the control group, once completed, was not of as high a level as was that of the experimental group.¹¹

Another study, also involving two groups of students, this time biology students, was performed by Burnett. His control group was taught biology by means of the recitation method, and his experimental group used the problem-solving approach. The expressed objectives for both groups were (1) to teach the problem-solving method, (2) to develop the ability to form conclusions and derive principles, and (3) to develop an appreciation of science. The significant results of this

¹¹J. Darrell Barnard and M. L. Robertson, "A Comparison of the Relative Effectiveness of Two Methods of Teaching General Science," Science Education, 20:200-206, December, 1936.

experiment were that the problem approach group proved to be 6.9 per cent better in developing scientific attitudes and 7 per cent better in factual recall than the control group. It was also mentioned that the problem approach group sought their own answers to problems with a greater degree of effectiveness than did the control group, taught by the recitation method. This study indicates, as have others mentioned above, that special methodology must be utilized in order to teach problem-solving.¹²

The Committee on Secondary School Science of the National Association for Research in Science Education sent a questionnaire to one hundred and eighty specialists in secondary school science teaching in 1938. These specialists were asked for their points of view regarding necessary changes that might take place in public school science education. The two most significant desires expressed were for a sequence of science content for grades kindergarten through twelve and for more teaching for thinking in public school science classes.¹³

"What Do You Think?," a test of problem-solving abilities devised by Noll in 1934 and 1935,¹⁴ was administered to three groups of students by Blair and Goodson in 1939. These three groups differed in that one

¹²R. Will Burnett, "An Experiment in the Problem Approach in the Teaching of Biology," Science Education, 22:115-120, March, 1938.

¹³"Science Education--A Report of the Committee on Secondary School Science of the National Association for Research in Science Teaching," Science Education, 22:223-233, October, 1938.

¹⁴Victor H. Noll, What Do You Think? Forms 1 and 2 (New York: Bureau of Publications, Teachers College, Columbia University, 1934, 1935).

had been taught general science with the problem-solving method, one had been taught general science with the traditional discussion-demonstration method, and one had no background in science. All three were ninth grade groups. Inasmuch as the traditional and non-science groups had similar results on the test--lower than the problem-solving group--it was concluded that the study of science does not, of itself, make a unique contribution to students' abilities in the use of the problem-solving procedure.¹⁵

A moderate word of dissent comes from a study made by Eberhard and Hunter. They administered a test for the scientific attitude to two groups of general science students. One of these groups was taught by the problem-solving method and the other by a more traditional method. After the test was given at the end of seven months of instruction, they found no significant difference between the two groups with regard to expressed scientific attitudes.¹⁶

Obourn and Montgomery let science students plan their own curriculum and study guide. These authors described the methods used in student planning of units on Vitamin B₁, the siphon, reproduction, etc. After evaluating the work of the students, it was concluded that the high school student can use the problem-solving approach with a certain

¹⁵Glenn M. Blair and Max R. Goodson, "Development of Scientific Thinking Through General Science," School Review, 47:695-701, November, 1939.

¹⁶J. Wesley Eberhard and George W. Hunter, "The Scientific Attitude As Related to the Teaching of General Science," Science Education, 24:275-281, October, 1940.

degree of success.¹⁷

In a study reported by Wessell, another indication is found that problem-solving must be taught directly. Two groups of ninth grade students were used: one with science experience and one without science experience. The groups together numbered one hundred and forty-seven students. Both groups were given pre-tests before the instruction began with the science group. The objectives of the course for the science group were listed as: (1) to develop a scientific attitude, (2) to develop the ability to solve problems, and (3) to increase the students' funds of scientific information. During the time of science instruction given to the one group, no effort was made to teach the problem-solving procedure directly, nor was there an attempt to teach scientific attitudes directly. At the end of the instruction, a test on the applications of scientific principles was administered to the two groups, and the result was that only in the area of knowledge of scientific facts was there any significant difference between the two groups. The results of test scores for the non-science group were almost identical to the scores of the science group in scientific attitudes and the ability to use the problem-solving procedure. The conclusion was drawn that direct teaching of scientific attitudes and problem-solving pro-

¹⁷Ellsworth S. Obourn and Gaylord C. Montgomery, "Classroom Procedures for Developing the Elements of Problem-solving," Science Education, 25:72-80, February, 1941.

cedure was necessary.¹⁸

Problem-solving in the English class curriculum was tested by Glaser in 1941. Students in four twelfth grade English classes in each of two different high schools were given opportunity to use the problem-solving method. Not only was it found that the students were able to solve problems more effectively, but also there was an improvement in their general intelligence, their reading ability, and their school marks.¹⁹ For another excellent outline for teaching for thinking in an area of the curriculum other than science, the reader is referred to Fawcett's *The Nature of Proof*.²⁰

Curtis, in 1943, analyzed thousands of questions posed in high school textbooks of science and discovered that there was a dearth of truly thought-provoking questions in these texts. He concluded that more thought questions leading directly to the use of the problem-solving method were needed in science textbooks.²¹

¹⁸George Wessell, "Measuring the Contribution of a Ninth Grade General Science Course to the Development of Scientific Attitudes," Science Education, 25:336-339, November, 1941.

¹⁹Edward M. Glaser, An Experiment in the Development of Critical Thinking, Contributions to Education, Number 843 (New York: Bureau of Publications, Teachers College, Columbia University, 1941).

²⁰Harold Pascoe Fawcett, The Nature of Proof, Thirteenth Yearbook of the National Council of Teachers of Mathematics (New York: Bureau of Publications, Teachers College, Columbia University, 1938).

²¹Francis D. Curtis, "Types of Thought Questions in Textbooks of Science," Science Education, 27:60-67, September-October, 1943.

Questionnaires were sent to science teachers by Hunter and Spore in which the teachers were asked to rank, in order of their importance, the objectives of science teaching that they considered desirable in the public schools. Although science problem-solving was ranked tenth, about fifty per cent of these teachers judged it to be a desirable objective. The objectives, in the order in which they were ranked, were (1) understanding the environment, (2) knowledge about the environment, (3) appreciation for the environment, (4) health knowledge, (5) power of observation, (6) worthwhile ideas and habits, (7) freedom from dogma and superstition, (8) good citizenship, (9) solving life's problems, and (10) applying the scientific method.²²

Six classes of biological science on the college level were used by Barnard in a study. Three of these classes were taught by using the lecture-demonstration method, and three were taught by using the problem-solving method. The six classes were tested for recall of facts, understanding of principles, use of the problem-solving method, and belief in scientific attitudes. All six classes scored roughly the same with regard to recall of facts and understanding of principles, but those three classes that were taught by means of the problem-solving procedure scored significantly higher with regard to the use of the problem-

²²George W. Hunter and Leroy Spore, "The Objectives of Science in the Secondary Schools of the United States," School Science and Mathematics, 43:633-647, October, 1943.

solving method and belief in scientific attitudes.²³

Two studies of a more descriptive nature were undertaken concerning the use of a problem-solving type of course outline. Teichman had a great deal of success in teaching five hundred and fifty ninth-grade general science students with this method,²⁴ as did Baker, who used this method in elementary science methods classes. These methods classes found the answer to the question, "What are the reactions of elementary school children to live animals in the classroom?" by planning their own study and carrying it out by means of the problem-solving approach.²⁵

In a sampling of secondary school science classes in Minnesota, Anderson found that there are several factors that contribute to the achievement of objectives in these science classes. He pointed out that (1) the teaching practices, (2) the teaching situation, (3) the pupils' backgrounds, (4) the amount of scientific attitudes and intelligence of the teacher, and (4) the amount of science facts and principles taught may affect this achievement of objectives. Moreover, the students had a better experience in science when (1) the teacher had taken more science classes in college, (2) the teacher had attended a

²³J. Darrell Barnard, "The Lecture-demonstration Versus the Problem-solving Method of Teaching a College Science Course," Science Education, 26:121-132, October-November, 1942.

²⁴Louis Teichman, "The Ability of Science Students to Make Conclusions," Science Education, 28:268-279, December, 1944.

²⁵Tunis Baker, "Teaching the Scientific Method to Prospective Elementary School Teachers," Science Education, 29:79-82, March, 1945.

private college, (3) the teacher had a higher degree than the bachelor of arts or the bachelor of science, (4) there was a maximum of laboratory work in the science class, and (5) the classes were of a minimum size.²⁶

In summarizing the results and conclusions of the foregoing selection of related research, several generalizations seem to be evident that indicate not only the desirability of the direct teaching of the problem-solving method, but also the need for this type of teaching.

It has been concluded many times, both descriptively and experimentally, that there is a lack of the direct teaching of the problem-solving method in our schools, that students need practice in problem-solving in order to utilize the method effectively, and that science teachers approve of this method in theory, but not in practice. Thus, it would seem highly desirable that steps be taken to help teachers, and especially science teachers, to relate their theoretical belief in the problem-solving approach to the practical application of teaching this method directly in the classroom.

The reasons for the importance of giving practice in problem-solving to the students in the classroom were demonstrated experimentally by studies that indicated that a knowledge of facts does not lead necessarily to an application of these facts, there may be little

²⁶Kenneth E. Anderson, "Summary of the Relative Achievements of the Objectives of Secondary School Science in a Representative Sampling of Fifty-six Minnesota Schools," Science Education, 33:323-329, December, 1949.

relationship between intelligence and reasoning ability or between age and reasoning ability, and there is no corresponding development in reasoning ability as the student grows older. On the other hand, while factual knowledge may aid in the explanation of phenomena, the ability to solve problems aids the student in all types of reasoning situations.

There would seem to be little disagreement among the research people in this area of education that practice in solving problems is necessary in the curriculum of the school. Most of them deplore the lack of this type of teaching, and most of them point out or imply that we are cheating school children, and consequently future generations, by not equipping students to solve problems effectively.

CHAPTER III

TECHNIQUES AND MATERIALS USED IN THE STUDY

It was felt that a mere request for expressed attitudes toward problem-solving through the use of a questionnaire would not be sufficient unless it could be compared with attitudes that might be exhibited by science teachers in their classroom teaching. Therefore, both a qualitative and a quantitative approach toward gathering data were decided upon. Prior to the distribution of questionnaires by mail, a series of observations was arranged in order to gain some familiarity with the amount and types of direct teaching of problem-solving skills that might be found in public school science classrooms.

I. The Qualitative Approach

The common science courses offered in high schools in the state of Michigan are biology, chemistry, and physics. Characteristically, schools in this state are set up on the 6-3-3 plan, in which the high school years are considered to be the tenth, eleventh, and twelfth grades. Even in those communities where six-year secondary schools are found, it is common practice to refer to the seventh, eighth, and ninth grades as "junior high school," and the tenth, eleventh, and twelfth grades as "senior high school." Usually, general science is taught in the seventh, eighth, and ninth grades or some combination of these three grades; biology is considered a tenth grade subject; and chemistry or

physics is considered to be an eleventh or twelfth grade subject. Therefore, since high school science courses were to be studied, and since advanced biology, chemistry, and physics, as well as physical science courses, are rarities in this state, only biology, chemistry, and physics teachers and classes were included in the research.

The Qualitative Techniques

It was decided that observations of classroom situations in selected high school science classes would be an effective technique to use in evaluating the kinds of direct teaching of the problem-solving procedure that might be found in public schools in Michigan. Arbitrarily, twenty observations were scheduled: twelve biology classes, four chemistry classes, and four physics classes. Equally arbitrarily, three biology classes, one chemistry class, and one physics class were selected in schools of four sizes: schools with enrollments of under five hundred, schools with enrollments of from five hundred to one thousand, schools with enrollments of from one thousand to two thousand, and schools with enrollments of over two thousand.

These schools were selected not only on the basis of size, but also on the basis of geography. It was felt that the best way to ensure cooperation for the study was to make contact with the schools and teachers involved through a member of the faculty of Michigan State University stationed in the vicinity. This faculty member was, in some cases, a Resident Coordinator of Student Teaching, and, in other cases, the director of a Continuing Education Center. Either responsibility

would put the faculty member in a position of being able to judge the teachers of the community concerning their desirability as subjects for the study. These men were asked to select and contact science teachers of average ability who would seem to reflect in their teaching the normal procedures and educational philosophy of the school in which they taught.

Observations were made at twelve different schools: four with enrollments of under five hundred, three with enrollments of between five hundred and one thousand, three with enrollments of between one thousand and two thousand, and two with enrollments of more than two thousand. Within each group, no two schools were less than twenty-five miles apart, geographically speaking, but all were within a radius of one hundred miles of the state capital, Lansing. By not observing in a wider radius than this, certain problems were avoided, such as differences in regional attitudes toward education in general, differences in courses of study, and differences in salary schedules of teachers.

The Qualitative Materials

Inasmuch as the teachers observed were carrying on a discussion session at the time of the observation, mere note-taking of what was said and done was not sufficient. A tape recorder was taken into the classrooms and notes of various observable behavior were integrated into the stenographic transcription of the class discussion. The chief reason for the use of the tape recorder was that most of the lists of problem-solving behaviors concern themselves almost exclu-

sively with behaviors that are orally verbal, including few that are non-verbal in character. Because of this fact, word-for-word transcriptions, with appropriate notations of non-verbal behavior relating to the problem-solving process, seemed to be the most effective way of carrying out the observations.

No observation in a classroom is completely effective unless the observer enters the situation with a knowledge of what it is that he might see in the classroom. Forty-four items concerning teachers' practices in teaching directly the problem-solving method to students were outlined by Obourn in an "Inventory of Problem Solving Practices." These items are as follows:

A. Sensing and Defining Problems:

To what extent do you

1. help pupils sense situations involving personal and social problems?
2. help pupils recognize specific problems in these situations?
3. help pupils in isolating the single major idea of a problem?
4. help pupils state problems as definite and concise questions?
5. help pupils pick out and define the key words as a means of getting a better understanding of the problem?
6. help pupils evaluate problems in terms of personal and social needs?
7. help pupils to be aware of the exact meaning of word-groups and shades of meaning of words in problems involving the expression of ideas?
8. present overview lessons to raise significant problems?
9. permit pupils to discuss possible problems for study?
10. encourage personal interviews about problems of individual interest?

B. Collecting Evidence on Problems:

To what extent do you

1. provide a wide variety of sources of information?
2. help pupils develop skill in using reference sources?
3. help pupils develop skill in note taking?
4. help pupils develop skill in using reading aids in books?
5. help pupils evaluate information pertinent to the problem?

6. provide laboratory demonstrations for collecting evidence on a problem?
7. provide controlled experiments for collecting evidence on a problem?
8. help pupils develop skill in interviewing to secure evidence on a problem?
9. provide for using the resources of the community in securing evidence on a problem?
10. provide for using visual aids in securing evidence on a problem?
11. evaluate the pupils' ability for collecting evidence on a problem as carefully as you evaluate their knowledge of facts?

C. Organizing Evidence on Problems:

To what extent do you

1. help pupils develop skill in arranging data?
2. help pupils develop skill in making graphs of data?
3. help pupils make use of deductive reasoning in areas best suited?
4. provide opportunity for pupils to make summaries of data?
5. help pupils distinguish relevant from irrelevant data?
6. provide opportunity for pupils to make outlines of data?
7. evaluate the pupils' ability to organize evidence on a problem as carefully as you evaluate their knowledge of facts?

D. Interpreting Evidence on Problems:

To what extent do you

1. help pupils select the important ideas related to the problem?
2. help pupils identify the different relationships which may exist between important ideas?
3. help pupils see the consistencies and weaknesses in data?
4. help pupils state relationships as generalizations which may serve as hypotheses?
5. evaluate the pupils' ability for interpreting evidence as you evaluate their knowledge of facts?

E. Selecting and Testing Hypotheses:

To what extent do you

1. help pupils judge the significance or pertinency of data for the immediate problem?
2. help pupils check hypotheses with recognized authorities?
3. help pupils make inferences from facts and observations?
4. help pupils devise controlled experiments suitable for testing hypotheses?
5. help pupils recognize and formulate assumptions basic to a given hypothesis?

6. help pupils recheck data for possible errors in interpretation?
7. evaluate the pupils' ability for selecting and testing hypotheses as carefully as you evaluate their knowledge of facts?

F. Formulating Conclusions:

To what extent do you

1. help pupils formulate conclusions on the basis of tested evidence?
2. help pupils evaluate conclusions in the light of the assumptions they have set up for the problem?
3. help pupils apply their conclusions to new situations?
4. evaluate the pupils' ability to formulate conclusions as carefully as you evaluate their knowledge of facts?¹

From this inventory a check list was formulated, changing the phrasing of the items so that the attention of the observer was transferred from the teachers' activities in the direct teaching of problem-solving to the behavioral characteristics of the students with regard to the activities of the problem-solving procedure. The check list items were as follows:

1. Do your pupils sense situations involving personal and social problems?
2. Do your pupils recognize specific problems in these situations?
3. Do your pupils isolate the single major idea of a problem?
4. Do your pupils state problems as definite and concise questions?
5. Do your pupils pick out and define the key words as a means of getting a better understanding of the problem?
6. Do your pupils evaluate problems in terms of personal and social needs?
7. Are your pupils aware of the exact meaning of word groups and shades of meaning of words in problems involving the expression of ideas?
8. Do your pupils have overview lessons to raise significant problems?
9. Do your pupils discuss possible problems for study?

¹Ellsworth S. Obourn, An Analysis and Check List on the Problem-solving Objective, A Science Teaching Service Circular, 481 (Washington: United States Department of Health, Education, and Welfare, 1956).

10. Do your pupils ask for personal interviews about problems of individual interests?
11. Do you have a wide variety of sources of information?
12. Do your pupils develop skill in using reference sources?
13. Do your pupils develop skill in note taking?
14. Do your pupils develop skill in using reading aids in books?
15. Do your pupils evaluate information pertinent to the problem?
16. Are the pupils able to use laboratory demonstrations for the collecting of evidence on a problem?
17. Do the pupils perform controlled experiments for collecting evidence on a problem?
18. Do your pupils develop skill in interviewing to secure evidence on a problem?
19. Do your pupils use community resources in securing evidence on a problem?
20. Do your pupils use visual aids in securing evidence on a problem?
21. Are the pupils' abilities for collecting evidence on a problem evaluated as carefully as their knowledge of facts?
22. Do your pupils develop skill in arranging data?
23. Do your students develop skill in making graphs of data?
24. Do your pupils make use of deductive reasoning in areas best suited?
25. Do your pupils have opportunities to make summaries of data?
26. Do your pupils distinguish relevant from irrelevant data?
27. Do your pupils have opportunity to make outlines of data?
28. Are the pupils' abilities for organizing data evaluated as carefully as their knowledge of facts?
29. Do your pupils select the important ideas related to their problems?
30. Do your pupils identify the different relationships which may exist between important ideas?
31. Do your pupils see the weaknesses and consistencies in data?
32. Do your pupils state relationships as generalizations which may serve as hypotheses?
33. Are the pupils' abilities in interpreting evidence evaluated as carefully as their knowledge of facts?
34. Do your pupils judge the significance or pertinence of data for the immediate problem?
35. Do your pupils check hypotheses with recognized authorities?
36. Do your pupils make inferences from facts and observations?
37. Do your pupils devise controlled experiments suitable for testing hypotheses?
38. Do your pupils recognize and formulate assumptions basic to a given hypothesis?
39. Do your pupils recheck data for possible errors in interpretation?

40. Are the pupils' abilities for selecting and testing hypotheses evaluated as carefully as their knowledge of facts?
41. Do your pupils formulate conclusions on the basis of tested evidence?
42. Do your pupils evaluate their conclusions in the light of the assumptions they set up for the problem?
43. Do your pupils apply their conclusions to new situations?
44. Are the pupils' abilities for formulating conclusions evaluated as carefully as their knowledge of facts?

The check list as outlined above was taken into the classrooms by the observer at the time of the observation, and a tally was made of the instances of observed behavior of students with regard to the items on the list.

Obviously, some of the items on the check list were unobservable: for example, the items concerning the evaluation of the students in the area of how well they select and test hypotheses. In order to secure information on these items, each of the observed teachers was asked to fill out a check list in private, indicating whether his students exhibited this behavior always, almost always, occasionally, seldom, or never. In this way, more complete data were obtained and also there was a check on the validity of the returns of questionnaires in the quantitative approach, to be discussed in the next section of this chapter.

II. The Quantitative Approach

The Quantitative Techniques

In essence, the technique of this method of obtaining data was the classifying of the results of the questionnaires that were sent to one hundred and ninety-two science teachers in the state of Michigan. The items checked and the degree of behavior indicated were tabulated grossly

and then broken down by sizes of schools, types of schools, academic and professional educational backgrounds of teachers, length of time of professional experiences, and class and extra-class loads of the teachers.

The Quantitative Materials

The questionnaire described above was sent to a selected list of science teachers in the state of Michigan. The list was compiled at random by obtaining copies of the Michigan membership lists of the National Science Teachers Association and of the Central Association of Science and Mathematics Teachers, and culling the names of those whose addresses could not be found. This list was then compared with the membership roll of the Michigan Science Teachers Association, and names were added or dropped if it were found that the teacher in question was not a biology, chemistry, or physics teacher, or if additional biology, chemistry, or physics teachers were found.

The questionnaire, complete with a cover letter and a stamped, self-addressed envelope, was sent to each of these science teachers on March 1, 1959, in order to ensure that the second semester was well enough under way so that the teachers would have had an opportunity to evaluate their students. This mailing date was also selected so that the teachers would have had enough time to complete the questionnaire before the Easter recess.

The teacher was asked questions about the size and type of school, science and science education courses taken in college by the teacher, years of experience of the teacher, and teaching load of the

teacher, in order that these items of information could serve as variables in interpreting the types of answers recorded with regard to the problem-solving behavior of their students. These items were followed by a question concerning their opinion of the value of the problem-solving approach in the school in order to shift their attention from themselves to the students concerned in the check list part of the questionnaire. A sample questionnaire may be found in Appendix D.

CHAPTER IV

RESULTS OF THE STUDY AND INTERPRETATION OF THESE RESULTS

The qualitative technique data were kept separate from the quantitative technique data until the final interpretation of the data was begun. Therefore, the results of the two techniques are discussed separately in the first two sections of this chapter.

I. The Qualitative Approach

The opinions expressed by the teachers observed, as found on the questionnaire returns, were compiled in the same categories as those listed on the questionnaire: "always," "almost always," "occasionally," "seldom," and "never." These were aligned with the data compiled through the subjective opinion of the observer. Clearly, the only valid data that might be derived by observation are the number of instances of observed behavior indicating that the student was performing some of the acts related to the problem-solving process. In the following discussion, emphasis is placed upon these positive results.

It was considered unfair to analyze the results of the tape recordings to discover negative data, those instances of opportunities for the direct teaching of problem-solving that were ignored by the teacher, for three reasons. First, upon examining the transcriptions, there was found no clear-cut pattern of predominance of any given omis-

sion in methodology among the twenty classrooms. Secondly, subjective evaluation of these omissions could not be defended adequately. Finally, the rooms were visited only once, and no general idea of whether these omissions were consistent could be derived. Because of these reasons, it was felt that to report on negative data would be statistically invalid.

Sensing and Defining Problems

Basically, the teachers observed indicated that they emphasized this activity at least occasionally, as shown in Table 1. Eighty-four per cent of them responded that the ten activities in this category were stressed "occasionally," "almost always," or "always." In the observation of these classes, one hundred and twenty-five instances of this type of behavior were found, or sixty-three per cent of the number possible.

Seventy per cent of the teachers indicated that their students always or almost always sensed situations involving personal and social problems, and this activity was observed in sixty-five per cent of the twenty rooms; all of the teachers indicated that their students recognized specific problems in these situations, and this activity was seen in sixty per cent of the twenty classrooms. In isolating the single major idea of a problem, only thirty per cent answered that their students were able to perform this activity "almost always," as compared to thirty-five per cent who answered that the students seldom did this. This activity was observed in seventy per cent of the twenty rooms. Sixty-five per cent of the teachers indicated that their students stated

TABLE 1

INDICATED AND OBSERVED ACTIVITIES RELATED
TO SENSING AND DEFINING PROBLEMS IN
TWENTY SELECTED CLASSROOMS

	RESPONSES BY TEACHERS										Seen By Observer	
	Always		Almost Always		Occasion- ally		Seldom		Never			
ITEM	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	7	35	7	35	5	25	1	5	0	0	13	65
2	2	10	5	25	13	65	0	0	0	0	12	60
3	0	0	6	30	6	30	8	35	0	0	14	70
4	0	0	13	65	4	20	3	15	0	0	15	75
5	0	0	8	40	9	45	3	15	0	0	12	60
6	0	0	6	30	12	60	2	10	0	0	12	60
7	0	0	5	25	13	65	2	10	0	0	12	60
8	2	10	4	20	10	50	4	20	0	0	17	85
9	0	0	3	15	14	70	3	15	0	0	9	45
10	0	0	2	10	12	60	6	30	0	0	9	45

problems as definite and concise questions, and this was observed in seventy-five per cent of the rooms.

With regard to the items of picking out and defining the key words as a means of getting a better understanding of the problem, evaluating problems with respect to personal and social needs, and being aware of the exact meaning of words in groups and shades of meanings of words in problems involving the expression of ideas, eighty-five, ninety, and ninety per cent, respectively, of the teachers felt that students performed this activity at least occasionally, if not almost always. These three activities were each observed in sixty per cent of the rooms. The item of having overview lessons to raise significant problems was done at least occasionally by eighty per cent of the teachers, and in eighty-five per cent of the rooms, this activity was either happening or was being discussed in the past or future tense.

The next item, that of discussing possible problems for study, occurred "occasionally" or "seldom" as mentioned by the teachers, and only forty-five per cent of the room observations indicated the presence of this activity. A pupil's asking for a personal interview about a problem of individual interest was checked "occasionally" or "seldom" by ninety per cent of the teachers and observed in forty-five per cent of the classrooms.

Collecting Evidence on Problems

This general activity was emphasized by the teachers at least occasionally, since eighty-three per cent indicated that the eleven

activities in this category were stressed "occasionally," "almost always," or "always." In the observation of these classes, eighty-seven instances of this type of behavior were found, or forty per cent of the number possible. This tabulation may be found in Table 2.

Item 11, that of having a wide variety of sources of information, was observed in eleven of the rooms, or fifty-five per cent, and all of the teachers indicated that they had these sources either "occasionally" or "almost always." With regard to the students' development of skills in using reference sources, item 12, seventy per cent indicated "occasionally" or "seldom," while this was observed in thirty per cent of the rooms. Eighty-five per cent of the teachers indicated "occasionally" or more to item 13, that of developing skill in note taking, while this was seen in thirty per cent of the rooms. Ninety per cent of the teachers indicated "occasionally" or more to item 14, that of developing skill in using reading aids in books, while this was observed in twenty-five per cent of the rooms.

Item 15, evaluating information pertinent to the problem, was answered "occasionally" or more by ninety per cent of the teachers, and was observed in sixty-five per cent of the rooms. Items 16 and 17 were checked "almost always" by sixty per cent of the teachers in each case, and were observed in eighty per cent of the rooms in the case of using laboratory demonstrations for the collecting of evidence on a problem, and in forty per cent of the rooms in the case of performing controlled experiments for collecting evidence on a problem. Sixty-five per cent of the teachers indicated that students seldom developed skill in inter-

TABLE 2

INDICATED AND OBSERVED ACTIVITIES RELATED
TO COLLECTING EVIDENCE ON PROBLEMS
IN TWENTY SELECTED CLASSROOMS

	RESPONSES BY TEACHERS										Seen By Observer	
	Always		Almost Always		Occasion- ally		Seldom		Never			
ITEM	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
11	0	0	15	75	5	25	0	0	0	0	11	55
12	0	0	6	30	12	60	2	10	0	0	6	30
13	0	0	7	35	10	50	3	15	0	0	6	30
14	2	10	4	20	12	60	2	10	0	0	5	25
15	2	10	2	10	14	70	2	10	0	0	13	65
16	0	0	12	60	5	25	3	15	0	0	16	80
17	0	0	12	60	3	15	5	25	0	0	8	40
18	0	0	0	0	7	35	13	65	0	0	3	15
19	0	0	8	40	10	50	2	10	0	0	5	25
20	1	5	7	35	11	55	1	5	0	0	10	50
21	2	10	4	20	10	50	4	20	0	0	3	15

viewing to secure evidence on a problem, item 18, and evidence of this was observed in only fifteen per cent of the rooms.

The skill of using community resources in securing evidence on a problem, item 19, was marked as "occasionally" or more by ninety per cent of the teachers, and was observed in twenty-five per cent of the rooms. The skill of using visual aids in securing evidence on a problem, item 20, was marked as "occasionally" or more by ninety-five per cent of the teachers, and was observed in fifty per cent of the rooms. Seventy per cent of the teachers checked as "occasionally" or "seldom" item 21, that of evaluating abilities for collecting evidence on a problem as carefully as evaluating the students' knowledge of facts, while this was observed in fifteen per cent of the rooms.

Organizing Evidence on Problems

In general, the teachers observed indicated that they emphasized this activity, at least occasionally. Seventy per cent of them responded that the seven activities in this category were stressed "occasionally," "almost always," or "always." In the observation of these classes, fifty-three instances of this type of behavior were found, or thirty-eight per cent of the number possible. This tabulation may be found in Table 3, on the page following.

Item 22, that of developing skill in arranging data, was checked "occasionally" or less by sixty-five per cent of the teachers, and was observed in fifty-five per cent of the classrooms. Seventy-five per cent of the teachers indicated that seldom or never did their students

TABLE 3

INDICATED AND OBSERVED ACTIVITIES RELATED
TO ORGANIZING EVIDENCE ON PROBLEMS
IN TWENTY SELECTED CLASSROOMS

	RESPONSES BY TEACHERS										Seen By Observer	
	Always		Almost Always		Occasion- ally		Seldom		Never			
ITEM	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
22	0	0	7	35	5	25	8	40	0	0	11	55
23	0	0	0	0	5	25	13	65	2	10	1	5
24	0	0	5	25	10	50	5	25	0	0	12	60
25	2	10	10	50	4	20	4	20	0	0	9	45
26	2	10	5	25	10	50	3	15	0	0	11	55
27	2	10	12	60	1	5	5	25	0	0	8	40
28	0	0	4	20	16	80	0	0	0	0	1	5

develop skill in making graphs of data, item 23, and this was observed in only five per cent of the classrooms. In item 24, making use of deductive reasoning in areas best suited, seventy-five per cent of the teachers answered "occasionally," or "seldom" and this was observed in sixty per cent of the classrooms.

With regard to the opportunities of making summaries of data, item 25, eighty per cent of the teachers responded "occasionally" or more, and this was observed in forty-five per cent of the twenty classrooms. Item 26, distinguishing relevant from irrelevant data, was marked "occasionally" or more by eighty-five per cent of the teachers, and was observed in fifty-five per cent of the rooms. Seventy per cent of the teachers said that their students had opportunity to make outlines of data, item 27, "almost always" or "always" and this was observed in forty per cent of the rooms. The last item in this category, number 28, that of the students' abilities for organizing data being evaluated as carefully as their knowledge of facts, was marked only "occasionally" by eighty per cent of the teachers, and was observed in only five per cent of the classrooms.

Interpreting Evidence on Problems

In general, as found in Table 4, the teachers observed indicated that they emphasized this activity less than the preceding three, since seventy-one per cent of them checked "occasionally" or "seldom" in regard to the items in this category. In the observation of these classes, forty-eight instances of this type of activity were found, or

TABLE 4

INDICATED AND OBSERVED ACTIVITIES RELATED
TO INTERPRETING EVIDENCE ON PROBLEMS
IN TWENTY SELECTED CLASSROOMS

	RESPONSES BY TEACHERS										Seen By Observer	
	Always		Almost Always		Occasion- ally		Seldom		Never			
ITEM	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
29	0	0	9	45	10	50	1	5	0	0	9	45
30	2	10	5	25	9	45	4	20	0	0	12	60
31	2	10	2	10	11	55	5	25	0	0	9	45
32	0	0	0	0	15	75	5	25	0	0	17	85
33	1	5	8	40	6	30	5	25	0	0	1	5

forty-eight per cent of the number possible.

The skill of selecting the important ideas related to the problem, item 29, was checked "occasionally" or "seldom" by fifty-five per cent of the teachers observed, and was found in forty-five per cent of the rooms. Item 30, that of identifying the different relationships which may exist between important ideas, was marked "occasionally" or "seldom" by sixty-five per cent of the teachers, and was observed in sixty per cent of the classrooms, while the item of seeing weaknesses and consistencies in data, number 31, was marked "occasionally" or "seldom" by eighty per cent of the teachers and observed in forty-five per cent of the classrooms.

With regard to item number 32, that of stating relationships as generalizations which may serve as hypotheses, all of the teachers marked either "occasionally" or "seldom" but this was observed in eighty-five per cent of the twenty rooms. Seventy-five per cent of the teachers checked "occasionally" or more to item 33, that of the evaluation of interpreting evidence being as significant as the evaluation of knowledge of facts, while this was observed in only five per cent of the classrooms.

Selecting and Testing Hypotheses

Basically, as seen in Table 5, the teachers observed indicated that this area was less stressed, as was the preceding one, since sixty-nine per cent of the teachers checked "occasionally" or less to the items in this category. These activities were observed in forty-eight instan-

TABLE 5
INDICATED AND OBSERVED ACTIVITIES RELATED
TO SELECTING AND TESTING HYPOTHESES
IN TWENTY SELECTED CLASSROOMS

	RESPONSES BY TEACHERS										Seen By Observer	
	Always		Almost Always		Occasion- ally		Seldom		Never			
ITEM	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
34	0	0	7	35	12	60	1	5	0	0	8	40
35	0	0	2	10	13	65	5	25	0	0	6	30
36	0	0	10	50	8	40	2	10	0	0	16	80
37	0	0	12	60	6	30	2	10	0	0	3	15
38	0	0	3	15	4	20	11	55	2	10	5	25
39	0	0	5	25	4	20	9	45	2	10	10	50
40	0	0	5	25	12	60	1	5	2	10	0	0

ces, or thirty-four per cent of the number possible.

Item 34, that of judging the significance or pertinence of data for the immediate problem, was checked "occasionally" or less by sixty-five per cent of the teachers and was observed in forty per cent of the classrooms, and item 35, that of checking hypotheses with recognized authorities, was marked "occasionally" or less by ninety per cent of the teachers and was observed in thirty per cent of the rooms. With regard to the item on making inferences from facts and observations, number 36, fifty per cent of the teachers indicated "almost always," and this was observed in eighty per cent of the rooms. Item 37, that of devising controlled experiments suitable for testing hypotheses, was checked as "almost always" by sixty per cent of the teachers, and was observed in only fifteen per cent of the rooms. Sixty-five and fifty-five per cent of the teachers checked items 38 and 39, respectively, as "seldom" or "never." These two items, dealing with the recognition and formulation of assumptions basic to a given hypothesis and the rechecking of data for possible errors in interpretation, were found in twenty-five per cent and fifty per cent of the classrooms, respectively. Item 40, the evaluation of the pupils' abilities for selecting and testing hypotheses as carefully as their knowledge of facts, was checked "occasionally" or less by seventy-five per cent of the teachers and was found in zero per cent of the classrooms.

Formulating Conclusions

There seemed to be less unanimity of opinion in this category than in the other five, since fifty-one per cent of the teachers indicated that they carried on these activities "always" or "almost always" and forty-nine per cent indicated that they carried them on "occasionally" or "seldom," as tabulated in Table 6. In the observation of these classes, twenty-five instances of this type of activity were found, or thirty-one per cent of the number possible.

Item 41, that of formulating conclusions on the basis of tested evidence, was checked "always" or "almost always" by seventy per cent of the teachers observed, and was found in fifty-five per cent of the rooms, while item 42, that of evaluating conclusions in the light of assumptions that the student has set up for the problem, was answered "occasionally" or "seldom" by fifty per cent of the teachers, and was observed in only twenty per cent of the rooms. Fifty per cent of the teachers indicated that students almost always applied their conclusions to new situations, item 43, and this was observed in fifty per cent of the rooms. Finally, item 44, that of evaluating the pupils' abilities for formulating conclusions as carefully as their knowledge of facts, was checked "occasionally" or "seldom" by sixty-five per cent of the teachers, and was observed in zero per cent of the rooms.

General Results

Fewer than half of the items on the check list were observed in a plurality of the rooms; eighteen of the items were seen in eleven or more rooms, and twenty-six were seen in ten or fewer rooms, as shown in

TABLE 6

INDICATED AND OBSERVED ACTIVITIES RELATED
TO FORMULATING CONCLUSIONS IN
TWENTY SELECTED CLASSROOMS

	RESPONSES BY TEACHERS										Seen By Observer	
	Always		Almost Always		Occasion- ally		Seldom		Never			
ITEM	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
41	2	10	12	60	3	15	3	15	0	0	11	55
42	2	10	8	40	9	45	1	5	0	0	4	20
43	0	0	10	50	7	35	3	15	0	0	10	50
44	2	10	5	25	10	50	3	15	0	0	0	0

Table 7. Out of eight hundred and eighty possible chances for observing the individual items, only three hundred and seventy-six were in evidence: a matter of forty-three per cent of possible observations. Out of the eight hundred and eighty checks made by the classroom teachers, thirty-five were in the column headed "always" (four per cent), two hundred and eighty-two in the column headed "almost always" (thirty-two per cent), three hundred and eighty-eight in the column headed "occasionally" (forty-four per cent), one hundred and seventy-six in the column headed "seldom" (nineteen per cent), and eight in the column headed "never" (one per cent).

The greatest amount of observational evidence of the direct teaching of phases of the problem-solving procedure was in the area of sensing and defining problems, and the least amount of this evidence was in the area of formulating conclusions.

There was little disagreement between the teachers' responses and the observational data. In only five instances was there a clear difference of opinion: items 14, 17, 32, 33, and 37, as described previously. In four of these, the teachers tended to overestimate the pupils' abilities as compared with the observer's data, and in one instance the observer tended to overestimate the pupils' abilities as compared with the teachers' data. Inasmuch as in only eleven per cent of the cases was there disagreement, it would seem that the answers of the teachers to the checklist items tended to be truthful.

TABLE 7
SUMMARY OF INDICATED AND OBSERVED
ACTIVITIES FROM TABLES 1-6

	RESPONSES BY TEACHERS										Seen By Observer	
	Always		Almost Always		Occasion- ally		Seldom		Never			
TABLE	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	11	5	59	30	98	49	32	16	0	0	125	63
2	7	3	77	35	99	45	37	17	0	0	87	40
3	6	4	43	30	51	36	38	29	2	1	53	38
4	5	5	24	24	51	51	20	20	0	0	48	48
5	0	0	44	31	59	42	31	23	6	4	48	32
6	6	8	35	43	29	37	10	12	0	0	25	31
TOTAL	35	4	282	32	388	44	167	19	8	1	376	43

II. The Quantitative Approach

As stated previously, one hundred and ninety-two questionnaires were sent to science teachers in the state of Michigan. The number of returns for these questionnaires was one hundred and forty-two, or approximately seventy-four per cent. A total tally was made of the responses on items one through forty-four of the check list, and individual tallies were made in the following categories: (1) size of school (under five hundred, five hundred to one thousand, one thousand to two thousand, and over two thousand), (2) number of science areas in which the teacher had had college credit (one to three areas, four or five areas, and six to eight areas), (3) number of science education courses taken by the teacher (zero to one, two or three, and four to six), (4) number of years of teaching experience (one to five, six to fifteen, and sixteen and over), and (5) the predominant teaching area (biology, chemistry, and physics). The tallies were converted into percentages. The question regarding extra-class activities brought too many diverse answers to be synthesized, and the question on the teachers' attitude toward problem-solving was ninety-nine per cent affirmative.

Sensing and Defining Problems

Fifty-one per cent of the teachers indicated that these ten activities were done "occasionally." Twenty-eight per cent checked "almost always," and two per cent marked "always." Only one per cent indicated "never," and eighteen per cent "seldom." Basically, there

was little percentage difference in the five other teacher categories as far as total percentages for these activities were concerned, as shown in Table 8, but there were discrepancies with regard to individual items.

In general, those teachers who taught in schools of under five hundred students tended to rate these activities as occurring more often than did the teachers of the other three size categories. Those teachers who had one, two, or three areas of science preparation tended to rate their activities as more frequent than those teachers who had had four or five areas, and these in turn rated their activities as more frequent than those who had had six, seven, or eight areas of preparation. Teachers who had had no science education courses or one science education course rated their activities as less frequent than those who had had two or three science education courses, and those teachers who had had four, five, or six science education courses rated their activities as most frequent of all. Teachers of one to five years of experience rated their activities as less frequent than those of six to fifteen years, and those with sixteen years or more rated their activities as the most frequent of the lot. In the subject matter category, all three subject areas conformed to the average frequency of activities.

Collecting Evidence on Problems

The teachers rated themselves higher in this category than in the previous one. Forty-two per cent indicated "always" or "almost always"

TABLE 8
INDICATED ACTIVITIES RELATED TO
SENSING AND DEFINING PROBLEMS

PERCENTAGE OF RESPONSES TO ITEMS 1-10					
Category	Always	Almost Always	Occasion- ally	Seldom	Never
Total	2	28	51	18	1
Size of school:					
under 500	3	32	48	16	1
500-1000	2	29	52	17	0
1000-2000	1	25	53	19	2
over 2000	4	26	52	18	0
Number of science areas studied by teacher:					
1-3	3	24	49	22	2
4-5	2	34	48	15	1
6-8	1	24	58	16	1
Number of science education courses:					
0-1	1	23	50	24	2
2-3	2	28	54	15	1
4-6	4	33	48	14	1
Years of experience:					
1-5	3	31	48	17	1
6-15	2	22	55	20	1
over 15	3	30	52	15	0
Predominant area:					
biology	2	29	51	17	1
chemistry	2	28	49	20	1
physics	2	26	56	15	1

as opposed to thirty per cent in the first category. Forty-two per cent marked "occasionally" and fourteen per cent "seldom." Two per cent indicated "never," as found in Table 9.

Once again, those teachers who taught in schools with five hundred or fewer students tended to rate their activities as being more frequent, while those who taught in schools with five hundred to one thousand students, and from one thousand to two thousand students were approximately the same as those who taught in schools with over two thousand students. The percentages within the categories of science areas of teacher preparation, however, were reversed. Those teachers with one, two, and three areas of preparation rated their activities as the least frequent and those teachers with four, five, six, seven, and eight areas were approximately the same as the total average percentages. In the category of the number of science education courses that were taken by the teacher, the percentages were consistent with the previous section of responses: that is, the more courses taken, the higher the percentage of frequency of activities. The teachers with one to five years of experience and those with six to fifteen years of experience responded with essentially the same frequencies as the total, but those with more than fifteen years of experience tended to show a lower frequency than average. Biology teachers and physics teachers approached the average percentages with their responses, but chemistry teachers reported fewer instances of these activities.

TABLE 9
INDICATED ACTIVITIES RELATED TO
COLLECTING EVIDENCE
ON PROBLEMS

PERCENTAGE OF RESPONSES TO ITEMS 11-21					
Category	Always	Almost Always	Occasion- ally	Seldom	Never
Total	5	37	42	14	2
Size of school:					
under 500	6	34	39	18	3
500-1000	5	39	43	12	1
1000-2000	5	38	39	15	2
over 2000	6	37	42	14	1
Number of science areas studied by teacher:					
1-3	4	33	43	18	2
4-5	6	38	42	12	2
6-8	6	39	42	12	1
Number of science education courses:					
0-1	6	33	41	17	3
2-3	4	38	44	13	1
4-6	7	40	41	11	1
Years of experience:					
1-5	6	35	40	16	3
6-15	6	31	43	18	2
over 15	4	44	44	8	0
Predominant area:					
biology	6	37	42	14	1
chemistry	5	33	43	16	3
physics	4	44	40	11	1

Organizing Evidence on Problems

The total percentages of responses in this area were roughly the same as in the preceding one, as is shown in Table 10. Five per cent indicated "always," thirty-five per cent "almost always," forty-three per cent "occasionally," sixteen per cent "seldom," and one per cent "never," in marking the degree of frequency in which these activities were found in their classrooms.

Teachers in schools of under five hundred students and in schools of from one thousand to two thousand students tended to rate their frequencies as about average with regard to the total percentage, while those in schools of from five hundred to one thousand students were above average, and those in schools with over two thousand students were below average. Teachers with one to three science areas in their backgrounds continued to rate their frequencies below those with from six to eight science areas, but those teachers with four or five areas increased their frequency in this category of activities. Teachers who had had no science education courses or those who had had one science education course in their backgrounds expressed a high frequency of these activities, while those with two or three, and those with four to six science education courses were about at the average percentage of the group. With regard to years of experience, those with from one to five years replied that their frequency was about average as compared with the total percentage, while those with from six to fifteen years were higher

TABLE 10
INDICATED ACTIVITIES RELATED TO
ORGANIZING EVIDENCE
ON PROBLEMS

PERCENTAGE OF RESPONSES TO ITEMS 22-2C					
Category	Always	Almost Always	Occasion- ally	Seldom	Never
Total	5	35	43	16	1
Size of school:					
under 500	8	28	45	18	1
500-1000	3	42	40	14	1
1000-2000	6	33	39	20	2
over 2000	3	36	50	10	1
Number of science areas studied by teacher:					
1-3	2	35	46	15	2
4-5	9	33	37	19	2
6-8	3	38	48	11	0
Number of science education courses:					
0-1	8	29	42	18	3
2-3	4	37	43	15	1
4-6	4	38	44	13	1
Years of experience:					
1-5	5	35	42	16	2
6-15	8	31	43	16	2
over 15	3	37	44	15	1
Predominant area:					
biology	6	32	42	19	1
chemistry	3	31	48	16	2
physics	6	47	40	7	0

than the average percentage, and those with over fifteen years experience were less frequent in their percentage. Biology teachers were about the same as the total group, chemistry teachers were lower, and physics teachers were higher than the average percentage of frequency.

Interpreting Evidence on Problems

In this area, as shown in Table 11, three per cent marked the items "always," twenty-eight per cent "almost always," fifty-one per cent "occasionally," seventeen per cent "seldom," and one per cent "never." Thus, there was a slight decrease in the percentages of "almost always" responses, and a corresponding increase in the number of "occasionally" responses. The results in each category of teachers were almost identical to the average percentage of responses, with the exception of those teachers in schools of from five hundred to one thousand students, who were found to have a slightly higher rate of frequency of these activities, and physics teachers, who also had a higher rate of frequency.

Selecting and Testing Hypotheses

In this area of activities, there was a slight drop in the frequency of "occasionally" responses and a corresponding rise in the percentage of "seldom" responses. Two per cent of these responses were "always," twenty-seven per cent "almost always," forty-six per cent "occasionally," twenty-two per cent "seldom," and three per cent "never," as seen in Table 12.

TABLE 11
INDICATED ACTIVITIES RELATED TO
INTERPRETING EVIDENCE
ON PROBLEMS

PERCENTAGE OF RESPONSES TO ITEMS 29-33					
Category	Always	Almost Always	Occasion- ally	Seldom	Never
Total	3	28	51	17	1
Size of school:					
under 500	3	26	53	18	0
500-1000	6	31	52	11	0
1000-2000	2	28	46	23	1
over 2000	1	33	56	10	0
Number of science areas studied by teacher:					
1-3	1	30	46	23	1
4-5	4	29	53	13	1
6-8	4	29	51	15	1
Number of science education courses:					
0-1	2	25	45	28	0
2-3	3	29	54	13	1
4-6	5	32	56	7	0
Years of experience:					
1-5	3	27	50	19	1
6-15	4	28	50	17	1
over 15	2	32	52	13	1
Predominant area:					
biology	3	26	53	17	1
chemistry	1	27	52	19	1
physics	5	40	47	8	0

TABLE 12
INDICATED ACTIVITIES RELATED TO
SELECTING AND TESTING
HYPOTHESES

PERCENTAGE OF RESPONSES TO ITEMS 34-40					
Category	Always	Almost Always	Occasion- ally	Seldom	Never
Total	2	27	46	22	3
Size of school:					
under 500	2	26	46	21	5
500-1000	2	31	46	20	1
1000-2000	3	25	41	28	3
over 2000	2	28	52	16	2
Number of science areas studied by teacher:					
1-3	1	21	39	34	5
4-5	4	32	44	17	3
6-8	2	27	56	15	0
Number of science education courses:					
0-1	2	25	39	30	4
2-3	1	31	44	21	3
4-6	4	26	56	12	2
Years of experience:					
1-5	2	21	46	26	5
6-15	3	27	42	25	3
over 15	2	34	48	15	1
Predominant area:					
biology	3	27	46	21	3
chemistry	1	26	45	25	3
physics	3	30	49	17	1

With the exception of three categories of teachers, the percentage of responses in each area tended to be roughly at the average percentage for the group as a whole. These three exceptions were teachers with one to three science areas in their backgrounds and teachers with four to six science education courses in their backgrounds, whose activities tended to be less frequent than the average, and teachers with over fifteen years of experience, whose frequencies tended to be higher than the average.

Formulating Conclusions

In this area, percentages of "never" and "seldom" responses decreased, and the other three responses increased over the preceding area. Four per cent were marked "always," thirty-two per cent were marked "almost always," forty-seven per cent were "occasionally," twelve per cent "seldom," and one per cent "never," as found in Table 13. Once again, all but three of the categories of teachers expressed a frequency that was roughly the same as the average percentage for this area of activities. Teachers from schools with fewer than five hundred students and physics teachers indicated a percentage of frequency slightly higher and teachers from schools with over two thousand students indicated a percentage slightly lower than the total average percentage of frequency.

TABLE 13
INDICATED ACTIVITIES RELATED TO
FORMULATING CONCLUSIONS

PERCENTAGE OF RESPONSES TO ITEMS 41-44					
Category	Always	Almost Always	Occasion- ally	Seldom	Never
Total	4	32	51	12	1
Size of school:					
under 500	5	27	51	17	0
500-1000	5	39	47	8	1
1000-2000	4	33	46	15	2
over 2000	2	28	62	8	0
Number of science areas studied by teacher:					
1-3	3	37	42	16	2
4-5	5	30	54	10	1
6-8	4	29	57	10	0
Number of science education courses:					
0-1	5	28	47	18	2
2-3	2	34	53	10	1
4-6	7	33	54	6	0
Years of experience:					
1-5	6	34	44	16	0
6-15	5	33	46	14	2
over 15	2	31	59	7	1
Predominant area:					
biology	6	29	53	11	1
chemistry	4	26	50	18	2
physics	1	47	47	5	0

General Results

As pointed out in Table 14, the total percentages of frequency of activities was four per cent "always," thirty-two per cent "almost always," forty-seven per cent "occasionally," sixteen per cent "seldom," and one per cent "never." All of the categories of teachers emerged, in a totality, with approximately equal percentages of frequency of activities.

In reviewing the six areas of problem-solving as mentioned in the questionnaire, all of the categories of teachers tended to remain at a level of frequency of activities which reflected the average percentage of the group as a whole, with four exceptions. Teachers in schools of over two thousand students and teachers with one to three science areas in their backgrounds tended to rate their frequency as somewhere between average and lower than the rest of the group. Teachers in schools with from five hundred to one thousand students and physics teachers tended to rate their frequency between average and higher than the rest of the group.

III. Interpretation of the Results

One of the chief reasons for the collecting of the data from the tape recordings was to validate the truthfulness of the answers of the teachers to the items on the questionnaire. As mentioned previously, the data collected indicated that the teachers were truthful in these answers. By comparing Table 7 and Table 14, a remarkable similarity

TABLE 14
SUMMARY OF INDICATED ACTIVITIES
FROM TABLES 8-13

PERCENTAGE OF RESPONSES TO ITEMS 1-44					
Category	Always	Almost Always	Occasion- ally	Seldom	Never
Total	4	32	47	16	1
Size of school:					
under 500	4	30	46	18	2
500-1000	4	35	46	14	1
1000-2000	4	31	44	19	2
over 2000	3	32	51	13	1
Number of science areas studied by teacher:					
1-3	3	34	40	21	2
4-5	5	34	44	15	2
6-8	3	31	52	13	1
Number of science education courses:					
0-1	4	27	44	22	3
2-3	3	33	48	15	1
4-6	5	34	48	12	1
Years of experience:					
1-5	4	31	45	18	2
6-15	4	28	47	19	2
over 15	3	35	49	12	1
Predominant area:					
biology	4	31	47	17	1
chemistry	3	29	47	19	2
physics	4	38	46	11	1

between the summary of data from tape recorded classrooms and the summary of data from the questionnaire responses. Four per cent in both cases marked "always," thirty-two per cent in both cases marked "almost always," and one per cent in both cases marked "never." Forty-four per cent of the tape recorded group and forty-seven per cent of the questionnaire group indicated "occasionally," while nineteen per cent of the tape recorded group and sixteen per cent of the questionnaire group indicated "seldom"--a difference of only three percentage points in each case.

CHAPTER V

CONCLUSIONS, RECOMMENDATIONS, AND SUMMARY

It has been ascertained that the questionnaires were completed truthfully, that the teachers contacted basically regarded problem-solving as a worthy objective of the high school science course, and that, judging by the small percentage of answers in the "never" category, this selected group of science teachers in Michigan make an attempt to provide problem-solving activities for their students. Several conclusions and recommendations can be made based upon this information.

I. Conclusions

The conclusions drawn from this study can be divided into those with regard to background and experience of the teachers, those with regard to the frequency of problem-solving activities, and those with regard to the statement of the problem of this study.

Background and Experience of the Teachers

It has been found that within the group questioned, background and experience count for little in judging the extent of the direct teaching of problem-solving that might be found in a classroom. The results and percentages of frequency of the forty-four separate problem-solving activities did not differ markedly in schools having five hun-

dred or fewer students, in those having from five hundred to one thousand students, in those having from one thousand to two thousand students, or in those having more than two thousand students. Although the several items on the questionnaire relative to both scientific and library equipment and materials might be assumed to weight the reactions in favor of the more populous school, such was not the case. Apparently the size of the school had little to do with classroom activities.

Background in subject matter seemed to make little difference in the teachers' responses. Some of the teachers had had college and university training in only one area, there were representatives from all areas and in all numbers up to eight science areas, including chemistry, physics, biology, zoology, botany, geology, astronomy, entomology, and meteorology, but there was essentially no difference in their percentage of responses. There were many who had never taken a science education course in college or university, even in their teaching field methodology. There were some who had had as many as six courses in science education, including methods of teaching chemistry, physics, biology, general science, and physical science, as well as science administration and supervision, science workshops, and science seminars. Essentially, however, there was no difference in their percentage of responses.

Years of experience in teaching science seemed to make little difference in the responses of these teachers. With a range of from one year to thirty-five years, there was found to be little difference in

their percentage of frequency. The area in which they taught had little value as a variable, also. Chemistry, physics, and biology teachers basically answered with the same percentages.

Frequency of Problem-solving Activities

When the percentages of frequency were examined, it was concluded that not enough attention is being given by the members of this group of teachers to the direct teaching of problem-solving. It has been pointed out previously that problem-solving must be taught directly, and it has also been pointed out that the forty-four items on the check list have been recommended as appropriate activities for the direct teaching of problem-solving. It must also be pointed out that the provision of these activities must be continuous and pervasive in the classroom of the science teacher who is dedicated to the direct teaching of problem-solving. In short, utilizing these activities "occasionally" is not enough.

In the total response, only thirty-six per cent of the science teachers questioned indicated that these activities were carried on "always" or "almost always," as against forty-seven per cent indicating "occasionally" and eighteen per cent indicating "seldom" or "never." In the responses to the six aspects of the problem-solving procedure, it was found that the range was from twenty-nine per cent to forty per cent in the combined "always" and "almost always" category, but this is still not sufficient direct teaching on the part of a group that has indicated its acceptance of this process as a worthy objective of science courses.

The Statement of the Problem of this Study

The first problem stated in Chapter I was: "What attitude is expressed by science teachers toward the teaching of problem-solving as a desirable objective of the science course?" The answer to this question lay in the response to the questionnaire query: "In your opinion, is skill in problem-solving a worthy objective of a high school science course?" Ninety-nine per cent of the teachers having answered this in the affirmative, it was concluded that the science teachers consulted approved of problem-solving as an objective of a high school science course.

The second problem was stated: "What methods do science teachers indicate that they use in teaching problem-solving skills?" Inasmuch as more than half indicated that they used all of the forty-four methods that were to be found in the questionnaire at least "occasionally," it was concluded that these Michigan science teachers do the following, at least to some extent:

1. help students sense situations involving personal and social problems.
2. help pupils recognize specific problems in these situations.
3. help pupils in isolating the single major idea of a problem.
4. help pupils state problems as definite and concise questions.
5. help pupils pick out and define the key words as a means of getting a better understanding of the problem.
6. help pupils evaluate problems in terms of personal and social needs.
7. help pupils to be aware of the exact meaning of word groups and shades of meaning of words in problems involving the expression of ideas.
8. present overview lessons to raise significant problems.
9. encourage personal interviews about problems of individual interest.
10. permit pupils to discuss possible problems for study.

11. provide a wide variety of sources of information.
12. help pupils develop skill in using reference sources.
13. help pupils develop skill in note taking.
14. help pupils develop skill in using reading aids in books.
15. help pupils evaluate information pertinent to the problem.
16. provide laboratory demonstrations for collecting evidence on a problem.
17. provide controlled experiments for collecting evidence on a problem.
18. help pupils develop skill in interviewing to secure evidence on a problem.
19. provide for using the resources of the community in securing evidence on a problem.
20. provide for using visual aids in securing evidence on a problem.
21. evaluate the pupils' ability for collecting evidence on a problem as carefully as the teacher evaluates their knowledge of facts.
22. help pupils develop skill in arranging data.
23. help pupils develop skill in making graphs of data.
24. help pupils make use of deductive reasoning in areas best suited.
25. provide opportunity for pupils to make summaries of data.
26. help pupils distinguish relevant from irrelevant data.
27. provide opportunity for pupils to make outlines of data.
28. evaluate the pupils' ability to organize evidence on a problem as carefully as the teacher evaluates their knowledge of facts.
29. help pupils select the important ideas related to the problem.
30. help pupils identify the different relationships which may exist between the important ideas.
31. help pupils to see the consistencies and weaknesses in data.
32. help pupils state relationships as generalizations which may serve as hypotheses.
33. evaluate the pupils' ability for interpreting evidence as carefully as the teacher evaluates their knowledge of facts.
34. help pupils judge the significant or pertinency of data for the immediate problem.
35. help pupils check hypotheses with recognized authorities.
36. help pupils make inferences from facts and observations.
37. help pupils devise controlled experiments suitable for testing hypotheses.
38. help pupils recognize and formulate assumptions basic to a given hypothesis.
39. help pupils recheck data for possible errors in interpretation.
40. evaluate the pupils' ability for selecting and testing hypotheses as carefully as the teacher evaluates their knowledge of facts.

41. help pupils formulate conclusions on the basis of tested evidence.
42. help pupils evaluate their conclusions in the light of the assumptions they set up for the problem.
43. help pupils apply their conclusions to new situations.
44. evaluate the pupils' ability to formulate conclusions as carefully as the teacher evaluates their knowledge of facts.¹

The third problem as stated was "What methods do science teachers actually use in teaching problem-solving skills?" It was concluded, on the basis of the data mentioned in the previous chapter, that these science teachers use all of the above mentioned methods, but basically do not use them enough.

General Conclusions

From the foregoing discussion of conclusions and results, it was deduced that the selected group of Michigan science teachers did not truly understand the definition of problem-solving. Inasmuch as one of the integral parts of the methodology related to this process in the schools is continuity, and there was virtually no evidence of this continuity, it would appear that most of these teachers failed to have an appreciation of the meaning of problem-solving and their own place in the teaching of this process.

In addition, it was concluded that these teachers did not truly understand the desirability of teaching this process directly. Since the data indicated that few of the items on the check list were carried out

¹Ellsworth S. Obourn, An Analysis and Check List on the Problem-solving Objective, A Science Teaching Service Circular, 481 (Washington: United States Department of Health, Education, and Welfare, 1956).

"always" or "almost always," it followed that these teachers in general did not appreciate the need for constant direct teaching of the process.

If the teachers as a group endorsed problem-solving while failing to provide problem-solving activities in the classroom, it would seem that their knowledge of this process is either non-existent or too abstract to be applicable in the classroom. In short, the teachers either do not understand the process or do not understand that it must be taught directly, since most evidence of direct teaching appeared either accidentally or incidentally.

The implications of the above conclusions are rather startling. If the direct teaching of problem-solving is one of the chief objectives of the high school science class, and if the teachers in this group who had taken science education courses did no better than those who had taken no science education courses in teaching for this objective, it appears that teachers of science education classes must re-evaluate their instruction in this area. In addition, since neither biology nor chemistry teachers achieved this objective with any more regularity than physics teachers, the methods teachers of all three areas seem to be at fault. It would be invalid to conclude that these methods teachers ignored the problem-solving techniques and laid no stress on these techniques in their methods courses, but in this group of science teachers it appeared to have had little effect. It can only be concluded that, although the science teachers were sufficiently taught the importance of the process as exhibited by the affirmative reaction to the question concerning the importance of problem-solving, they had

not learned techniques of teaching this method directly.

Teachers of science education courses in institutions of higher education must, therefore, scrutinize their courses to find the reasons for the lack of carry-over of the problem-solving objective. In the field, administrators and teachers must re-evaluate the science offerings in the high school. The poor showing by this group of science teachers relative to this objective must be corrected.

II. Recommendations

The recommendations drawn from this study can be divided into those for the use of teachers and parents, those for the use of administrators, and those for the use of future investigators.

For the Use of Teachers and Parents

Perhaps the most important recommendation that could be made to both teachers and parents, inasmuch as they are the persons who share the responsibility for the basic education of children, is that they learn to appreciate the value of the problem-solving process in the total education of young people. They must also learn that this process must be taught and the proper activities that should be carried on in order that this process may be taught. They should learn that a child's question is, in reality, a problem, and should be solved as such. They should learn that the child may need help in isolating hypotheses and selecting the proper solution, but if he is to become expert in solving problems, the child must not have these hypotheses outlined too often

or chosen for him too often. They should learn that an ability to solve problems is part of the measure of maturity, and that maturity may well be postponed if problem-solving practice is not provided. In short, they must become aware of the necessity of problem-solving, and must know how to provide for it.

For the Use of Administrators

The principal or superintendent of the public schools should learn the same things that were recommended for parents and teachers to become familiar with. He should then use this information and appreciation in his hiring and evaluating of teachers in his school or system. He must not judge the teacher exclusively on how much students were able to memorize while taking a particular science sequence, but rather on how well the children were taught to think in those courses. The administrator as curriculum leader must also, in his planning for curriculum and course of study, provide for the equipment and activities that will aid the teacher in the direct teaching of the problem-solving process. He must then assist the teacher in putting these practices into action. If he finds that there is no problem-solving occurring in a given room, it might be that the teacher in that room does not truly know how to provide for problem-solving, and therefore must be given help in learning to teach directly the problem-solving process. This, also, is the responsibility of the administrator.

For the Use of Future Investigators

Probably the most important suggestion for further research in this area is to ascertain if all states might reflect the findings of this study. Is there a dearth of direct teaching of problem-solving in other localities as in this sampling of the state of Michigan? Another possible study that might be carried out would concern the depth of feeling on the part of science teachers as to the desirability of problem-solving as an objective. Is the response of ninety-nine per cent affirmative, as found in this study, a true picture of their feelings, or is it an example of lip-service?

A study of this type might be carried on in other curricular areas, since problem-solving is of equal importance in the field of social studies as it is in science. Another problem that needs investigation is the amount of direct teaching of problem-solving in the elementary schools of the nation. Finally, no one seems to know whether the vast majority of teachers in the public schools have ever been told of suggested methods of direct teaching of the problem-solving process.

III. Summary

The basic problems of this study were concerned with the attitudes of classroom teachers of science in Michigan toward problem-solving as a worthy objective of the teaching of science, with the methodology used in the direct teaching of this method as described by a selected group of science teachers in Michigan, and with the actual methodology used by this group. The preliminary investigation was one of observing and tape recording a series of twenty classes in science in selected Michigan high schools of various sizes and in various science areas. Notes were taken and methodology was scrutinized and equated with a check list of Obourn on the problem-solving objective.² The teachers of these twenty classes were given a copy of a questionnaire following the observation. This questionnaire consisted of two parts: the first dealing with the size of the school, the teachers' backgrounds both in science courses taken and in science education courses taken, their years of experience, and their class schedule, the second asking them to react to Obourn's forty-four points, indicating whether they practiced this activity in the classroom "always," "almost always," "occasionally," "seldom," or "never."

The returned questionnaires from these twenty teachers were compared with the observed and tape recorded activities found in the classrooms and it was concluded that the questionnaires had been filled out

²Ibid.

realistically, inasmuch as the results tallied with the observation form that was used. The questionnaire was then sent to one hundred and ninety-four teachers of science in the state of Michigan, and the one hundred and forty-two returns were tabulated in total, by size of school, by number of science areas studied by the teachers, by number of science education courses taken by the teachers, by years of experience, and by area of instruction. The total percentages were almost identical to the total percentages of the observed group, and in a division into the above mentioned categories, little change was found in the basic percentages.

Essentially, the results were that science teachers in this group indicated that the forty-four check list items were done in their classrooms "always," by four per cent; "almost always," by thirty-two per cent; "occasionally," by forty-seven per cent; "seldom," by sixteen per cent; and "never," by one per cent. The conclusions that were drawn were that (1) the various items of background of the teachers caused the ultimate percentage of frequency of the activity to change very little, (2) not enough attention is being given by these teachers to the direct teaching of problem-solving, and (3) although they stated that they approved of problem-solving as an objective of science teaching and although they carry on the activities on the check list to some extent, the teachers are not fully cognizant of the necessity for the direct teaching of problem-solving.

Recommendations were made to parents, teachers, and administra-

tors that they make every effort to familiarize themselves with the necessity for direct teaching of problem-solving, that they learn how to teach this process directly, and that they maintain vigilance to see that it is being taught directly and continuously in their classrooms, homes, and schools. Further research was suggested in the areas of probing to find the real feelings of science teachers toward problem-solving, further research in the other curricular areas and the elementary school. Investigations were suggested of a similar nature in other states, and in the knowledges of teachers regarding the steps of problem-solving and the steps in the direct teaching of this process.

APPENDIXES

APPENDIX A

A BIOLOGY CLASS TRANSCRIPTION

Teacher: There are a few points to review on the Metazoan Phyla in this chapter. What phyla are included in the chapter? The simplest phyla here is what?

Student: Platyhelminthes.

Teacher: And the next?

Student: Nemathelminthes.

Teacher: And the next higher phylum?

Student: Annelida.

Teacher: And the next higher phylum?

Student: Echinodermata.

Teacher: That's the next one in the book? No. What is it?

Student: Mollusca.

Teacher: And the last one?

Student: Echinodermata.

Teacher: On what basis are the animals divided into these separate phyla?

Student: On their complexity.

Teacher: What do you mean by that?

Student: Their structures and their functions. The structures--your more simple phyla are not complex--but the higher up you go, the more complex.

Teacher: Alright. What specifically is it that becomes more complex?

Student: Systems.

Teacher: Well, all animals have systems?

Student: The structure of the animal.

Teacher: Where do systems come into this business of structure? How are they related to structure--systems, I mean? John has pointed out that these animals divided into phyla based on how complex the bodies are. In terms of structure, what is the system?

Student: All the phyla have tissues but not all have systems.

Teacher: That's getting close to it. Do the tissues directly make up a system?

Student: Tissues form organs first.

Teacher: Tissues are arranged to form organs and organs form systems. We can speak of the level of organization of animals according to tissues, organs, and systems. Do the animals in Platyhelminthes contain tissues, organs, systems, or what?

Student: The tape worm contains a reproductive system.

Teacher: Any other systems?

Student: No.

Teacher: Why doesn't it need a circulatory system?

Student: Because circulatory systems carry the food in our body but the tape worm just absorbs the food--whatever it needs.

Student: Does Planaria have a nervous system because they do have nerves throughout their bodies?

Teacher: Does Planaria have a nervous system?

Student: They have ganglia.

Teacher: What are ganglia?

Student: It's just nerves stuck together. A nerve net but not a system.

Teacher: A group of nerve cells, not a net. In what animal did we find the nerve net?

Student: Hydra.

Teacher: Hydra.

Student: Isn't the tape worm a degenerate form of that general group, the Platyhelminthes?

Teacher: What do you mean by degenerate?

Student: Well, it doesn't contain what the others contain because it doesn't need it. It doesn't need it. It doesn't locomote.

Teacher: Tape worm is considered a degenerate form. It doesn't contain the structures that other members of this phylum contain. But going back to the question. Do Planaria have a nervous system? You said that a ganglion was a group of cells.

Student: It has nerve tissue.

Teacher: It has nerve tissue but not a nervous system. How does the general structure of the Nemathelminthes compare with the Platyhelminthes? Is it more or less complex?

Student: More.

Teacher: It tends to be more. Can you state any specific reason why you tend to think this way? What animals belong to the Nemathelminthes?

Student: Hookworm, horsehair snake, vinegar eel, Ascaris.

Teacher: Do these animals have more complex structure than the Planaria? Can you think of any structures that are more complex?

Student: A digestive system.

Teacher: Is it a digestive system?

Student: I think so.

Teacher: It must then be composed of what?

Student: Organs.

Teacher: Right. And for the first time in the Nemathelminthes. What is different about the structures? Other than the fact that they are composed of organs.

Student: It has two openings.

APPENDIX B

A CHEMISTRY CLASS TRANSCRIPTION

Teacher: Why does carbon form no ionic bonds? What's the reason?

Student: Because it has four loose atoms--electrons.

Teacher: Four loose?

Student: Well, they're loose, I mean.

Teacher: What's loose?

Student: Unattached.

Teacher: What? Protons?

Student: Electrons.

Teacher: Oh. What does it have to have to form ionic bonds? Where do you find the elements that form ionic bonds on the periodic chart? Well, to form ionic bonds they usually have how many in their outer ring?

Student: Less than four.

Student: Seven?

Teacher: Seven may form an ionic bond. What would be a metal that would form an ionic bond? You had some for lunch.

Student: Iron.

Teacher: Table salt. Which is what, Sharon?

Student: Calcium?

Teacher: Sodium chloride--which forms an ionic bond. Sodium has one electron in the outer shell so the main reason that carbon forms no ionic bond is that it has four electrons in its outer shell and it's much easier to form covalent bonds and equalize its outer shell. How are artificial diamonds produced?

Student: They come from carbon compounds that are put under a great deal of pressure and a great deal of heat and after a period of time it forms a diamond because the carbon compounds are not so tight together and it puts them together to harden.

Teacher: You say a carbon compound. Give me an example.

Student: Maybe graphite.

Teacher: Well, that's pure carbon.

Student: It said in the book carbon compound.

Teacher: I think it needs to be pure carbon. Otherwise, you'd have impurities in the diamond. Graphite is not a carbon compound, it's a form of carbon. But possibly if you have enough heat, you can drive off the other elements. When coke is used as a reducing agent, what is oxidized? If we use coke as a reducing agent as we do in steel mills and so on, what is oxidized? I mean, what is it always oxidized to, what would be the product of this reaction?

Student: It would be carbon dioxide, wouldn't it?

Teacher: Right. The coke.

Student: Because it would combine with the oxygen in the oxide in the metal and it would form CO_2 .

Teacher: Right. Take something like ferric oxide reacting with coke to form CO_2 and pure iron. Why is charcoal a good absorbent?

Student: Because of its density.

Teacher: What do you mean by its density?

Student: Well, it's less dense than water, isn't it?

Teacher: Well, yes, slightly. Well, what would you suspect that helps charcoal to be a good absorbent? Is it the way it's made?

Student: It's porous.

Teacher: Yes. Carbon is very porous. It has a large surface area. If you think of the area on the inside of the charcoal, it's really a surface area because the gas can be put in and absorbed. What is the orientation in space of the valence bond of the carbon atom? Some of you solid geometry students?

Student: A tetrahedron.

Teacher: Yes, it forms a tetrahedron. The orientation in space of the valence bond of the carbon atom is the shape of a tetrahedron. They go out in four directions such that the angle between the bonds looks the same, if you see what I mean. When you draw a triangle--not a triangle--a figure, the angles will form a tetrahedron and the carbon molecules will be in the center of the tetrahedron. What proof do we have that a diamond is made of pure carbon?

Student: If it is put in pure oxygen it will form carbon dioxide.

Teacher: How does a printer make a plate from which books such as this one are printed? If it were not for a certain type of carbon, it would change the printing industry a great deal. So how do they make the type for printing a book?

Student: Out of graphite.

Teacher: Alright. First they make their impressions in wax and then they cook that with graphite. This will conduct electricity and then they can make the electric type out of it. Why will a form of carbon such as charcoal or coke remain after the destructive distillation of bituminous coal? If we heat bituminous coal in the absence of air we have a residue of carbon. Why do we have a residue of carbon? Carbon is not vaporized at the temperature that we can subject to these materials. Why is the specific gravity of graphite less than that of diamonds? We had that the other day.

Student: Because the atoms are farther apart.

Teacher: You mean that the distance of carbon atoms is farther apart in graphite than it is in diamonds?

Student: The crystals are shaped differently.

Teacher: The layers are closer together in diamonds. In diamonds we have bonds in all directions. In graphite we have a hexagon type plane and then that plane is quite a ways away from the next plane. Further apart than it would be in a diamond. So that's what gives the difference in density and specific gravity. Why is it difficult to remove stains made by printer's ink? That shouldn't be very hard to answer.

Student: Printer's ink is made of carbon and it's hard to dissolve it.

APPENDIX C

A PHYSICS CLASS TRANSCRIPTION

Teacher: We're going to take up change of phase today. Exactly what do we mean by change of phase? It's a new term, we might say. What could be a change of phase? What is a phase?

Student: A phase would be a thing like liquid, solid, or gas, and a change of phase would be the other way.

Teacher: Alright. A phase is simply one of the three states of matter, isn't it? Liquid, solid, or gas. So a change of phase would simply be changing from one of the states to the other. In this unit we are concerned with heat and what is our definition of heat? It's not quite the same definition that you may have had before you came.

Student: The thermal energy that can be transmitted from one object to another.

Teacher: Alright. Heat, then, is the thermal energy that can be changed and we measure the temperature with a thermometer. What kind of instrument can we use to measure the heat that a body has? Heat being the amount of thermal energy that can transfer. Is there any kind of an instrument that can be attached to a body to measure its heat? How are we going to measure the heat, then?

Student: By changes that it produces in other substances.

Teacher: Alright. By the effect. So now that we have a way of determining the amount of heat that a body has. If you know the volume and the specific heat and the temperature, from past experience you can know how much heat it can hold. But sometimes it's rather awkward to take the volume of an object to find the amount of heat it has. We have an easier way. If we measure the temperature in degrees, what kind of units do we measure heat in?

Student: Calories.

Teacher: Calories. These are rather small units, and the larger ones would be what?

Student: Kilocalories.

Teacher: Yes. That is for the metric system.

Student: BTU.

Teacher: BTU in the English system. Those are the three main ways. Actually, there's only two main divisions. A kilocalorie is simply how many calories?

Student: One thousand.

Teacher: Now we need to define our terms here. Exactly how is a calorie defined?

Student: It raises one gram of water one degree centigrade.

Teacher: Yes. It's the amount of heat that will increase the temperature of one gram of water one degree centigrade. And it has to be water in its liquid state. And, of course, a kilocalorie would be a thousand times that. It would raise one liter one degree centigrade. Now what is a BTU?

Student: The amount of heat required to raise one pound of water one degree Fahrenheit.

Teacher: Alright. Using the English system and also the weight and also the temperature is to the calorie in the metric system using grams and centigrade. Now it may be convenient to transfer from one system to another, and what is the relationship between calories and BTU's? Remember 262 and remember that the BTU is the larger unit and you'll keep them straight. Incidentally, food is measured in calories. You girls know that, I'm sure. Which type of calorie is food measured in?

Student: It's really measured in kilocalories, but we call it calorie.

Teacher: Yes. When they say something is one hundred calories they really mean one hundred kilocalories, because calories are such small units it's impractical to use them. Alright, we have our term for measuring heat now. Now I want to go into what is called the heat capacity of an object. What is that?

Student: It would be the heat required to raise the temperature of the body one degree centigrade.

Teacher: Really, heat capacity is how much it will hold. We are always concerned with amount of thermal energy that can be taken out or put in. So heat capacity is how much it will hold. What is specific heat? This is analogous to specific gravity, if you can remember. I think that sometimes students lose the insight into what we mean by these terms like specific gravity and specific heat. But remembering specific gravity, what do you suppose specific heat is?

Student: Doesn't that have the same definition as a calorie?

Teacher: Well, it gets around to the same effect after awhile.

Student: It's the amount of heat required to raise one gram one degree.

Teacher: Yes, it's numerically equal to that.

Student: In this system it's the number of calories.

Teacher: Let's get down to the roots. What do we mean when we say specific something?

Student: It's a number that will always be accurate.

Teacher: And it's equal to what?

Student: It's all in relation to the amount of heat needed to raise one gram of water one degree centigrade.

Teacher: It's a standard. Actually, it's the amount of heat required to raise some substance a certain number of degrees over the amount of heat required to raise water the same amount. So in specific gravity we had the density of an object over the density of water, here we have an amount of heat over the amount of heat required to raise the temperature of water one degree. And your book goes on and tells you this: it says that the heat capacity of water is what?

Student: One.

APPENDIX D

THE QUESTIONNAIRE

Approximate number in the student body of your school _____

Check the type of secondary school: 2 yr. ____ 3 yr. ____ 4 yr. ____ 6 yr. ____

Check the areas of science in which you have had college credit:

Biology _____	Botany _____	Astronomy _____
Physics _____	Chemistry _____	Entomology _____
Zoology _____	Geology _____	Meteorology _____

What courses in science education have you had?

Methods of teaching:	Science Administration or
Chemistry _____	Science Supervision _____
Physics _____	Science Workshops _____
Biology _____	Science Seminars _____
General _____	Others _____
Physical _____	_____

How many years have you taught? _____

How many at your present position? _____

List the courses you teach and the enrollment of each:

<u>Period</u>	<u>Title of Course</u>	<u>Enrollment</u>
1	_____	_____
2	_____	_____
3	_____	_____
4	_____	_____
5	_____	_____
6	_____	_____

What extra-class activities do you sponsor? _____

In your opinion, is skill in problem-solving a worthy objective of a high school science course? Yes _____ No _____

In answering the following questions, check the appropriate box:

	Always	Almost Always	Occasionally	Seldom	Never
1. Do your pupils sense situations involving personal and social problems?					
2. Do your pupils recognize specific problems in these situations?					
3. Do your pupils isolate the single major idea of a problem?					
4. Do your pupils state problems as definite and concise questions?					
5. Do your pupils pick out and define the key words as a means of getting a better understanding of the problem?					
6. Do your pupils evaluate problems in terms of personal and social needs?					
7. Are your pupils aware of the exact meaning of word groups and shades of meaning of words in problems involving the expression of ideas?					
8. Do your pupils have overview lessons to raise significant problems?					
9. Do your pupils discuss problems for study?					
10. Do your pupils ask for personal interviews about problems of individual interest?					
11. Do you have a wide variety of sources of information?					
12. Do your pupils develop skill in using reference sources?					
13. Do your pupils develop skill in note taking?					
14. Do your pupils develop skill in using reading aids in books?					
15. Do your pupils evaluate information pertinent to the problem?					
16. Are the pupils able to use laboratory demonstrations for the collecting of evidence on a problem?					
17. Do the pupils perform controlled experiments for collecting evidence on a problem?					
18. Do your pupils develop skill in interviewing to secure evidence on a problem?					

	Always	Almost Always	Occasionally	Seldom	Never
19. Do your pupils use community resources in securing evidence on a problem?					
20. Do your pupils use visual aids in securing evidence on a problem?					
21. Are the pupils' abilities for collecting evidence on a problem evaluated as carefully as their knowledge of facts?					
22. Do your pupils develop skill in arranging data?					
23. Do your students develop skill in making graphs of data?					
24. Do your pupils make use of deductive reasoning in areas best suited?					
25. Do your pupils have opportunity to make summaries of data?					
26. Do your pupils distinguish relevant from irrelevant data?					
27. Do your pupils have opportunity to make outlines of data?					
28. Are the pupils' abilities for organizing data evaluated as carefully as their knowledge of facts?					
29. Do your pupils select the important ideas related to their problems?					
30. Do your pupils identify the different relationships which may exist between important ideas?					
31. Do your pupils see the consistencies and weaknesses in data?					
32. Do your pupils state relationships as generalizations which may serve as hypotheses?					
33. Are the pupils' abilities in interpreting evidence evaluated as carefully as their knowledge of facts?					
34. Do your pupils judge the significance or pertinence of data for the immediate problem?					
35. Do your pupils check hypotheses with recognized authorities?					
36. Do your pupils make inferences from facts and observations?					

	Always	Almost Always	Occasionally	Seldom	Never
37. Do your pupils devise controlled experiments suitable for testing hypotheses?					
38. Do your pupils recognize and formulate assumptions basic to a given hypothesis?					
39. Do your pupils recheck data for possible errors in interpretation?					
40. Are the pupils' abilities for selecting and testing hypotheses evaluated as carefully as their knowledge of facts?					
41. Do your pupils formulate conclusions on the basis of tested evidence?					
42. Do your pupils evaluate their conclusions in the light of the assumptions they set up for the problem?					
43. Do your pupils apply their conclusions to new situations?					
44. Are the pupils' abilities for formulating conclusions evaluated as carefully as their knowledge of facts?					

Adapted, in part, from: Obourn, Ellsworth S. An Analysis and Check List on the Problem-solving Objective, A Science Teaching Service Circular, 481. Washington: United States Department of Health, Education, and Welfare, 1956.

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AUTOBIOGRAPHY

I, Thomas Gibbons Aylesworth, was born in Valparaiso, Indiana, November 5, 1927. I received my high school diploma from Rochester High School, Rochester, Indiana. Following my army service, I was granted a Bachelor of Arts degree with a major in zoology from Indiana University. From this same institution, I was granted a Master of Science degree in general secondary education. I have taught in the public secondary schools of Illinois, Indiana, and Michigan. While in residence at The Ohio State University, I was employed as a graduate assistant to Mr.

Lewis Evans of the University School. At the present time, I am assistant professor of teacher education and resident coordinator of student teaching at Michigan State University, East Lansing, Michigan.